MIT
Design Standards

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DIVISION 00 — Procurement Requirements

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1. PROCUREMENT REQUIREMENTS

1.1 MIT Issued Contracts

Contracting and procurement requirements are issued by MIT on a project-by-project basis. Coordinate with the MIT Project Manager to review, discuss, and incorporate the contracting and procurement requirements for each project. Coordinate with Division 01 - General Requirements and additional project specifications. The following documents are typically issued:

- Master Agreement Between Owner and Architect
- Master Construction Agreement
- Architect Release
- Preconstruction Release
- Construction Release

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1. GENERAL REQUIREMENTS

1.1 MIT Standard Division 01 - General Requirements

The A/E is required to issue Division 1 - General Requirements for the project, coordinated with MIT's procurement and contracting requirements. Contact the MIT Project Manager for base text in Microsoft Word format for the following Division 01 Sections which are to be used for MIT projects.

1. Section 015640 - MIT Temporary Tree and Soil Protection
2. Section 019113 - MIT General Commissioning Requirements.

1.2 Project-Specific Requirements

The A/E is required to review the following list of topics, and include in Division 01 as applicable to the project prior to the issue of construction documents:

1. Project specific alternates, allowances and unit prices. Use of allowances is discouraged.
2. Existing site conditions and restrictions.
3. Requirements for sequencing, scheduling and completion date.
4. Prior or concurrent work by MIT or others.
5. Prior hazardous material work by MIT or others.
6. MIT pre-purchased long-lead items.
7. MIT purchased, MIT installed items.
8. MIT purchased, Contractor-installed items.
9. MIT's early or partial occupancy.
10. Occupancy of adjacent facilities.
11. Contractor's use of new and existing facilities.
12. Scope of separate prime contracts.
13. Allowable working hours.
14. Days when construction is not allowed. MIT anticipates 10 no-work days per year based on MIT activities including commencement and exam weeks. Confirm dates with the MIT Project Manager.
15. Utility Costs: MIT will allow the use of existing utility systems and pay for cost of utility services consumed, including electricity, water and gas. The Contractor shall provide sub-metering, and provide and pay for connections for temporary utilities, and for temporary heat prior to the complete enclosure of the building and availability of suitable permanent systems as applicable.
16. Temporary Offices: A separate field office for the Architect and the MIT Project
Representative is typically not required.

17. Toilet Facilities: The Contractor shall provide and maintain temporary toilets outside the building. Confirm location with the MIT Project Representative.

1.3 Sustainable Design

Refer to requirements in the Thematic Folder for Sustainability in Volume 1 of the MIT Design Standards. The A/E is required to coordinate with MIT sustainability consultants for Division 01 Specifications.

2. APPENDICES

2.1 Construction Specifications

Refer to the following documents, to be used in their entirety for applicable projects.

2.2 Spec Section 015640 - MIT Temporary Tree and Soil Protection

END OF DOCUMENT
SECTION 015640

MIT TEMPORARY TREE AND SOIL PROTECTION

PART 1 - GENERAL

1.1 GENERAL PROVISIONS

A. Attention is directed to the CONTRACT AND GENERAL CONDITIONS and all Sections within DIVISION 01 - GENERAL REQUIREMENTS which are hereby made a part of this Section of the Specifications.

B. Examine all Drawings and all Sections of the Specifications for requirements and provisions affecting the Work of this Section.

1.2 DESCRIPTION OF WORK

A. Protection of existing trees, plants and soil from damage as a result of the Contractor's operations including, but not limited to:

1. Tree and soils protection fencing.
2. Critical root zone protection.
3. Pre-construction root invigoration and deep root watering by certified arborist
4. Fertilization of preserved trees.

B. Contractor is directed to prevent construction activities from occurring on soil to the greatest extent possible and redirect them to paved areas. Where construction activities must take place on soils, those activities shall be constrained within the limits reviewed with the Owner and Architect.

C. Much of the work required under this Section will be performed by a Certified Arborist. This Arborist will be approved by the Owner and paid for by the Contractor.

1.3 DEFINITIONS

A. Certified Arborist: An individual engaged in the profession of arboriculture who, through experience, education and related training, possesses the competence to provide for, or supervise the management of, trees and other woody ornamentals, approved by the Owner, and hired by the Contractor, with a minimum five years experience, who has successfully completed a certification program equal to the Massachusetts Certified Arborist (MCA) program/examination sponsored by the Massachusetts Arborists Association, 8-D Pleasant Street, South Natick, MA 01760; (508) 653-3320; FAX: (508) 653-4112; E-mail: MaarbAssn@aol.com.

B. Critical Root Zone (CRZ): The minimum volume of roots necessary for maintenance of tree health and stability, typically determined by measuring the tree diameter 4.5 ft. above grade and multiplying by 12 in., a minimum radius of 10’ from the trunk, or at the tree's dripline, whichever is farthest from the trunk, or as otherwise indicated on the Drawings, or established in the field. CRZ will be determined/established on a case by case basis by the Arborist and approval by the Architect.

C. Compacted Soil: A high density soil lacking structure and porosity characterized by restricted water infiltration and percolation (drainage), and limited root penetration.
D. **Dripline**: An imaginary line defined by the branch spread; the farthest extension of the tree branches.

E. **Owner**: An MIT Landscape Architect, and/or MIT Grounds Supervisor.

### 1.4 SUBMITTALS

A. Prepare and submit a "Logistics Plan for Tree and Soil Protection", indicating the extent of tree and soils protection fencing required, and areas where soil compaction prevention measures shall be implemented. Show all areas of proposed staging, vehicle or equipment access, trenching, excavating, or other disturbance to soils.

1. Proposed plan will be reviewed and approval by the Owner. No work of this Section shall commence prior to approval.

B. Proposed methods, materials, and schedule for effecting tree and soil protection within the limits indicated on the Logistics Plan for Tree and Soil Protection.

C. Mitigation or preventative maintenance operations such as root pruning and tree fertilization shall be submitted by Certified Arborist for Owner’s approval.

D. Product samples for review and approval by the Owner.

1. Submit 1.0 lb. sample of wood chips.
2. Submit 1.0 lb. sample of crushed stone.

### 1.5 MODIFICATIONS TO TREE AND SOIL PROTECTION PLAN

A. Modifications deemed necessary by the Contractor to the approved Logistics Plan for Tree and Soil Protection shall be submitted to the Architect and Owner for review and approval prior to implementing any changes to tree and soil protection areas, materials and methods. All modifications shall be submitted by Contractor in written form, approved by the Owner and signed by all parties.

### 1.6 PRECONSTRUCTION CONFERENCE

A. Pre-Construction Conference: Prior to implementing tree and soil protection measures, conduct meeting with Owner and Architect to verify and review the following:

1. Project requirements for tree and soil protection measures as set out in Contract Documents.
2. Manufacturer's product data including application instructions.
3. Limits where tree protection measures shall be implemented.
4. Limits where soil protection measures shall be implemented.
5. Areas of proposed staging, vehicle or equipment access, trenching, excavating, or other disturbance to soils.

### 1.7 QUALITY ASSURANCE

A. All tree work shall be performed by a professional Certified Arborist.

B. Mitigation or preventative maintenance operations such as root pruning and tree fertilization shall be performed in accordance with ANSI A300 Tree Management standards specification writing guidelines.

### 1.8 DAMAGE PENALTIES
A. Damages to trees and shrubs during construction activities will be assessed by the Architect, in accordance with the Council of Tree and Landscape Appraiser 9th Edition Guide for Plant Appraisal.

B. If any trees or shrubs designated to be saved are damaged and replacement is required, a number and diameter of trees or shrubs of the same species and variety, as specified by the Owner and Architect, shall be furnished and planted by the Contractor. The total inch diameter of the replacement trees or shrubs shall equal the diameter of the tree or shrub to be replaced.

PART 2 PRODUCTS

2.1 TREE AND SOIL PROTECTION FENCING AND SIGNAGE

A. Tree and soil protection fencing shall be the following:

1. Galvanized chain link fencing, 6 ft. high.
2. Fabric shall be a good commercial quality of steel wire of 2 in. mesh and 11 gage.
3. Fittings shall be malleable iron casting, wrought iron forgings, or pressed steel and provided with pin connections. Equipment shall be designed to carry 100% overload.
4. Piping shall be steel conforming to ASTM A 120 except that pipe shall be unthreaded and untested for water pressure.

B. Stakes for fencing shall be 9 ft. galvanized steel posts. Fence panels shall be clamped and bolted.

C. For fencing within the drip line of trees, surface mounted post anchors may be acceptable. Review with Architect and Owner and obtain written approval prior to installing. Post installation shall not damage tree root systems.

D. Unless otherwise indicated, warning signs will be provided by the Owner.

E. If signs are not provided by the Owner, then provide signs conforming to the following requirements:

1. A warning sign shall be displayed on the street side of the fence. The size of the sign must be no less than 8.5 x 11 inches. The sign must clearly state in bold red lettering: “Tree and Soil Protection Zone”. The sign shall clearly list the name and current contact information of the project owner or authorized representative.
2.2 SOILS AND CRITICAL ROOT ZONE PROTECTION

A. To prevent soil compaction within this protected zone, there should be no nonessential activity. Construction backfill material, construction stockpiles of material, and utility
structures should not be stored (or construction equipment parked) in or around the bases of existing trees or within the protected zones.

B. Soils and root zone protection shall include one of the following materials on an as needed basis, subject to review and approval by the Owner and Architect during the course of construction, incidental to an unforeseen need for construction access.

1. Road Mats: Critical root zones shall be protected with AlturnaMats, 1/2" thick recycled polyethylene mats capable of supporting vehicles and equipment weighing up to 60 tons, manufactured by AlturnaMats, Inc., 701 E. Spring Street, Mailbox #9, Titusville, PA 16354 • Phone: 888.544.6287 • Fax: 866-723-2903, or approved equal.

2. Steel Plates: ½ in. thick steel plates shall be placed on top of wooden cribbing to allow for air and gas exchange in soils.

3. Crushed Stone: shall be an angular, washed, durable, dense graded 3/4" crushed stone, crushed and screened through a 3/4" square screen. Following the crushing and screening of the crushed stone, it shall be cleaned extensively to ensure that it is free from stone dust and other residues.

4. Aged Wood Chips: shall be a 100% wood and bark chips free from dye, debris and stones, shredded and stockpiled no less than six months and no more than two years before use.

2.3 ROOT PRUNING MATERIALS

A. Root pruning materials will be determined and applied by a Certified Arborist.

PART 3 EXECUTION

3.1 FIELD VERIFICATION

A. If Logistics Plan for Tree and Soil Protection is required, conduct the following:

1. Flag trees to be preserved in accordance with approved Logistics Plan for Tree and Soil Protection.

2. Flag trees to be removed in accordance with approved Logistics Plan for Tree and Soil Protection.

3. Stake out extents of construction disturbance for review and approval by Owner and Architect, in accordance with approved Logistics Plan for Tree and Soil Protection.

B. If no Logistics Plan for Tree and Soil Protection is required, conduct field verification in accordance with methods agreed upon during Preconstruction Conference.

3.2 INSTALLATION OF FENCING AND SIGNAGE

A. Prior to start of demolition work and clearing and grubbing operations, tree and soil protection fencing shall be installed in accordance with the following:

1. Fencing shall be installed at the tree and soil protection areas indicated on the Drawings and approved submittals.

2. Fencing shall be installed on a tree by tree basis, beyond the drip line of trees to be protected, unless otherwise approved by the Owner and Architect.

B. Tree protection fencing to be installed over tunnels, vaults or other underground structures or utilities with less than 30 in. of cover shall be installed using surface anchors. No poles or stakes shall be driven into the ground at these locations.
C. Tree and soil protection signage shall be installed on fencing at locations indicated on the Drawings or determined in the field by the Owner.

3.3 CRITICAL ROOT ZONE IMPACTS

A. Unless otherwise directed by the Certified Arborist, trees impacted shall have a minimum of a six (6) inch layer of mulch placed and maintained over the critical root zone and the undisturbed area within the dripline.

1. Immediate pruning and fertilization shall occur per the pruning and fertilization sections of this specification.
2. Provide water in a slow drip manner to impacted trees as approved by the Architect and Owner.
3. Provide water to apply equivalent to 1 inch once per week to deeply soak in over the area within the dripline of the tree during periods of hot, dry weather.
4. Spray tree crowns periodically to reduce dust accumulation on the leaves.

B. No disturbance shall occur closer to the tree than inside the radius of the CRZ or within ten (10) feet of the tree, whichever is greater, and not without approval by the Architect and Owner.

C. Trimming of roots shall be performed by Certified Arborist.

3.4 PROTECTION FOR EXISTING TREES AND SOIL TO BE PRESERVED

A. All trees and soil to be preserved on the property shall be protected against damage from construction operations.

1. Includes associated understory.

B. Only those trees located within the limits of improvements to be constructed as indicated, shall be removed.

1. All trees to remain shall be flagged for review after the location of improvements to be constructed are staked in the field.
2. Any tree to be removed shall be reviewed by the Owner and Architect for approval prior to removal.
3. Obtain approval of installation of tree barricade fencing from Owner and Architect prior to the initiation of any removal of vegetation and construction.

C. Erect fencing prior to beginning any clearing, demolition or construction activity, and unless otherwise instructed, maintain in place until construction is completed.

1. Obtain approval of installation of tree barricade fencing from Architect and Owner prior to the initiation of any removal of vegetation and construction.
2. Tree and soil protection barricade shall be erected at the edge of the dripline where possible; in extreme circumstances and with the approval of the Architect and Owner, fencing may be located at the edge of the critical root zone.
   a. For trees 10 inch caliper and less, the minimum distance the barrier shall be erected is ten (10) feet from the trunk of tree or clump of trees.
3. Trees immediately adjacent to or within 25 ft. of any construction activities shall be protected by barricade fencing; subject to approval of the Architect and Owner.
4. The tree and soil protection barricade shall be placed before any excavating, trenching or grading is begun and maintained in repair for the duration of the construction work unless otherwise directed in writing by the Architect and Owner.
5. No material shall be stored or construction operation shall be carried on within the tree and soil protection barricade.
6. Tree and soil protection barricades shall remain in place until all work is completed and removal is permitted by the Architect and Owner.

D. Protect trees that are to remain, whether within barricade fencing or not, from the following (Refer to EXCAVATING AROUND TREES paragraph for additional information):
1. Compaction of soils by equipment or material storage; construction materials shall not be stored within the CRZ.
2. The proposed finished grade within the critical root zone of any preserved tree shall not be raised or lowered more than one and one half (1-1/2) inches. No soils within the CRZ shall be raised or lowered without prior on-site approval from the Owner. Review proposed grade with Architect prior to commencing work.
   a. Retaining methods can be used to protect and/or provide lateral support to the area outside the critical root zone.
3. Trunk damage by moving equipment, material storage, nailing or bolting.
4. Girdling or abrading by tying ropes or guy wires to the tree trunk or large branches.
5. Poisoning by pouring solvents, gas, paint, chemical solutions applied in masonry washing, etc., on or around tree soils and roots.
6. Drought from failure to water or by cutting or changing normal drainage patterns past roots, or disconnection, breakage or shut off of existing irrigation system. Contractor shall provide means as necessary to ensure adequate watering and positive drainage.
7. Changes of soil pH factor by disposal of lime base materials such as concrete, plaster, lime treatment at pavement subgrade, etc. When installing concrete adjacent to the root zone of a tree, use a minimum 6 mil. plastic vapor barrier behind the concrete to prohibit leaching of lime into the soil.
8. Do not cut roots 3/4” in diameter or over without approval of the Owner. All excavation and earthwork within the CRZ of trees shall be done by hand or as directed.
9. Protect all existing trees near areas to be stabilized from underground contaminations by placing a 6 mil. Plastic film barrier along exposed vertical cut extending a minimum 12” into undisturbed subgrade below depth of stabilization.
10. No vehicular traffic shall occur within the drip line of any tree or in protected soil zones; including parking of vehicles.
11. No soil shall be spread, spoiled or otherwise disposed of under any tree within the CRZ.

E. Any damage done to existing tree crowns or root systems shall be repaired by the Certified Arborist to the satisfaction of the Owner and Architect.
1. Broken branches shall be pruned in accordance with industry standards.
2. Roots shall be exposed and cut cleanly with an airspade or other means approved by the Architect.

F. Damages to trees caused through negligence of Contractor or his employees will be assessed as described in Paragraph 1.10.

3.5 EXCAVATING AROUND TREES

A. Excavate within the dripline of trees only where required and when absolutely necessary and with prior written approval from the Owner and Architect.
1. Any excavation within the CRZ of trees shall be under the direction of the Certified Arborist.
2. A Certified Arborist shall be at site prior to and for periodic observation while excavation is occurring within the CRZ.
3. Air spade operations of all removals within the CRZ are by Certified Arborist as directed by the Owner and Architect.
4. Refer to CRITICAL ROOT ZONE (CRZ).

B. When excavating for new construction is required within the CRZ, air spade and hand excavate to minimize damage to root systems.
   1. Air spade operations shall be performed by Certified Arborist.
   2. Use narrow tine spading forks and comb soil to expose roots.
   3. Relocate roots back into backfill areas wherever possible.
   4. If large main lateral roots are encountered, expose beyond excavation limits as required to bend and relocate without breaking.
   5. If root relocation is not practical, clean cut roots using sharp hand saw approximately three (3) inches back from new construction.

C. Where existing grade is above new finish grade, carefully excavate within the dripline to the new finish grade.
   1. Carefully hand excavate an additional six (6) inches below the finish grade.
   2. Use narrow tine spading forks to comb the soil to expose the roots, and prune the exposed root structure as recommended by the Arborist.
   3. Keep the exposed roots damp.
   4. Treat the cut roots as specified and as recommended by the Certified Arborist.
   5. After pruning and treatment of the root structure is complete, backfill to finish grade with eight (8) inches of approved plant mix, or structural soil.

D. Where noted on plan, use airspade to expose roots for required cutting to accommodate hardscape elements. Landscape Architect to verify all cuts prior to proceeding.

E. Temporarily support and protect roots against damage until permanently relocated and covered with recommended landscape material.

3.6 ROOT PRUNING

A. Where construction will occur within drip line of existing trees designated to remain, roots shall be pruned in accordance with ANSI A300.

B. All root pruning shall be done by Certified Arborist only. Trenching, vibrating plow, and stump grinding are NOT suitable means for root pruning.

C. Roots greater than 1 in. diameter shall be pruned by means of a hand saw, or other approved means.

D. Install root protection measures as prescribed by Certified Arborist.

3.7 CROWN PRUNING

A. Pruning of tree crowns shall not be permitted.

3.8 FERTILIZATION OF PRESERVED TREES

A. All existing trees to be preserved, and impacted by construction activities taking place within the dripline, including but not limited to trenching and grading, shall be fertilized as determined by a soils analysis report.
B. Subsurface deep root fertilization of the existing trees to be impacted by construction shall be accomplished in accordance with the following specifications and performed by Certified Arborist under direction from the Owner:

1. Fertilization shall be completed prior to construction of permanent improvements adjacent to all trees including site fill or paving including trenching operations.
2. Liquid tree fertilizer applied with a standard hydraulic sprayer at a pressure of 100 to 200 psi shall be injected in slightly slanted holes approximately 6 to 8 inches in depth.
3. Concentration of suspension to be forty (40) pounds of fertilizer for trees in each 100 gallons of water. Application rate: six (6) pounds of actual nitrogen per 1,000 square feet of area under drip-line.
4. Holes are to be made in concentric circles and 3' on center around the tree with the last ring located at the dripline of the foliage of the trees.
5. Area beneath the dripline of the trees is to be well watered after the fertilization is placed.

3.9 CLEANUP

A. Wood and debris shall become property of the Contractor and shall be removed from the site. Cost of disposal shall be paid by Contractor.

B. If acceptable to Owner, wood from tree removal and pruning activities can be double shredded/grinded and used on site as mulch at locations approved by the Owner.

3.10 REMOVAL OF PROTECTION AND SIGNAGE

A. All protection measures shall remain in place throughout the construction period. Remove protection devices only after written permission has been granted by the Architect.

B. Signage shall be removed and returned to the Owner.

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1. **023000 - SUBSURFACE INVESTIGATION**

1.1 **Geotechnical Information**

MIT maintains a database of subsurface conditions. Contact the MIT Project Manager for a list of available information for the project site.

1.2 **Information not Guaranteed**

Information provided by MIT relating to subsurface conditions and existing utilities and structures is from sources presently available. Such information is furnished only for the information and convenience of the design team, and the accuracy or completeness of this information is not guaranteed.

1.3 **Prior to Excavation**

No excavation may begin without notification to the MIT Project Manager.

1.4 **Geotechnical Monitoring**

Excavation adjacent to historic structures at MIT requires geotechnical monitoring. The geotechnical engineer on the design team is required to establish a program for geotechnical monitoring and reporting throughout construction operations.

2. **024100 - DEMOLITION**

2.1 **Selective Demolition**

Selective Demolition includes the following:

1. Selective demolition of exterior facade, structures, and components designated to be removed.
2. Selective demolition of interior partitions, systems, and building components designated to be removed.
3. Protection of portions of building adjacent to or affected by selective demolition.
4. Removal of abandoned utilities and wiring systems.
5. Notification to Owner of schedule of shut off of utilities which serve occupied spaces.
6. Pollution control during selective demolition, including noise control.
7. Removal and legal disposal of materials.
8. Savage of items based on project requirements.

2.2 Site Demolition

Site Demolition includes the following:

1. Demolition of designated site improvements including paving, curbing, site walls, and utility structures.
2. Demolition of below grade foundations and site improvements to depth to avoid conflict with new construction or site work.
3. Removal of hollow items or items which could collapse.
4. Protection of site work and adjacent structures.
5. Disconnection, capping, and removal of utilities.
6. Pollution control during selective demolition, including noise control.
7. Removal and legal disposal of materials.
8. Savage of items based on project requirements.

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1. **033000 - CAST-IN-PLACE CONCRETE**

1.1 **Project Includes**

Cast-in-place concrete, reinforcing and accessories.

1.2 **Quality Assurance**

Standards:

2. ACI 301, Specifications for Structural Concrete for Buildings.
3. ACI 117, Specifications for Tolerances for Concrete Construction and Materials.
4. ACI 318, Building Code Requirements for Structural Concrete.

Testing: Employ an independent testing agency acceptable to Owner to design concrete mixes and to perform material evaluation tests. Provide 7- and 28-day cylinder tests. Comply with ASTM C143, C173, C31 and C39.

Mock-Ups: Provide mock-up as required to demonstrate quality of workmanship.

Floor Flatness and Levelness Tolerances:

1. Subfloors Under Materials Such as Concrete Toppings, Ceramic Tile, and Sand Bed Terrazzo: ACI 302.1R and ASTM E 1155, floor flatness (Ff) of 15, floor levelness (Fl) of 13.
2. Subfloors Under Materials Such As Vinyl Tile, Epoxy Toppings, Paint, and Carpet: ACI 302.1R and ASTM E 1155, floor flatness (Ff) of 20, floor levelness (Fl) of 17.

Comply with ACI 301. Calcium chloride admixtures are not permitted.

Tolerances: ACI 117.

1.3 **Products**

Design Mix: ASTM C 94, 3500 psi min. typical, 28 day compressive strength.

Formwork: Plywood or metal panel formwork sufficient for structural and visual requirements.

Reinforcing Materials:

1. Reinforcing Bars: ASTM A 615, Grade 60, galvanized.
2. Steel Wire:  ASTM A 82, galvanized.

Concrete Materials:


Admixtures:

2. Concrete Admixtures:  Containing less than 0.1 percent chloride ions.

Waterstops:  Rubber, PVC or self expanding butyl/bentonite waterstops.

Underslab Vapor Retarder:  ASTM D 4397, polyethylene sheet, 10 mils.

Liquid Membrane-Forming Curing Compound:  ASTM C 309, Type 1, Class B, dissipating.

Slab Finishes:

1. Scratch: For surfaces to receive mortar setting beds or cementitious flooring materials.
2. Trowel: Hard, smooth, uniform surface for areas to receive resilient flooring, carpet, or other thin finish material.
3. Broom: After trowel finishing, roughen surface by fine brooming perpendicular to traffic direction for exposed exterior walks, steps and ramps.
4. Non-Slip Aggregate: After trowel finishing, uniformly trowel 25-lbs./100 square feet of damp non-slip aggregate into surface. Cure, then rub lightly to expose aggregate. Use for interior exposed concrete stairs and ramps.
5. Exposed Aggregate: Use chemical retarder or tamp aggregate into wet concrete and expose by brushing with water. Use where indicated.

2. **034500 - ARCHITECTURAL PRECAST CONCRETE**

2.1 **Project Includes**

Architectural precast concrete panels and shapes.
2.2 **Sustainable Design**

Provide Architectural precast concrete with the following sustainable design features:

1. Recycled content.
2. Regional materials.

2.3 **Quality Assurance**

Standards:

1. ACI 318, Building Code Requirements for Reinforced Concrete.
3. PCI MNL 117, Manual for Quality Control for Plants and Production of Architectural Precast Concrete Products.

Testing: Independent testing laboratory.

Fabrication and Erection Tolerance Limits: PCI MNL 117.

2.4 **Products**

Design Mix: 5000 psi (34 MPa), 28 day compressive strength, 4 to 6 percent total air content.

Formwork: Plywood or metal panel formwork sufficient for structural and visual requirements.

Reinforcing Materials:

1. Reinforcing Bars: ASTM A615, Grade 60, deformed.
2. Steel Wire: ASTM A82.

Concrete Materials:

1. Standard Gray Cement: Portland cement, ASTM C150, Type I or Type III.

Concrete Admixtures:

1. Containing less than 0.1 percent chloride ions.
2. Connection Materials: Steel plates and finishes, galvanized.
3. **034900 - GLASS FIBER-REINFORCED CONCRETE**

3.1 **Project Includes**

Glass-fiber-reinforced concrete units.

3.2 **Quality Assurance**

Comply with PCI MNL 130.

3.3 **Products**

Factory-formed portland cement, glass fiber, sand and admixtures complying with PCI MNL 130.

4. **035400 - CONCRETE FLOOR TOPPING**

4.1 **Project Includes**

Concrete floor topping at floors requiring slope.

Gypsum topping is not acceptable where concrete floor topping is indicated.

4.2 **Products**

Concrete Floor Topping: Cement based underlayment / topping.

5. **035410 - GYPSUM CEMENT UNDERLAYMENT**

5.1 **Project Includes**

Self-leveling gypsum-cement based floor underlayment.

5.2 **Products**

Gypsum-Cement Floor Underlayment:

1. **Type:** Gypsum-cement-based, self-leveling underlayment:

2. **Compressive Strength:** Not less than 2000 psi at 28 days when tested according to ASTM C472.
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1. **040120 - MASONRY AND STONE RESTORATION AND CLEANING**

### 1.1 Project Includes

Masonry and Stone Restoration may include the following:

1. Repointing mortar joints.
2. Repair of damaged clay masonry.
3. Repair of damaged stone masonry.
4. Re-anchoring veneer.

Masonry and Stone Cleaning may include the following:

1. Removal of plant growth.
2. Washing and cleaning exposed masonry surfaces.

### 1.2 Quality Assurance

Existing Masonry and Stone: MIT maintains a database of existing masonry types and sources. Request information from the MIT Project Manager.

Specialist: Historic Building Restoration Specialist is required.

Materials: Cleaning materials acceptable to environmental agencies and authorities having jurisdiction.

Protection: Protect contractor employees, general public, adjacent building materials, and surroundings from damage.

Field Constructed Mock Up: Each type of cleaning, repointing, and repair.

### 1.3 Products

Face Brick: Match existing or new as applicable. Reuse salvaged bricks where available.

Stone: Match existing or new as applicable. Reuse salvaged stone where available.

Repointing Mortar: Match existing with strength suitable for project conditions.

1. Portland Cement: ASTM C150, Type I, non-staining type.
2. Hydrated Lime: ASTM C207, Type S.
7. Water.

Patching Materials: Compatible with existing materials; visual matching.

1. Composite patching mortars.
2. Cementitious and epoxy injection grout for cracked stone units.

Epoxy adhesives.

Ties and Anchors: Stainless steel, Type 304 or 316.

Cleaning Materials:

1. Water and steam.
2. Chemical cleaner.

2. **042000 - UNIT MASONRY**

2.1 **Project Includes**

Unit masonry may include the following:

1. Brick veneer cavity walls on metal stud and concrete masonry unit partitions.
2. Concrete masonry bearing and non-bearing partitions.
3. Remodeling of existing masonry partitions

2.2 **Sustainable Design**

Provide unit masonry with the following sustainable design features:

1. Recycled content: CMU and metal accessories.
2. Regional materials: Brick and CMU.

2.3 **Quality Assurance**

Existing Masonry: MIT maintains a database of existing masonry types and sources. Request information from the MIT Project Manager.

Procedures for Historic Buildings at MIT: MIT maintains a database of drawings and specifications for project procedures. Request information from the MIT Project Manager.

### 2.4 Products

**Face Brick:**

1. Grade: ASTM C216, Grade SW, severe weathering type areas subject to freeze thaw.
2. Type: ASTM C216, Type FBS, for general exposed use.
3. Special Shapes: As required by building configuration.

**Concrete Masonry Units (CMU):**

1. Type: ASTM C90, 1500 f'm compressive strength, normal weight.
3. Concrete Building Brick: ASTM C55.
4. Special Shapes: As required by building configuration.

**Mortar and Grout:**

1. Mortar Mix: ASTM C270, Type N.
2. Mortar Materials: Portland cement, ASTM C150, Type I or II.

**Joint Reinforcing:** Welded wire with deformed side rods.

1. Steel Wire: 9 gage galvanized steel.
2. Type: Galvanized ladder or truss type.

**Ties and Anchors:**


### 3. 044300 - STONE MASONRY

#### 3.1 Project Includes

Stone masonry may include the following:

1. Exterior stone wall panels.
2. Exterior stone base.
3. Exterior stone stair treads and risers

### 3.2 Sustainable Design

Provide stone masonry with the following sustainable design features:

1. Recycled content: Metal accessories.
2. Regional materials: Stone.

### 3.3 Quality Assurance

Existing Stone: MIT maintains a database of existing masonry types and sources. Request information from the MIT Project Manager.

Procedures for Historic Buildings at MIT: MIT maintains a database of drawings and specifications for project procedures. Request information from the MIT Project Manager.

### 3.4 Products

Stone:

2. Limestone: Bedford limestone, typically honed finish.

Joints: Mortar only.

Accessories: Stainless steel anchors, fasteners, flashings.

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1. **051200 - STRUCTURAL STEEL FRAMING**

1.1 **Project Includes**

Structural steel assemblies and accessories.

1.2 **Sustainable Design**

Provide structural steel framing with the following sustainable design features:

1. Recycled content.
2. Regional materials.

1.3 **Quality Assurance**

Standards:

2. AISC Code of Standard Practice for Steel Buildings and Bridges, and applicable regulations.
3. AISC Specification for Load and Resistance Factor Design for Structural Steel Buildings
4. AWS D1.1, Structural Welding Code.

Architecturally Exposed Structural Steel: Comply with fabrication requirements, including tolerance limits, and installation tolerances of the AISC Code of Standard Practice for Steel Buildings and Bridges for structural steel identified as architecturally exposed structural steel.

Employ a registered engineer to check elevations and plumb and level tolerances; certify that installed work is within AISC Standards. MIT may engage testing/inspection agency to inspect welded and bolted connections.

1.4 **Products**

Structural Steel Shapes: ASTM A992, unless indicated otherwise below.

Structural Steel Plates, and Bars: ASTM A36.

Structural Steel Hollow Structural Sections (HSS): ASTM A500, Grade B, 46 ksi.

Cold-Formed Steel Tubing: ASTM A500, Grade B.

Hot-Formed Steel Tubing: ASTM A501.
Steel Pipe: ASTM A53, Type E or S, Grade B; or ASTM A501.
Steel Castings: ASTM A27, Grade 65-35.
Headed Stud-Type Shear Connectors: ASTM A108, Grade 1015 or 1020.
Anchor Bolts: ASTM F1554, unless indicated otherwise on plans.
Unfinished Threaded Fasteners: ASTM A307, Grade A.
High-Strength Threaded Fasteners: ASTM A325N or ASTM A490N, as applicable.
Direct Tension Indicators: ASTM A959.
Electrodes for Welding: E70XX.
Structural Steel Primer Paint: SSPC - Paint 13, compatible with topcoats.
Structural Steel Finish Coating: As selected by the Architect from manufacturer’s full range.
Cement Grout: Portland cement, sand.
Metallic Shrinkage-Resistant Grout: Premixed ferrous aggregate grouting compound ASTM C1107.
Nonmetallic Shrinkage-Resistant Grout: Premixed nonmetallic grouting compound, ASTM C1107.

2. 053100 - METAL DECKING

2.1 Project Includes

Metal decking may include the following:

1. Steel roof deck.
2. Acoustical steel roof deck.
3. Steel floor deck.
5. Composite cellular metal floor deck with electrical distribution

2.2 Sustainable Design

Provide metal decking with the following sustainable design features:

1. Recycled content.
2. Regional materials.

2.3 Quality Assurance

Metal decking for steel deck roofs shall be FM Approved and installed according to the RoofNav assembly appropriate for the needed, wind, hail and interior and exterior fire ratings.

Standards:

2. AISI Specification for the Design of Cold-Formed Steel Structural Members.
3. SDI Design Manual for Composite Decks, Form Decks, and Roof Decks.

2.4 Products

Steel Type: Steel for painted metal deck, ASTM A1008; steel for galvanized metal deck, ASTM A653 Grade 40 minimum, 18GA min, G90 coating.

Steel Shapes: ASTM A36.

Headed Stud Type Shear Connectors: ASTM A108, Grade 1015 or 1020.

Sheet Metal Accessories: Galvanized per ASTM A653, G60 coating, commercial quality.

Galvanizing: ASTM A653, G90.

Galvanizing Repair: ASTM A780.

3. 054000 - COLD-FORMED METAL FRAMING

3.1 Project Includes

Cold-formed metal framing may include the following:

1. Cold-formed metal framing for support of exterior walls.
2. Cold-formed metal framing for support of interior demising partitions.

3.2 Sustainable Design

Provide cold-formed metal framing with the following sustainable design features:

1. Recycled content.
2. Regional materials.
3.3 Quality Assurance

Standards:

1. AISI, Specification for Design of Cold Formed Steel Structural Members.

Deflection Criteria: L/600 for masonry; L/360 for metal panels and siding.

Fabrication Tolerances: 1/8 inch in 10 feet.

Erection Tolerances: 1/16 inch.

Engineering: Systems engineered and stamped by contractor’s professional engineer.

3.4 Products

Cold-Formed Metal Framing Materials:

1. Wall Framing: C shaped load bearing steel studs.
2. Units 16 gage (0.0598 inch): ASTM A446, yield point 50,000 psi.

Cold-Formed Metal Framing Accessories:

1. Supplementary framing.
2. Bracing, bridging, and solid blocking.
3. Web stiffeners.
4. Deflection track and vertical side clips.
5. Reinforcement plates.
6. Anchors, clips, and fasteners.
7. Screw strips.

4. 055000 - METAL FABRICATIONS

4.1 Project Includes

Miscellaneous Metal Fabrications may include the following:

1. Ladders.
2. Galvanized steel lintels at exterior; primed steel at interior.
3. Galvanized steel loading dock edge angles.
4. Bollards, concrete filled galvanized steel at exterior, shop primed steel at interior.
5. Galvanized steel areaway bar gratings and support frames.
6. Miscellaneous metal framing and supports for overhead doors and grilles.
7. Miscellaneous metal framing and supports for ceiling hung toilet partitions.
8. Miscellaneous metal framing and supports for operable partitions.
9. Miscellaneous metal framing and supports for elevators.
10. Miscellaneous metal framing and supports for mechanical, electrical and audiovisual equipment.
11. Roof davits for window washing equipment.

Metal Stairs may include the following:

1. Galvanized steel exterior steel stairs, with concrete filled pans.
2. Shop-primed interior steel stairs, with concrete filled pans.

Metal Railings may include the following:

1. Galvanized exterior steel railings, handrails, and guardrails.
2. Decorative interior stainless steel and glass railings, handrails, and guardrails.

Metal Gratings may include the following:

1. Galvanized exterior steel bar gratings and supports at areaways.

Decorative Metal Fabrications may include the following:

1. Stainless steel fabrications, satin finish typical.

4.2 Sustainable Design

Provide metal fabrications with the following sustainable design features:

1. Recycled content.
2. Regional materials.
3. Low VOC adhesives and sealants.
4. Low VOC paints and coatings.

4.3 Quality Assurance

Handrail and Railing Structural Performance: ASTM E985.

Accessibility Requirements:

3. Local regulations.
4.4 Products

Ferrous Materials:

2. Cold-Formed Steel Tubing: ASTM A500.
3. Hot-Formed Steel Tubing: ASTM A501.
   b. Bollards: Schedule 80.

5. Stainless-Steel:
   a. Sheet, Strip, Plate, and Flat Bars: ASTM A666.
   c. Types: Type 304 at interior, Type 316L at exterior.

7. Welding Rods and Bare Electrodes: AWS specifications.

Non-Ferrous Materials:

1. Aluminum Extrusions and Bars: ASTM B221.

Auxiliary Materials:

6. Fasteners: Corrosion-resistant, suitable for use.

Finishes: Unless otherwise indicated, provide the following:

1. Steel: Shop primed, color and sheen as selected by the Architect.
2. Stainless Steel: AISI No. 4.

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1. **061000 - ROUGH CARPENTRY**

1.1 **Project Includes**

Rough carpentry may include the following:

1. Wood grounds, nailers, and blocking.
2. Wood furring.

1.2 **Sustainable Design**

Provide rough carpentry with the following sustainable design features:

1. Recycled content.
2. FSC certified wood.
3. Low VOC adhesives and sealants.
4. No added urea-formaldehyde.

1.3 **Quality Assurance**

Rough carpentry nailers for roofing shall comply with the securement guidelines in FM Data Sheet 1-49, Perimeter Flashing.

Standards:

1. Lumber Standards and Grade Stamps: PS 20, American Softwood Lumber Standard and inspection agency grade stamps.
4. Fire Retardant Treatment: AWPA C20 for lumber and AWPA C27 for plywood; noncorrosive type.

1.4 **Products**

Miscellaneous Lumber:

1. Moisture Content: 19 percent.
2. Grade: Standard grade light framing.
Construction Panels:

1. Plywood Backing Panels: APA C-D Plugged Exposure 1 with exterior glue, fire retardant treated.

Auxiliary Materials:

1. Framing Anchors and Fasteners: Non corrosive, suitable for load and exposure.

2. 061600 - SHEATHING

2.1 Project Includes

Exterior sheathing over metal studs at designated exterior wall assemblies.

2.2 Sustainable Design

Provide sheathing with the following sustainable design features:

1. Recycled content, plywood.
2. FSC certified wood.

2.3 Products


1. Thickness: 5/8 inch.

Plywood Sheathing:

1. Wall Sheathing: APA Structural Grade, C-D Plugged Exterior with exterior glue, fire retardant treated.
2. Thickness: 5/8 inch.

Auxiliary Materials:

1. Fasteners: Non corrosive, suitable for load and exposure.

3. 062010 - EXTERIOR FINISH CARPENTRY

3.1 Project Includes

Exterior standing and running trim and rails.
3.2 **Sustainable Design**

Provide exterior finish carpentry with the following sustainable design features:

1. Recycled content, plywood.
2. FSC certified wood.

3.3 **Quality Assurance**

Preservative Treatment: Non-pressure method, exterior type, NWWDA I.S. 4.

Fire Retardant Treatment: AWPA C20 for lumber and AWPA C27 for plywood; non corrosive exterior type.

Synthetic Trim: Not acceptable.

3.4 **Products**

**Exterior Standing and Running Trim and Rails:**

1. Wood Species: Western Red Cedar, clear vertical grain; or match existing as indicated.

**Auxiliary Materials:**

1. Nails: Stainless steel or hot dip galvanized siding nails.
2. Screws and Anchors: Noncorrosive, type required for secure anchorage.

4. **064020 - INTERIOR ARCHITECTURAL WOODWORK**

4.1 **Project Includes**

Interior architectural woodwork may include the following:

1. Interior standing and running trim and rails, including wood handrails at stairs.
2. Wood casework.
3. Plastic laminate casework.
4. Plastic laminate countertops.
5. Solid surfacing countertops and window sills.
6. Wood paneling and trim.
7. Shelving.
4.2 Sustainable Design

Provide interior architectural woodwork with the following sustainable design features:

1. Recycled content.
2. FSC certified wood.
3. Low VOC adhesives and sealants.
4. Low VOC paints and coatings.
5. No added urea-formaldehyde.

4.3 Quality Assurance

Standards:


4.4 Products

Wood Species and Cuts for Transparent Finish: Match building standard where applicable, select for new applications.

Wood Species and Cuts for Opaque Finish:

   Poplar or any closed grain hardwood.

Plastic Laminate:

   High pressure decorative laminate, NEMA LD 3.

Panel Cores:

   Plywood, particleboard or medium density fiberboard (MDF).

Sold Surfacing:

   Synthetic surfacing or quartz agglomerate.

Countertops:

1. Plastic laminate clad plywood cores.
2. Solid surfacing materials.
3. Countertop support brackets.

Shelving:

1. Plastic laminate clad plywood cores.
2. Adjustable standards and brackets.

Casework Hardware and Auxiliary Materials:

2. Hardware Finish and Base Metal: Satin stainless steel.
3. Adhesives and metal fasteners.

Factory Finishing: AWS premium grade finishes.

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15. **079500 - EXPANSION CONTROL**

15.1 **PROJECT INCLUDES**

15.2 **QUALITY ASSURANCE**

15.3 **PRODUCTS**
1. **071000 - WATERPROOFING**

1.1 **Project Includes**

Waterproofing may include the following:

1. Sheet membrane waterproofing applied to foundation walls and footings.
2. Metal oxide waterproofing on interior side of concrete floors and walls at elevator pits and sump pits.

1.2 **Quality Assurance**

Field Quality Testing: Flood testing horizontal applications.

1.3 **Products**

Sheet Waterproofing: Self adhering rubberized asphalt and polyethylene sheet membrane, 56 mils thick, tensile strength 250 psi.

Metal Oxide Waterproofing: Pulverized iron and a chemical oxidizing agent to cause the iron particles to rust and grow in size in the presence of water for negative side waterproofing.

Accessories: Primer, drainage board and protection course.

2. **071100 - DAMPROOFING**

2.1 **Project Includes**

Bituminous dampproofing applied to foundation and site walls not requiring waterproofing.

2.2 **Products**

Cold-Applied, Emulsified-Asphalt Dampproofing, Brush and Spray Coats: ASTM D1227, Type III, Class 1.

Accessories: Primers, patching compound and protection course.
3. 072100 - THERMAL INSULATION

3.1 Project Includes

Thermal insulation may include:

1. Rigid insulation at foundation walls, under slabs on grade.
3. Spray foam insulation at precast panels.
4. Glass-fiber batts or blankets at exterior walls.
5. Spray foam insulation.

3.2 Sustainable Design

Provide thermal insulation with the following sustainable design features:

1. Recycled content.

3.3 Quality Assurance

R-Values: Comply with applicable local requirements, but not less than R-19 at exterior walls and R-30 at roof.

Field Quality Testing: Infrared thermographic survey.

Foam Insulation: The use of spray applied polyurethane foam insulation for interior building application is prohibited.

3.4 Products

Extruded polystyrene insulation board, ASTM C578.

1. R-Value: R 5.4 per inch.

Mineral wool board, ASTM C612, Type IVB, 4 pounds per cubic square foot.

1. R-Value: R-4.3 per inch.

Spray polyurethane foam insulation, closed cell type typical.

1. R-Value: R-6.2 per inch.
2. Soy-based foams not acceptable.

Glass-fiber batts or blankets, ASTM C665, unfaced type.
1. R-Value: R 3.2 per inch.

Accessories:

1. Adhesives.
2. Vapor barriers.
3. Thermal barriers.

### 4. 072700 - AIR BARRIERS

#### 4.1 Project Includes

Continuous air and vapor barrier membrane over concrete masonry units and gypsum sheathing at exterior assemblies.

#### 4.2 Quality Assurance

Standards:

1. NFPA 285 compliant assemblies.

#### 4.3 Products

Air and Vapor Barrier Membrane, Fire-Rated Type: Self-adhering rubberized asphalt and polyethylene sheet membrane, 56 mils thick.

Air Permeance: Not to exceed 0.004 cubic foot per minute per square foot of surface area at 1.57-pounds per square foot pressure difference when tested to ASTM E2178.

Vapor Permeance: 0.05 perms maximum when tested to ASTM E96, Water Method.

Accessories: Silicone strips at seal to penetrations.

### 5. 073126 - SLATE SHINGLES

#### 5.1 Project Includes

Slate shingles for roofing and accessories.

#### 5.2 Sustainable Design

Provide slate shingles with the following sustainable design features:
1. Regional materials, slate.

5.3 Quality Assurance

FM Global: Projects must comply with FM Global requirements. Materials must be listed in the FM Approval Guide.

Existing Buildings at MIT: MIT maintains a database of roofing and warranties for existing buildings. Request information from the MIT Project Manager.

Ice/water shield underlayment should extend throughout as much of the roof area as possible.

5.4 Products

Slate Shingles: ASTM C406, Grade S1.

Accessories:

2. Underlayment: Rubberized asphalt ice and water shield.
4. Slater’s nails.

6. 074200 - METAL WALL PANELS

6.1 Project Includes

Metal wall panels, mounting systems and accessories.

6.2 Sustainable Design

Provide metal wall panels with the following sustainable design features:

1. Recycled content.

6.3 Quality Assurance

Aluminum-faced or metal-faced composite material panels shall be FM Approved. If no FM Approved panels are available, the proposed panels shall have a mineral fiber or similar less-combustible core, or have passed a large scale fire test such as FM 4880; NFPA 285; or BS 8414. NFPA 285 compliant assemblies.

FM Global: Projects must comply with FM Global requirements. Materials must be listed in the FM Approval Guide.
6.4 Products


Insulated Metal Wall Panels: ASTM B209, aluminum sheet on rigid foam core, 3 inches thick.
  1. Attachment System: Concealed fasteners.

Corrugated Metal Wall Panels: ASTM B209, aluminum sheet, 0.040 inch thick.

Steel Framing: ASTM C645 with ASTM A653 G60 hot-dipped galvanized coating.

Accessories: Trims and fasteners.

Finish: AAMA 2605, 3-coat metallic fluoropolymer finish, 70 percent resin.

7. 074300 - FIBER-CEMENT WALL PANELS

7.1 Project Includes

Fiber-cement wall panels, mounting systems and accessories.

7.2 Sustainable Design

Provide fiber-cement wall panels with the following sustainable design features:
  1. Recycled content.

7.3 Products

  1. Attachment System: Rainscreen, concealed fasteners.

Steel Framing: ASTM C645 with ASTM A653 G60 hot-dipped galvanized coating.

Accessories: Trims and fasteners.

Finish: AAMA 2605, 3-coat metallic fluoropolymer finish, 70 percent resin.

8. 075000 - MEMBRANE ROOFING
8.1 Project Includes

Single-ply membrane roofing and roof insulation.

8.2 Sustainable Design

Provide membrane roofing with the following sustainable design features:

1. Roofing: High solar reflectance index (SRI).
2. Solar ready design and construction.

8.3 Quality Assurance

FM Global: Projects must comply with FM Global requirements. Materials must be listed in the FM Approval Guide and installed according to the RoofNav assembly appropriate for the needed, wind, hail and interior and exterior fire ratings.

FM RoofNav: Roofing assemblies must be designed based on a specific FM Global RoofNav number. The number must be included in the specifications issued for bidding.

The installing contractor must provide a completed FM Global Form 2688, Checklist for Roofing System, for FM Global review and comment prior to the purchase, delivery or installation of any roof materials. The Form 2688 should include actual building dimensions, a proposed RoofNav number, and the proposed brand, thickness, securement type, and securement rate of all proposed assembly components.

If a fully adhered membrane will be installed, the roof covering should pass either visual construction observation (VCO) or uplift testing in accordance with Data Sheet 1-52, Field Verification of Roof Wind Uplift Resistance, before the installation is considered complete.

R-Values: Comply with applicable local requirements, but not less than R-30 at roof.

Existing Buildings at MIT: MIT maintains a database of roofing and warranties for existing buildings. Request information from the MIT Project Manager. Predominant manufacturer is Sika Sarnafil.

Product: Manufacturer’s standard 20 year warranty.

8.4 Products

Membrane Roofing:

1. Membrane: PVC 60 mils min. thickness, white color.
2. Type: Fully adhered or mechanically fastened.

Accessories:
1. Vapor Barrier: Reinforced polyethylene.
2. Insulation: Extruded polystyrene, tapered and cricketed.
4. Walkway pads.

9. **076100 - SHEET METAL ROOFING**

9.1 **Project Includes**

Custom fabricated sheet metal roofing.

9.2 **Sustainable Design**

Provide sheet metal roofing with the following sustainable design features:

1. Recycled content, metals.

9.3 **Quality Assurance**


FM Global: Projects must comply with FM Global requirements. Materials must be listed in the FM Approval Guide and installed according to the RoofNav assembly appropriate for the needed, wind, hail and interior and exterior fire ratings.

Products: Manufacturer’s standard 20 year warranty.

9.4 **Products**

Aluminum Sheet: ASTM B209.

1. Finish: AAMA 2605, 3-coat metallic fluoropolymer finish, 70 percent resin.

Copper Sheet: ASTM B 370, cold-rolled copper sheet, H00 temper.

1. Non-Patinated Exposed Finish: Mill.

Stainless-Steel Sheet: ASTM A240, Type 304.

1. Finish: No. 2D dull, cold rolled.

Fabrication: Comply with SMACNA, provide one of the following seam types as indicated.

1. Standing seam.
2. Flat seam.
3. Batten seam.

Accessories:

1. Underlayment, high temperature.
2. Gutters and downspouts
3. Snow guards.
4. Solder, compatible with metal, and flux.
5. Elastomeric sealants.

10. 076200 - SHEET METAL FLASHING AND TRIM

10.1 Project Includes

Sheet metal flashing and trim may include the following:

1. Metal flashing and counterflashing.
2. Metal copings.
3. Gutters and downspouts.
4. Sheet metal accessories.

10.2 Sustainable Design

Provide sheet metal flashing and trim with the following sustainable design features:

1. Recycled content, metals.

10.3 Quality Assurance


FM Global: Projects must comply with FM Global requirements. Materials must be listed in the FM Approval Guide.

Product: Manufacturer’s standard 20 year warranty.

10.4 Products

Aluminum Sheet: ASTM B209.

1. Finish: AAMA 2605, 3-coat metallic fluoropolymer finish, 70 percent resin.
Copper Sheet:  ASTM B370, cold-rolled copper sheet, H00 temper.

1. Non-Patinated Exposed Finish:  Mill.

Stainless-Steel Sheet:  ASTM A240, Type 304.

1. Finish:  No. 2D dull, cold rolled.

Fabrications:

1. Metal Copings and Roof Edges:  Aluminum, 0.040 thick, brake-formed.
2. Roof Drain and Penetration Flashing:  Stainless steel, 0.0187 inch thick.
3. Through-Wall Flashing:  Stainless steel, 0.0156 inch thick.
4. Miscellaneous Flashings at Metal Wall Panels:  Aluminum, 0.040 thick.

Accessories:

1. Solder, compatible with metal, and flux.
2. Bituminous isolation coating.
3. Building felts and slip sheets.
4. Elastomeric sealants.
5. Epoxy seam sealer.

### 11. 077200 - ROOF ACCESSORIES

#### 11.1 Project Includes

Roof accessories may include the following:

1. Roof hatches.
2. Elevator vents.

#### 11.2 Products

**Roof Hatches:**

1. Type:  Single leaf, galvanized steel or aluminum, insulated curb.

**Elevator Vents:**

1. Type:  Automatic dampers.

### 12. 078100 - APPLIED FIREPROOFING
12.1 Project Includes

Applied fireproofing may include the following:

1. Spray applied fireproofing for concealed and exposed locations.
2. Spray applied intumescent fireproofing for exposed locations.

12.2 Quality Assurance

Independent Inspection: Engage an independent inspector for fireproofing in accordance with the Massachusetts State Building Code.


FM Global: Projects must comply with FM Global requirements. Materials must be listed in the FM Approval Guide.

12.3 Products

Concealed Sprayed On Fireproofing:

1. Type: Cementitious, 15 pounds per cubic foot dry density, ASTM E605.

Exposed Fireproofing:

1. Type: Intumescent.
2. Finish Coating: As selected by the Architect from manufacturer’s full range.

Accessories: Primers, adhesive, lath, and reinforcing fabric and as recommended by the manufacturer.

13. 078400 - FIRESTOPPING

13.1 Project Includes

Firestopping may include the following:

1. Penetrations through fire-resistance-rated floor and roof construction.
2. Penetrations through fire-resistance-rated walls and partitions.
3. Penetrations through smoke barriers and construction enclosing compartmentalized areas.
13.2 Sustainable Design

Provide firestopping with the following sustainable design features:

1. Low VOC adhesives and sealants.
2. No added urea-formaldehyde.

13.3 Quality Assurance


FM Global: Projects must comply with FM Global requirements. Materials must be listed in the FM Approval Guide.

Firestop Contractor: FM 4991 approved.

13.4 Products

Through-Penetration Firestop Systems: Subject to compliance with requirements, provide one of the following:

1. Endothermic, latex sealant and compounds.
2. Intumescent latex sealant, putty and wrap strips.
3. Mortar.
4. Pillows/bags.
5. Silicone foams and sealants.

Fire-Resistive Elastomeric Joint Sealants:


14. 079200 - JOINT SEALANTS

14.1 Project Includes

Joint sealers at exterior and interior vertical and horizontal joints.

14.2 Sustainable Design

Provide joint sealants with the following sustainable design features:

1. Low VOC adhesives and sealants.
2. No added urea-formaldehyde.
14.3 **Quality Assurance**

Field Constructed Mock Ups: Each joint type.

14.4 **Products**

Silicone Elastomeric Joint Sealants:

1. Exterior Type and Application: Multi part nonacid curing silicone sealant, ASTM C920, for joints in vertical surfaces, modulus as required for application, exterior use.
2. Interior Type and Application: One part mildew resistant silicone sealant, ASTM C920, for sanitary applications, interior use.

Latex Joint Sealants:

1. Interior Type and Application: Acrylic emulsion, ASTM C834, for limited movement joints in vertical and overhead surfaces, interior use.

Paving Joint Fillers:

1. Exterior Type and Application: Bituminous fiber filler for exterior paving joints.

Accessories:

1. Plastic foam joint fillers.
2. Elastomeric tubing backer rods.
3. Bond breaker tape.

15. **079500 - EXPANSION CONTROL**

15.1 **Project Includes**

Expansion joint cover assemblies at walls and floors.

15.2 **Quality Assurance**

Fire Performance Standards:

1. ANSI/UL 263.
2. NFPA 251.
3. UBC 43-1.
4. ASTM E119 and ASTM E814 as applicable.
15.3 Products

Assemblies:

1. Type: Metal assembly with flat cover plates.
2. Performance: Based on building use.

Expansion Joint Cover Materials:

1. Stainless Steel: ASTM A167, Type 304 for plates, sheet, and strips.
3. Elastomeric Sealant: ASTM C920, Use T.

Finishes:

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1. **081110 - HOLLOW METAL DOORS AND FRAMES**

1.1 **Project Includes**

Hollow metal doors and frames at interior and exterior.

1.2 **Quality Assurance**

General Standards:

1. ANSI/SDI 100, Recommended Specifications for Standard Steel Doors and Frames.

Performance Standards:

1. Fire Rated Assemblies: NFPA 80, and acceptable testing agency listing.
3. Sound Rated Assemblies at Mechanical Rooms: ASTM E90, and ASTM E413.

1.3 **Products**

Steel Doors:

1. Door Type: Standard steel doors with composite construction.
2. Interior Doors: ANSI/SDI 100, Grade II, heavy duty, minimum 16 gage cold rolled steel, 1-3/4 inches thick, seamless.
5. Finish: Factory primed and field painted.

Steel Frames:

1. Interior Frames: Welded, 16 gage sheet steel, mitered or coped corners.
2. Exterior Frames: Welded, 14 gage galvanized steel, mitered or coped corners.
3. Accessories: Door silencers and plaster guards.
2. **081210 - INTERIOR ALUMINUM FRAMES**

2.1 **Project Includes**

Interior aluminum framing system, typically at offices and conference rooms.

2.2 **Sustainable Design**

Provide interior aluminum frames with the following sustainable design features:

1. Recycled content.
2. Low VOC adhesives and sealants.

2.3 **Products**

Material: Extruded aluminum, ASTM B221.

Glass and Glazing: Tempered glazing typical.

Finish: Clear anodized typical.

Auxiliary Materials:

1. Door hardware, including silencers.
2. Glazing stops and sealants.

NOTE: Door stiles to be 5 inch “rugged rail” on any doors requiring locksets or exit devices.

3. **081400 - WOOD DOORS**

3.1 **Project Includes**

Wood doors:

1. Interior flush wood doors.
2. Interior stile and rail wood doors.

3.2 **Sustainable Design**

Provide wood doors with the following sustainable design features:

1. Recycled content, wood door cores.
2. FSC certified wood.
3. Low VOC adhesives and sealants.
4. No added urea-formaldehyde.
3.3 Quality Assurance

Quality Standards: NWWDA I.S. 1A, and AWI Architectural Quality Standards.

Fire Rated Wood Doors: Meeting ASTM E152 requirements.

3.4 Products

Grade: AWI Custom grade for transparent finish typical.

Core: Solid core.


Construction: 5 ply construction with particleboard core.

Wood Species and Cuts for Transparent Finish: Match building standard where applicable, select for new applications.

Accessories: Glazing stops and intumescent seals.

Hardware: Factory-fitted.

Finish: AWI Premium grade, catalyzed lacquer.

4. 083110 - ACCESS DOORS AND PANELS

4.1 Project Includes

Access doors for walls and ceilings.

4.2 Products

Access Doors:

1. Frames: 16 gage sheet steel with flange suitable for adjacent material.
3. Door Type: Flush panel.
4. Locking Devices: Cylinder locks, keyed alike.
5. **083300 - COILING DOORS AND GRILLES**

5.1 **Project Includes**

Coiling doors and grilles:

1. Overhead coiling doors.
2. Fire shutters.
3. Overhead coiling counter doors.
4. Overhead coiling grilles.

5.2 **Products**

Fire Shutters:

2. Operation: Building fire alarm system and fusible link.

Interior Overhead Coiling Doors and Counter Doors:

2. Operation: Electric typical.

Interior Overhead Coiling Grilles:


6. **083350 - HORIZONTAL SLIDING FIRE DOORS**

6.1 **Project Includes**

Horizontal sliding accordion-type fire doors.

6.2 **Products**

Horizontal sliding fire doors:

1. Type: Accordion folding.
3. Operation: Building fire alarm system and fusible link.
7.  **083610 - SECTIONAL DOORS**

7.1 **Project Includes**

Exterior sectional overhead doors.

7.2 **Products**

Material: Galvanized steel, flat sections.

Core: Insulated construction, thermal break.

Operation: Motorized.

Auxiliary Materials: Tracks, supports, weatherstripping, hardware, and accessories.

Finish: Factory finished or factory-primed for site finish.

8.  **084110 - ALUMINUM-FRAMED ENTRANCES AND STOREFRONTS**

8.1 **Project Includes**

Aluminum-framed entrances and storefronts. Interior and exterior applications.

8.2 **Sustainable Design**

Provide aluminum-framed entrances and storefronts with the following sustainable design features:

1. Recycled content.
2. Low VOC adhesives and sealants.

8.3 **Quality Assurance**

Testing: Entrance and storefront performance in accordance with project specifications.

Performance Design: Sill pans and receptors with end dams.

8.4 **Products**

Entrances and Storefront:
4. Door Style: Rugged (five inch wide) stile and rail doors as shown on the Drawings.
5. Glass and Glazing: Insulated units at exterior, tempered glass as required.
6. Door Hanging Devices: Ball-bearing hinges.
7. Aluminum Finish: AAMA 2605, 3-coat metallic fluoropolymer finish, 70 percent resin.

Auxiliary Materials – See Hardware Section

1. Push/pulls, door stops, overhead holders, and deadlocks.
2. Weatherstripping and thresholds.
3. Exit devices.

9. **084226 - ALL-GLASS ENTRANCES**

9.1 Project Includes

Interior all-glass entrances and sidelites.

9.2 Products

Material: Tempered glass with polished edges; mandatory film or decal to minimize injury to the visually impaired.

Fittings: Stainless steel with No. 4 finish typical.

Hardware: Closers, push-pull, locks.

10. **084410 - GLAZED ALUMINUM CURTAIN WALLS**

10.1 Project Includes

Glazed aluminum curtain walls:

1. Aluminum stick type glazed aluminum curtain wall with interior and exterior exposed metal framing.
2. Structural sealant glazed curtain walls.
10.2 Sustainable Design

Provide glazed aluminum curtain walls with the following sustainable design features:

1. Recycled content.
2. Low VOC adhesives and sealants.

10.3 Quality Assurance

Testing: Curtain wall performance in accordance with project specifications.

Performance Design: Sill pans and receptors with end dams.

10.4 Products

Primary Components: Extruded aluminum framing, internal reinforcement, insulated spandrel panels, trim, and filler units, sealants, and gaskets.

2. Vents: Operable vents with screens.
4. Anchors, Clips, and Accessories: Aluminum, nonmagnetic stainless steel, or galvanized steel.
5. Mullion Caps: Custom profile.
6. Integral Sun Control Fins: Custom profile where indicated.

Construction: Thermal break type.

Finish: AAMA 2605, 3-coat fluoropolymer finish, 70 percent resin.

11. 085110 - ALUMINUM WINDOWS

11.1 Project Includes

Aluminum windows, factory glazed.

11.2 Sustainable Design

Provide aluminum windows with the following sustainable design features:

1. Recycled content.
2. Low VOC adhesives and sealants.
11.3 **Quality Assurance**

Testing: Window performance in accordance with project specifications.

Procedures for Historic Buildings at MIT: MIT maintains a database of drawings and specifications for project procedures. Request information from the MIT Project Manager.

11.4 **Products**

Window Operation: Casement, double-hung and fixed windows; screens at operable units.

Heavy Commercial grade to AAMA 101.

Glazing: Insulating glass 1 inch thick; low-e coating and as specified.

Construction: Thermal break type.

Aluminum Window Members: Aluminum extrusions.

Anchors, Clips, and Window Accessories: Aluminum, nonmagnetic stainless steel, or galvanized steel.

Finish: AAMA 2605, 3-coat fluoropolymer finish, 70 percent resin.

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12. **085200 - WOOD WINDOWS**

12.1 **Project Includes**

Wood windows may include:

1. Wood windows.
2. Wood frames for stained glass windows.
3. Reinstallation of stained glass windows with exterior protective panels.

12.2 **Sustainable Design**

Provide wood windows with the following sustainable design features:

1. Recycled content.
2. Low VOC adhesives and sealants.
3. FSC certified wood.
12.3 **Quality Assurance**

Testing: Window performance in accordance with project specifications.

Procedures for Historic Buildings at MIT: MIT maintains a database of drawings and specifications for project procedures. Request information from the MIT Project Manager.

12.4 **Products**

Window Operation: Casement, double-hung and fixed windows; screens at operable units.

Glazing: Insulating glass 1 inch thick; low-e coating and as specified.

Construction: Thermal break type.

Anchors, Clips, and Window Accessories: Aluminum, nonmagnetic stainless steel, or galvanized steel.

Finish: Manufacturer’s standard high-performance painted finish at exterior; primed for field painting at interior.

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13. **086300 - METAL FRAMED SKYLIGHTS**

13.1 **Project Includes**

Metal framed skylight systems.

13.2 **Sustainable Design**

Provide metal framed skylight systems with the following sustainable design features:

1. Recycled content.
2. Low VOC adhesives and sealants.

13.3 **Quality Assurance**

Testing: Skylight performance in accordance with project specifications.

13.4 **Products**

Metal Framed Skylights:

1. Type: Standard cap system, self supporting.
2. Construction: Thermal break.
Sloped Glazing:

1. Type: Clear insulating glass, laminated inner lite, heat strengthened exterior lite, and low-e coating.
2. Sealants: Silicone.

Aluminum Finish: AAMA 2605, 3-coat fluoropolymer finish, 70 percent resin.

14. 087100 - DOOR HARDWARE

14.1 Project Includes

Hardware for doors, coordination with final cores and keys to be furnished and installed by MIT.

14.2 Quality Assurance

Accessibility Requirements:

3. Local regulations.

Hardware for Fire-Rated Openings: NFPA 80 and local requirements.

Materials and Application: ANSI A156 series standards.

Security: Coordinate with electronic components and MIT access control system.

14.3 Products

Door Hardware: Campus standard:

1. Quality Level: Commercial type – Grade 1.
2. Hinges: 4-1/2 by 4-1/2 inch, ball bearing hinges. Use Heavy Weight Hinges on exterior applications and openings with leaves in excess of 36 inches in width. Electric hinges shall not be used. If power or signal transfer is required, use Von Duprin EPT-10; no substitutions. Non-rising pin (NRP) hinges to be used on all exterior openings and all outswing access controlled openings.
3. Exit Devices: Von Duprin; no substitutions. 99 Series for flush and wide stile doors, 33 series if narrow stile leaves are approved by MIT, 88 series for historical applications only. Rim exit devices on single leaves shall be basis for design. If pairs of doors are required, surface vertical rod devices - 9927 series shall be used, with top latches only. Concealed vertical rod devices are not to be used. If mullions are to be used, Von Duprin
KR4954 mullion shall be used. For access controlled openings, add QEL & RX options. Cylinder dogging only on devices where dogging feature is required – no hex key dogging.

4. Closers: LCN 4040 XP Series, no substitutions. Closers to be supplied with metal covers and sex bolts. Hold open applications, where required to use H CUSH parallel arm configuration, or Spring H-Cush on exterior applications. Hold open feature shall not be used on access controlled openings.

5. Locksets: Schlage L9000 mortise locks, no substitutions. Campus standard is 06 Lever, with L escutcheon trim. For access controlled applications, use L9092 RX & finish per project.

6. Keying: Removable cores for all exit locksets and exit devices. FSIC Schlage (JD option) for Physical Plant and Education areas, SFIC (BD option) for Resident Life areas.

7. Automatic Operators: LCN Senior Swing or Tormax Operators per application requirements; no substitutions. Openings equipped with automatic operators to use 4 inch high head jamb sections. Actuator buttons to be 4-1/2 inch square. Jamb mounted actuators to be used only if wall and area conditions do not permit use of wall mounted buttons. All actuator buttons shall include universal handicap symbol and text. If RF actuator option is required due to mounting and wiring issues, 433 MHz type devices shall be used.

8. Finishes: 626 (US26D) or brushed stainless steel on exposed surfaces typical. Brass or bronze finishes only to be used to match existing building historical conditions for partial renovation and repair projects.

9. Magnetic Locks and Electric Strikes: Not acceptable for MIT projects without prior review and approval by MIT Facilities and Security Departments. If electric strikes must be used, Von Duprin 6000 series, model specific for application; no substitutions.

10. Power: For access controlled exit devices and locksets provided by access control equipment furnished and installed by MIT approved Access Control Systems Integrators.

Auxiliary Materials:

1. Door Trim Units: Kickplates and related trim. Kickplates 8 inches high, 2” LDW on single leaves, 1” LDW on pairs. Thresholds – Zero Manufacturing, no substitutions. Thermal break thresholds are required on exterior openings. Smooth top thresholds at all openings equipped with automatic door bottoms.

2. Stops: Floor stops are MIT standard, wall stops are not to be used. Kick down door stops are not to be used on any opening where ADA accessibility is required.

3. Overhead Door Holders: Glynn-Johnson 450 series for medium duty interior, 900 series for heavy duty and any exterior applications. For concealed applications, use 100 series.

4. Flush Bolts and Coordinators for Paired Doors: Manual or constant latching flush bolts only. Automatic flush bolts are not to be used. Use only flat bar coordinators with filler plates to opening size as required.

5. Weatherstripping and Thresholds for Exterior Doors: Zero Manufacturing; no
substitutions. Profile and type as required for application. Where door closers or surface applied strikes are required, gasket type shall be have solid metal substrate allowing closer brackets and strikes to be mounted directly to gasket, or brackets manufactured by Zero are to be utilized to allow installation of gasketing with no breaks.

6. Soundstripping and Gaskets: Zero Manufacturing; no substitutions, profile and type as required for application. Where door closers or surface applied strikes are required, gasket type shall be have solid metal substrate allowing closer brackets and strikes to be mounted directly to gasket, or brackets manufactured by Zero are to be utilized to allow installation of gasketing with no breaks.

7. Card Readers: Provided by MIT approved access control vendors.

15. **088000 - GLAZING**

15.1 **Project Includes**

Glazing may include:

1. Exterior insulated glass.
2. Door glazing and interior glazed panels.
3. Unframed mirrors.

15.2 **Sustainable Design**

Provide glazing with the following sustainable design features:

1. Low VOC adhesives and sealants.

15.3 **Quality Assurance**

Field-Constructed Mock-Up: Each type of glazing.

Glazing Standards:


Testing: Glazing performance in accordance with project specifications.
15.4 Warranty

Insulated Glass Warranties: Manufacturer’s 10 year warranty.

15.5 Products

Glass:

1. Primary Glass Products: Clear float glass, ASTM C1036.
4. Fire Rated Ceramic Glazing: Clear with thickness and fire rating as required.
6. Glazing Film: 3M or equal. Use of partial glazing film is mandatory to prevent injury to the visually impaired; typically at all-glass entrances and sidelights.

Glazing:

1. Elastomeric glazing sealants.
2. Preformed glazing tapes.
3. Setting blocks, spacers, and compressible filler rods.
4. Mirror adhesive and mounting hardware.

16. 089000 - LOUVERS AND VENTS

16.1 Project Includes

Fixed metal wall louvers.

16.2 Sustainable Design

Provide louvers and vents with the following sustainable design features:

1. Recycled content.

16.3 Quality Assurance

Performance: Fire, structural, and seismic performance meeting requirements of building code and local authorities.

FM Global: Projects must comply with FM Global requirements. Materials must be listed in the FM Approval Guide.
Performance Design: Sill pans to drain water.

16.4 Products

Aluminum Louvers:

1. Aluminum Extrusions: ASTM B221, alloy 6063 T5 or T51.
2. Blades: Horizontal drainable blades typical.

Accessories: Bird screens, insect screens, and blank-off panels.

Aluminum Finish: AAMA 2605, 3-coat fluoropolymer finish, 70 percent resin.

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1. **092110 - GYPSUM BOARD ASSEMBLIES**

1.1 **Project Includes**

Gypsum board (drywall) assemblies may include the following:

1. Gypsum board for walls and ceilings.
2. Cementitious backer board for tile.
3. Steel framing systems to receive gypsum board.
4. Acoustic insulation in gypsum drywall systems.
5. Resilient mounting channels.
6. Installation of access panels in gypsum board assemblies.

1.2 **Sustainable Design**

Provide gypsum board assemblies with the following sustainable design features:

1. Recycled content.
2. Regional materials.
3. Low VOC adhesives and sealants.
4. No added urea-formaldehyde.

1.3 **Quality Assurance**

Performance: Fire, structural, and seismic performance meeting requirements of building code and local authorities.

Veneer Plaster: Not preferred, use by exception only.

1.4 **Products**

Gypsum Board:

1. Gypsum Wallboard: ASTM C36, fire rated and moisture-resistant types, 5/8 inch typical thickness; special types where indicated.
2. Joint Treatment: ASTM C475 and ASTM C840, 3 coat system.
3. Finish: Level 4 typical; Level 5 at writable wall surfacing and wall coverings.

Cementitious Backer Board: ANSI A118.9 and ASTM C1288 or 1325, 5/8 inch typical thickness.
Trim Accessories:

1. Material: Metal cornerbead, edge trim, and control joints.

Steel Framing for Walls and Partitions:

1. Steel Studs and Runners: ASTM C645, 20 gage with manufacturer’s standard corrosion-resistant coating.
3. Auxiliary Framing Components: Furring brackets, resilient furring channels, Z furring members, and non corrosive fasteners.

Steel Framing for Suspended and Furred Ceilings:

1. Furring Channels: ASTM C645, 20 gage channels with manufacturer’s standard corrosion-resistant coating.
2. Accessories: Hangers and inserts.

Auxiliary Materials:

1. Concealed acoustical sealant at top and bottom of all partition walls.
2. Mineral fiber, fire rated sound attenuation blankets.

2. **092120 - GYPSUM BOARD SHAFT WALL ASSEMBLIES**

2.1 **Project Includes**

Gypsum board shaft wall assemblies.

2.2 **Sustainable Design**

Provide gypsum board shaft wall assemblies with the following sustainable design features:

1. Recycled content.
2. Regional materials.
3. Low VOC adhesives and sealants.
4. No added urea-formaldehyde.
2.3 Quality Assurance

Performance: Fire, structural, and seismic performance meeting requirements of building code and local authorities.

2.4 Products

Cavity Shaft Wall Assemblies:

1. Shaftwall Board Thickness: Not less than 3/4 inch.
2. Studs: I, C H or double E studs, 20 gauge.

Gypsum Board Shaft Wall Materials: Synthetic gypsum board complying with the following:

Steel Framing: ASTM C645.

Gypsum Shaftwall Board: ASTM C442, Type X.

Auxiliary Materials:

1. Cornerbeads, edge trim, and control joints.
2. Laminating adhesive.
4. Concealed acoustical sealant.
5. Mineral fiber sound attenuation blankets.

3. 093000 - TILING

3.1 Project Includes

Tiling may include:

1. Interior floor and wall tile.
2. Thresholds, edge strips and tile accessories.

3.2 Sustainable Design

Provide tiling with the following sustainable design features:

1. Low VOC adhesives and sealants.
2. Low VOC flooring systems.
### 3.3 Quality Assurance

Tile Materials: ANSI 118 series standard specifications.


Accessibility Requirements:

3. Local regulations.

Attic Stock: 2 percent of each type installed.

### 3.4 Products

Floor, Wall and Base Tile: Ceramic and stone tile as applicable.

Tile Accessories:

1. Matching trim units.
2. Metal edge trim and transition strips.

Setting Materials:

1. Mortar:

   a. Typical: Thinset latex portland cement mortar.
   b. Where Required: Mortar set.


Crack Suppression Membranes: For large format tiles.

Waterproofing Membranes: At toilet rooms on elevated slabs.

Refer to thematic folder for Restrooms for additional information.
4. 095110 - ACOUSTICAL CEILINGS

4.1 Project Includes

Acoustical ceilings may include:

1. Typical Acoustical Lay In Panel Ceilings: which may including mineral fiber, fiberglass, and other standard acoustical ceiling materials.
2. Project Specific Specialty Ceilings: which may include special shapes, fire rating, vinyl facing for labs and clean rooms, and high performance acoustical properties.
3. Suspension systems and trims.

4.2 Sustainable Design

Provide acoustical ceilings with the following sustainable design features:

1. Recycled content.
2. Regional materials.
3. Low VOC adhesives and sealants.
4. No added urea-formaldehyde.
5. Asbestos free.

4.3 Quality Assurance

Performance: Fire, structural, and seismic performance meeting requirements of building code and local authorities. Acoustical and cleaning performance based on project requirements.

Concealed Spline Grids: Not acceptable.

Attic Stock: 2 percent of each type installed.

4.4 Products

Acoustical Tile Ceilings:

1. Manufacturers: Armstrong or USG preferred.
2. Typical Type: 2 by 2 foot, tegular edge, exposed grid.
3. Project Specific Types: As shown on the drawings.
4. Suspension: ASTM C635 intermediate duty unless otherwise indicated.

Auxiliary Materials:

1. Specialty trims.
2. Concealed acoustical sealant.
5. **096400 - WOOD FLOORING**

5.1 **Project Includes**

Wood flooring is not acceptable based on durability.

6. **096500 - RESILIENT FLOORING**

6.1 **Project Includes**

Resilient flooring may include:

1. Resilient flooring.
2. Resilient wall base.
3. Resilient stair treads and risers.
4. Surface preparation including moisture mitigation coating.

6.2 **Sustainable Design**

Provide resilient flooring with the following sustainable design features: Submit HPD's and EPD's.

1. Recycled content.
2. Low VOC adhesives and sealants.
3. Low VOC flooring systems, FloorScore certification.
4. No added urea-formaldehyde.
5. Asbestos free.

6.3 **Quality Assurance**

Accessibility Requirements:

3. Local regulations.

Concrete Substrate Preparation: ASTM F710.

2. Test concrete for pH and other properties in accordance with the flooring manufacturers recommendations.

Attic Stock: 2 percent of each type installed.

6.4 Products

Biobased Tile (BBT): Non-PVC.

Vinyl Composition Tile (VCT): ASTM F1066.

Luxury Vinyl Tile (LVT): ASTM F1700.

Vinyl Sheet Flooring: ASTM F1303 with backing, ASTM F1913 without backing.

Anti-Static Vinyl Sheet Flooring: To meet project specific requirements.

Linoleum Sheet: ASTM F2034; Marmoleum by Forbo, with recycled content.

Rubber Sheet: ASTM F1859.

Stairs: Rubber treads with abrasive strips.

Wall Base: ASTM F1861.

1. Size: 4 inch high by 1/8 inch thick.
2. Shapes: Straight at carpet and coved at resilient flooring and exposed concrete.

Installation Accessories:

1. Concrete Slab Primer: Non-staining type.
3. Adhesives: Water-resistant, low VOC type.
4. Edge and transition strips.

Refer to thematic folder for Classrooms and Lecture Halls for additional information.

7. 096600 - TERRAZZO FLOORING

7.1 Project Includes

Terrazzo flooring may include:

1. Modifications to existing terrazzo flooring systems.
2. New terrazzo at high traffic common areas only.
3. Surface preparation including moisture mitigation coating.

### 7.2 Sustainable Design

Provide terrazzo flooring with the following sustainable design features:

1. Recycled content.
2. Low VOC adhesives and sealants.
3. No added urea-formaldehyde.

### 7.3 Quality Assurance

Standards: National Terrazzo and Mosaic Association (NTMA).

Accessibility Requirements:

3. Local regulations.

Concrete Substrate Preparation: ASTM F710.

4. Test concrete for pH and other properties in accordance with the flooring manufacturers recommendations.

### 7.4 Products

Materials: Comply with NTMA standards.

Mix: Comply with NTMA standards.

Thickness: 3/8 inch.

Integral Coved Base: 4 inch high or as required to match the historic base.

Installation Accessories:

1. Trowelable underlayments and patching compounds.
2. Divider and control joint strips.
8. 096710 - RESINOUS FLOORING

8.1 Project Includes

Resinous flooring may include:

1. Resinous flooring systems.
2. Surface preparation including moisture mitigation coating.

8.2 Sustainable Design

Provide resinous flooring with the following sustainable design features:

1. Recycled content.
2. Low VOC adhesives and sealants.
3. No added urea-formaldehyde.

8.3 Quality Assurance

Accessibility Requirements:

3. Local regulations.

Concrete Substrate Preparation: ASTM F710.

2. Test concrete for pH and other properties in accordance with the flooring manufacturers recommendations.

8.4 Products

Description: Troweled urethane mortar, decorative quartz broadcast, and clear epoxy or urethane sealer; Tnemec 241 and 256 MVT. System shall provide moisture control at 99% RH.

Thickness: 3/16 inch typical.

Integral Coved Base: 4 inches high.

Refer to thematic folder for Classrooms and Lecture Halls for additional information.
9. 096800 - CARPETING

9.1 Project Includes

Carpeting may include:

1. Tile carpeting.
2. Sheet carpeting.
3. Surface preparation including moisture mitigation coating.

9.2 Sustainable Design

Provide carpeting with the following sustainable design features:

1. Recycled content.
2. Low VOC adhesives and sealants.
3. Low VOC flooring systems to Carpet and Rug Institute (CRI) Green Label Plus
   a. Carpet products may not include SBR backings.

9.3 Quality Assurance

Accessibility Requirements:

3. Local regulations.

Performance: Fire performance meeting requirements of building code and local authorities.

Concrete Substrate Preparation: ASTM F710.

2. Test concrete for pH and other properties in accordance with the flooring manufacturers recommendations.

Attic Stock: 2 percent of each type installed.

9.4 Products

Carpet and Carpet Tile: Mohawk, MIT preferred manufacturer.

Auxiliary Materials:
1. Edge guards.
2. Low VOC adhesives, cements and fasteners for direct glue-down installation.

10. 097200 - WALL COVERING

10.1 Project Includes

Wall covering may include:

1. Wall covering.
2. Surface preparation.

10.2 Sustainable Design

Provide wall coverings with the following sustainable design features:

1. Low VOC adhesives and sealants.
2. Low VOC paint / primers.

10.3 Quality Assurance

Performance: Fire performance meeting requirements of building code and local authorities.

Passing Boston Fire Department Test: BFD IX-1.

Attic Stock: 2 percent of each type installed.

10.4 Products

Wall-Covering Standard: Provide mildew-resistant strippable wall coverings that comply with ASTM F793 for Category V, Type II, Commercial Serviceability products.

Accessories:

1. Adhesive: Mildew-resistant, stripple, recommended by wall covering manufacturer.
2. Primer/Sealer: Mildew resistant.
3. Wall Liner: Nonwoven, synthetic underlayment and adhesive as recommended by wall-covering manufacturer.

11. 098430 - SOUND-ABSORBING PANELS
11.1 Project Includes

Back-mounted acoustical wall panels.

11.2 Quality Assurance

Acoustical Performance: based on project requirements

Fire Performance: meeting requirements of building code and local authorities

Passing Boston Fire Department Test: BFD IX-1.

11.3 Products

Back-Mounted, Edge-Reinforced Acoustical Wall Panels with Glass-Fiber Board Core:

1. Facing Material: Fabric from same dye lot; color and pattern.
2. Back-Mounting Devices: Concealed on backside of panel, as recommended by the manufacturer to support weight of panel.

Refer to thematic folder for Classrooms and Lecture Halls for additional information.

12. 099000 - PAINTING AND COATING

12.1 Project Includes

Painting and coating may include:

1. Painting and surface preparation for interior unfinished surfaces as scheduled.
2. Painting and surface preparation for exterior unfinished surfaces as scheduled.
3. Field painting and surface preparation of exposed mechanical and electrical piping, conduit, ductwork, and equipment

12.2 Sustainable Design

Provide painting and coating systems with the following sustainable design features:

1. Low VOC paints and coatings.

12.3 Quality Assurance

Manufacturer: Architectural commercial-quality products for all coating systems.

Vinyl Copolymer Paint: Not acceptable.
Attic Stock: 2 unopened gallons of each color and type.

12.4 Exterior Paint Schedule

High-Performance Coatings: Tnemec.

Galvanized Metal: Primer plus 2 coats semi-gloss epoxy or urethane finish, semi-gloss.

Wood Trim: Primer plus two coats exterior acrylic latex, semi-gloss.

12.5 Interior Paint Schedule

Gypsum Board and Plaster Walls: 1 coat interior acrylic primer, 2 coats interior acrylic latex, eggshell.

Gypsum Board and Plaster Ceilings: 1 coat interior acrylic primer, 2 coats interior acrylic latex, flat.

Wood Doors and Trim: 1 coat interior acrylic primer, 2 coats interior acrylic latex, semi-gloss.

Architectural Woodwork, Transparent Finish: 1 coat water-based stain, 2 coats satin polyurethane sealer.

Architectural Woodwork, Opaque Finish: 1 coat interior acrylic primer, 2 coats acrylic latex, semi-gloss.

Ferrous Metal, Doors, Frames and MEP/FP: 1 coat synthetic rust-inhibiting primer, 1 coat interior enamel undercoat, 1 coat interior acrylic latex, semi-gloss.

Ferrous Metal, Handrails: Shop primer, 2 coats semi-gloss epoxy paint.

Ferrous Metal, Exposed Ceilings: 1 coat water-based dry-fall (dry-fog) paint.

Concrete Masonry Units: 1 coat high-performance latex block filler, 2 coats acrylic latex, semi-gloss.

Exposed Concrete Floors: 1 coat clear penetrating sealer.

High-Performance Coatings: Tnemec.

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1. **101100 - VISUAL DISPLAY SURFACES**

1.1 Project Includes

Visual display surfaces may include the following:

1. Chalkboards.
2. Tackboards.
3. Writable surfaces.

1.2 Products

**Chalkboards:**

1. Each classroom or lecture hall shall have two to three sets of vertical sliding, wall mounted chalkboards in accordance with the Classrooms and Lecture Halls Thematic Folder. MIT classrooms use chalkboards only. No whiteboards unless specifically requested.

**Tackboards:**

3. Trim: One of the following as indicated:
   a. Wood frame and tray.
   b. Aluminum frame and tray with clear anodized finish.

**Writable Surfaces:** Commercial grade, low VOC, IdeaPaint preferred.

2. **101400 - SIGNAGE**

2.1 Project Includes

Signage may include the following:

2. Wayfinding signage.
2.2 Quality Assurance

Accessibility Requirements:

3. Local regulations.

2.3 Products

Signage and Graphics: Refer to the thematic folder for Signage.

1. Type: Unframed.
3. Copy: Raised lettering.

3. 102110 - TOILET COMPARTMENTS

3.1 Project Includes

Toilet compartments and urinal screens.

3.2 Quality Assurance

Accessibility Requirements:

3. Local regulations.

3.3 Products

Toilet Compartment Materials: Refer to the thematic folder for Restrooms.

Type and Mounting:

1. Compartments: Floor-mounted, overhead braced.
5. Finish: As selected by the Architect from manufacturers full range. More than one color may be required as indicated.
4. **102210 - WIRE MESH PARTITIONS**

4.1 **Project Includes**

Wire mesh partitions at storage areas.

4.2 **Products**

Wire Mesh:

1. Partition Type: Standard duty, 10 gage (0.13 inch) crimped steel wire, 1 1/2 inch diamond mesh.
2. Framing: Cold rolled steel channels.
3. Finish: Galvanized.

Accessories:

1. Hinged door with padlock hasp and hardware.
2. Floor shoes.

5. **102219 - DEMOUNTABLE PARTITIONS**

5.1 **Project Includes**

Demountable partitions at interior office walls.

5.2 **Products**

Demountable Partitions:

1. Doors: Swinging.
2. Glazing: 5/16 inch laminated glass.

6. **102220 - FOLDING PANEL PARTITIONS**
6.1 Project Includes

Folding panel partitions with manual operation.

6.2 Quality Assurance

Accessibility Requirements:

2. Local regulations.

Fire Performance: to meet Code requirements.

Acoustical Performance: Sound Transmission Class (STC) per ASTM E90.

Field Quality Testing: Acoustical control testing.

6.3 Products

Partition Type: Top-supported steel frame panels.

1. Sound Transmission Class (STC): 50 minutes.
2. Noise Reduction Coefficient (NRC): 65 minutes.
3. Facing: 50 percent whiteboard and 50 percent vinyl-covered tackable surface in finishes selected by the Architect from manufacturers full range.
4. Suspension System: Tracks and carriers.

Accessories:

1. Pocket door and hardware.
2. Acoustical seals.

7. 102600 - WALL AND DOOR PROTECTION

7.1 Project Includes

Wall and door protection may include the following:

1. Wall bumper rails.
2. Corner guards.
7.2 Quality Assurance

Accessibility Requirements:

3. Local regulations.

Fire Performance: To meet Code requirements.

7.3 Products

Wall Bumper Rails: Construction Specialties, InPro, Boston Bumper or equal.

Corner Guards: Surface mounted, stainless-steel.

8. 102800 - Toilet Accessories

8.1 Project Includes

Toilet accessories. Coordinate with Restrooms Thematic Folder as required.

8.2 Quality Assurance

Accessibility Requirements:

3. Local regulations.

8.3 Products

Toilet Accessories: Refer to the thematic folder for restrooms.

Mirrors and Frames:

1. Glazing: Mirror glass, 1/4 inch thick (6 mm), ASTM C1036.
2. Frames: Stainless steel.
3. Type: Standard wall unit.
4. Refer to glazing for frameless wall mirrors.

Materials and Finishes:
1. Stainless Steel: AISI Type 302 or 304, No. 4 polished finish.

9. **104400 - FIRE PROTECTION SPECIALTIES**

9.1 **Project Includes**

Fire extinguishers and cabinets.

9.2 **Quality Assurance**

Standards: Underwriters Laboratory (UL) and Factory Mutual (FM) listed products.

9.3 **Products**

Fire Extinguishers:

1. Type: Multipurpose dry chemical type.
2. Rating: Sized for project requirements.
3. Public Area Mounting: Cabinet mounted.
4. Service Area Mounting: Metal brackets.

Cabinets:

1. Mounting: Recessed.
2. Trim: Trimless with hidden flange.
4. Door Style: Duo panel.
5. Accessories: Glass breaker or fire handle.

Stainless Steel Finish: AISI No. 4.

10. **105100 - LOCKERS**

10.1 **Project Includes**

Lockers may include:

1. Metal lockers.
2. Locker benches.
10.2 Products

Metal Lockers:

2. Locking: Padlock type.

Locker Benches:

1. Type: Maple tops on pedestal bases.

Accessories:

1. Number plates.
2. Filler strips.

11. 105500 - POSTAL SPECIALTIES

11.1 Project Includes

Mailboxes, USPS-approved types.

11.2 Products

Mailboxes: Aluminum, front loading type.

Accessories:

1. Package lockers.
2. Letter drops.
3. Number plates.
4. Filler strips.
5. Aluminum Finish: Clear anodized.

12. 105720 - WIRE CLOSET AND UTILITY SHELVING

12.1 Project Includes

Wire closet hanging and shelving system.
12.2 Products

Material: Vinyl clad steel.

Finish: White.

13. 107110 - EXTERIOR SUN CONTROL DEVICES

13.1 Project Includes

Exterior sunshades.

13.2 Products

Aluminum: ASTM B209 and ASTM B221.

Accessories: Fasteners, anchors and inserts.

Aluminum Finish: AAMA 2605, 3-coat metallic fluoropolymer finish, 70 percent resin.

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MIT

Design Standards

DIVISION 11 — Equipment

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1.  **110000 - EQUIPMENT (GENERAL)**

   1.1  **Project Includes**

   Specialty equipment.

   1.2  **Products**

   Project specific equipment selected in conjunction with user groups.

2.  **113000 - LOADING DOCK EQUIPMENT**

   2.1  **Project Includes**

   Loading dock equipment may include the following:

   1.  Dock levelers.
   2.  Dock bumpers.
   3.  Transparent strip door curtains.

   2.2  **Products**

   Dock Levelers: Capacity verified with user group.

   Dock Bumpers: Laminated tread types.

   Transparent-Strip Door Curtains: Verified with user group.

3.  **113100 - APPLIANCES**

   3.1  **Project Includes**

   Appliances may include the following:

   2.  Laundry appliances.
3.2 Sustainable Design

Provide appliances with the following sustainable design features:

2. Mercury free switches.

3.3 Quality Assurance

Accessibility Requirements:

3. Local regulations.

Field Quality Testing: Test each appliance to verify proper operation

3.4 Products

Refrigerator and Freezers: Full size.

Stoves: Electric.

Ventilation Range Hoods: Vented directly to exterior.

Dishwashers: Built-in.

Clothes Washing Machines: Front loading type.

Clothes Dryers: Vented directly to exterior.

Vent Accessories: Including bird screens.

4. 115210 - PROJECTION SCREENS

4.1 Project Includes

Projection screens.

4.2 Products

Front Projection Screens:

3. Viewing Surface: Matte white surface.

Refer to thematic folder for Classrooms and Lecture Halls for more information.

5. 115300 - LABORATORY EQUIPMENT

5.1 Project Includes

Laboratory equipment.

5.2 Products

Project specific equipment selected in conjunction with user group.

Refer to the thematic folder for Lab Design for more information.

6. 111720 - WASTE COMPACTORS

6.1 Project Includes

Commercial waste compactors for normal building wastes.

6.2 Products

Waste Compactor Units: Packaged, pre-engineered units with load direction, discharge, and capacity based on building requirements.

Waste Bins and Hoppers: Suitable for compaction unit and method of waste removal.

7. 114000 - FOODSERVICE EQUIPMENT

7.1 Project Includes

Foodservice equipment.

7.2 Products

Products: Refer to the thematic folder for Residences.

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1. MIT Furnishings Goal

It is the intent of the MIT Furnishings Standards to provide a guideline to ensure an acceptable level of product quality and cost, continuity of the MIT brand, flexibility of existing resources, and to capitalize on 2nd life opportunities.

It is not the intent of these design standards to limit designs or creativity, but to provide guidance for consultants to follow, and to stimulate discussions, questions, and the exchange of information.

The requirements for new building furnishings versus renovations in existing buildings may vary significantly. Therefore, design teams should always review project requirements with the project team prior to design concept development.

2. Design Review Requirements

The Design Consultant is responsible for reviewing and submitting the following information at each phase of the design process as a guide for review by MIT Facilities and MIT Strategic Sourcing Office. This information should be approved prior to sharing with the end user / client.

2.1. Project Initiation / Concept

2.1.1. Meet with MIT Facilities and MIT Strategic Sourcing Office

2.1.2. Review project requirements

2.1.3. Review MIT Design Standards

2.2. Schematic Design

2.2.1. Submit concept level plan

2.2.2. Discuss furniture concept design

2.3. Design Development

2.3.1. Submit design development level plan

2.3.2. Submit furniture concept design

2.4. Construction Documents
2.4.1. Submit construction document level plan

2.4.2. Coordinate furniture plan with engineering consultant plans, specifications, blocking requirements, etc.

2.4.3. Confirm furniture plans and specifications meet all applicable building codes and regulations (ADAAG, MAAB, CAL117, etc).

2.4.4. Submit furniture requirement spreadsheet including furniture tags, quantities, new versus existing to be reused, locations, etc. See Appendix 1 for example.

2.5. Construction Administration

2.5.1. Ensure that shop drawing submittals comply with all aspects of the contract documents; note in writing any deviations for discussion with MIT or provide written certification that shop drawing submittals are compliant.

2.6. Record Drawings

2.6.1. Confirm As-Built drawings accurately reflect installed product and any architectural or engineering adjustments made in the field.

2.6.2. MIT Expects Record drawings to be high-quality, easily-readable, and to clearly show deviations from the original Contract Drawings, precise location of each item of work, and field changes. Record Drawings must be submitted to and approved by MIT as a prerequisite to final payment. Please refer to the thematic folder “BIM/CAD Standards” elsewhere in the MIT Design Standards.

3. Documentation

MIT may have documentation on existing construction, depending on the project location and scope, of facility related information and standard details, which may be of value to the designer for integration into project Construction Documents. To determine the availability of these documents, contact MIT’s Facility Information Systems (FIS) group and/or MIT’s Strategic Sourcing Office through the MIT Project Manager. The designer shall be responsible for determining the usability and appropriateness of MIT documents to a particular project.

4. Operations & Reuse Opportunities

Any single piece of furniture, furnishing or equipment purchased for the project and valued at or above $5,000 must be registered with the MIT Property Office through the MIT Project Manager.
Any single piece of furniture, furnishing or equipment discarded by the project and valued at or above $5,000 must be decommissioned with the MIT Property Office through the MIT Project Manager.

All projects looking to reuse or discard furniture systems, and/or furniture, furnishings and equipment valued below $5,000 must coordinate with the MIT Strategic Sourcing Office through the MIT Project Manager.

5. Furnishings Specifications / Products

Use of the vendors listed below is required for systems and office furniture. Other vendors for ancillary furniture including seating, tables, lounge furniture, and conference room furniture shall be reviewed and pre-approved by MIT Facilities and MIT Strategic Sourcing.

5.1 Systems Furniture Vendors and Lines

COP Herman Miller: Red Thread Steelcase.

5.2 Preferred Ancillary Furniture Vendors

KI; Teknion; Moduform; Sauder.

5.3 Window Treatments

Roller Shades:

- Openness: 3-5% Open
- Material / Color: Requirements may apply depending on location. Confirm requirements with the MIT Project Manager.
- Operation: Manual or hard wired electric only, no battery operated shades are permitted

Louver Blinds:

- Size: Minimum 1” wide, no mini-blinds are permitted.
- Material / Color: Horizontal / Aluminum
- Operation: Manual or hard wired electric only, no battery operated shades are permitted.
5.4 Walk Off Mats

All walk off mats must be compliant with federal and local building codes (ADAAG, MAAB, CAL117, etc.).

Refer to thematic folder for Classrooms and Lecture Halls for tables, seating and similar items, additional manufacturers and consultants

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   1.2 QUALITY ASSURANCE
   1.3 PRODUCTS

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1. **134800 - RADIATION PROTECTION**

1.1 **Project Includes**

Radiation protection for building equipment.

1.2 **Quality Assurance**

Level of protection required to be established by a CIH/CIAH Certified Industrial Hygienist. Refer to MIT Environmental Health & Safety (EHS) standards.

1.3 **Products**

Radiation Protection: As applicable for partitions, doors and frames, viewing windows, ceilings, and slabs.

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1. **142100 - ELECTRIC TRACTION ELEVATORS**

1.1 **Project Includes**

Machine-room-less electric traction elevators, passenger types.

1.2 **Quality Assurance**

Elevator Consultant: Engage Syska Hennessy Group Boston as the elevator consultant for all capital projects.


Accessibility Requirements:

3. Local regulations.

Controls: Non-proprietary.

1.3 **Products**

Type: Machine-room-less, gearless traction.

Capacity: 3,500 pounds typical.

Cab Finishes: Stainless steel walls and ceiling with resilient flooring.

Door Panels: Stainless steel.

Hoistway Entrances: Stainless steel.

Miscellaneous Finishes: Stainless steel, AISI No. 4 satin finish.

Auxiliary Operations and Controls:

1. Key controlled car light switch and fan switch.
2. Alarm / emergency stop button.
3. Audible signals.
5. Liner blanket hooks and blankets.
6. Emergency power operation
2. 144200 - WHEEL CHAIR LIFTS

2.1 Project Includes

Wheelchair lifts are not acceptable for new MIT projects. Remodeling of existing projects shall consider design options to remove existing wheelchair lifts.

3. 149100 - CHUTES

3.1 Project Includes

Chutes are not acceptable for new MIT projects.

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1. MIT FIRE PROTECTION SYSTEM GOALS

The first goal of MIT's fire protection system is to ensure the safety of students, faculty and staff. A secondary goal is to reduce the Institute's exposure to property loss or interruption in carrying out its mission of education and research. In order to meet these goals, fire sprinkler coverage is required in 100% of all spaces in all facilities. Projects in existing buildings will bring all renovated areas into conformance with the Institute standards and current code requirements.

Designers should understand that M.I.T. requirements may differ from normal industry practice. This is most apparent in the level and quality of testing that M.I.T. requires for all fire protection systems whether new or modified. Particular attention must be paid to such differences and the contract documents must clearly explain the contractor's responsibilities. This document will point out some of those differences but close cooperation with the M.I.T. project manager and fire protection engineer will be necessary for a complete understanding of the Institute's requirements.

M.I.T.'s insurer is FM Global which has additional and sometimes more restrictive design and product requirements that must be adhered to. FM Global, now posts all of its data sheets with guidelines for the design of fire protection systems online at www.fmglobaldatasheets.com/. The appropriate FM Global data sheets must be reviewed during the design process to ensure requirements to a particular project are incorporated into the design. The fire protection system designer must submit the basis of design, working drawings and hydraulic calculations for review and approval of the FM loss prevention consultant in addition to review by M.I.T. The required data for this review is listed in FM Data Sheet 2-0 and summarized below.

Maintenance of the fire protection systems is a high priority of the Institute. M.I.T. conducts regular maintenance on fire protection systems in accordance with NFPA 25 and FM Global requirements. The designer must consider the impacts of the system design and installation on maintenance, which may include requiring all control valves, flow switches, pressure switches etc., as being readily accessible. Identification of the fire protection systems is important to minimize the impacts of an impairment associated with modifications and to prevent damage in the event of an activation.

M.I.T. maintains several active campus fire mains that serve portions of the campus. It is the designer's responsibility to coordinate with the M.I.T. Fire Protection Engineer to determine if a particular project should utilize the campus fire main as well as any required hydraulic flow results. Projects may be required to extend the existing fire main to connect to the specific project.
2. DESIGN REVIEW CHECKLIST

The designer is required to submit documentation at the Tier One, Two and Three stages of the project in accordance with section 901.2.1 of 780 CMR. M.I.T. requires documentation beyond that required in 780 CMR as specified below at the Schematic (SD), Design Development (DD), 90% Contract Documents (CD) and CD phases as well as during the Shop Drawing and Record Drawing phases of each project. A summary of those requirements follows and, in some cases, a more detailed description is contained in the relevant portion of the Guideline.

The Design Consultant is responsible for filling out, signing, and submitting this checklist at each phase of design as a guide for review by M.I.T. Facilities.

2.1 Schematic Design (SD) Phase

1. Review of applicable codes, regulations, and standards.
2. One-line riser diagram.
3. Fire pump / service room layout (coordinate water service entrance location).
4. Space requirements for distributed wet / dry / pre-action risers.
5. Shaft requirements (concealed standpipes at egress stairs).
6. Preliminary fire pump sizing and basis for sizing (refer also the section on fire pump zone control assemblies below).

2.2 Design Development (DD) Phase

1. Legend, notes, and abbreviations.
2. Floor Plans: Main distribution to standpipes; standpipes and Zone Control Assemblies (ZCAs); sprinkler mains; areas or hazards requiring pre-action or fire extinguishing systems identified.
4. Sprinkler layout in representative areas.
5. Standard details.
6. Updated one-line riser diagram.
7. Preliminary sprinkler plans for submittal to Factory Mutual.

2.3 90% Construction Documents and Construction Documents (CD) Phase

1. Legend, notes, and abbreviations.
2. Floor Plans: Main distribution to standpipes; standpipes and Zone Control Assemblies (ZCAs); sprinkler mains; areas or hazards requiring pre-action or fire extinguishing systems identified; at minimum sprinklers shown in remote areas with reflected ceiling plan overlay.
3. Sprinkler Layout: Reflected ceiling plan sprinkler layouts in key architectural areas shown as part plans with remote calculations
4. Completed sprinkler plans with design densities, hydraulic calculations with nodes and pipe layout for resubmittal to Factory Mutual.
5. Written response to FM comments and suggestions.
8. Part Plans:
   a. Fire pump and service room.
   b. Pre-action, clean agent, and foam.
10. Project specific details.
11. One-line riser diagram.
12. Final product schedules.

2.4 Shop Drawing Phase

1. Ensure that shop drawing submittals comply with all aspects of the contract documents; note in writing any deviations for discussion with M.I.T. or provide written certification that shop drawing submittals are compliant.
2. Shop drawings shall distinguish between settings the contractor must set in the field, and manufacturer specific settings established in the factory.
3. Review of, and written comment on, final hydraulic calculations.
4. Additional requirements as specified below.

2.5 Record Drawing Phase

1. Review record drawings and final submittals for compliance. Provide a written report of compliance or deviations.
2. Insure that hydraulic design information signs are installed; see Acceptance Testing section of this document for further information.
3. Laminated as-built drawings are to be located as indicated below and as requested.
3. FIRE PROTECTION SYSTEMS DESIGN CRITERIA

3.1 General Requirements

Fire protection systems must conform to the latest referenced editions of NFPA 13 and NFPA 14 as adopted by the Commonwealth of Massachusetts in addition to meeting the above referenced FM requirements. The FM requirements are contained in a series of Approval Standards which are available on the FM website or through M.I.T.’s FM representative. While these requirements deal with the characteristics of specific products they also have a fundamental impact on system design in such areas as sprinkler flow rates and coverage areas. The designer is cautioned regarding the need to understand these requirements at the very beginning of the design process to avoid major changes later in the design. Particular attention should be paid to FM Data Sheet 3-26, Fire Protection Water Demand for Non Storage Sprinklered Properties which will determine sprinkler design demands and therefore impact pipe sizing.

Where small, light hazard areas with 6 or fewer sprinklers are to be renovated, hydraulic calculations may not be required and a pipe schedule approach may be substituted with prior approval. If this approval is given, the requirements of NFPA 13 chapter 22.5 must still be followed.

Automatic sprinklers shall be installed throughout all areas of each building, unless otherwise indicated. All sprinkler systems shall be designed to meet NFPA 13 and FM Global requirements. Designing to NFPA 13R or 13D is not permitted.

Small room exceptions as permitted in NFPA 13 shall not be utilized at MIT. Small rooms shall not be permitted to be omitted from hydraulic calculations, and spacing exceptions for small rooms per NFPA 13 shall not be permitted. Exceptions as permitted in NFPA 13 for omission of sprinklers in closets and bathrooms shall not be permitted.

All components of the fire protection system are required to be listed by UL and FM Global. UL and FM provide an online database of all listed products at the following locations:

1. www.ul.com/database
2. www.ApprovalGuide.com

3.2 Sprinkler Systems Design Criteria

Supply for the sprinkler system will be provided from one of the three campus fire main loops (West, Central, and East) or from city water if the campus fire mains are not readily accessible. Discuss the connection of the fire protection system to the water supply source with the M.I.T. Fire Protection Engineer and project manager.

Preliminary and final hydraulic calculations are required to be completed by the designer, who must be a Massachusetts licensed Fire Protection Engineer or Mechanical Engineer with
minimum twenty years of fire protection design experience. Sprinkler system layouts may be
done by a NICET Level 4 certified designer but must be approved by the Engineer of Record.
The hydraulic calculations based on the final sprinkler fabrication drawings must be completed
by the contractor and reviewed by the engineer of record. The calculations shall include hose
stream allowances in accordance with NFPA 13 and FM Global requirements, but in no case shall
the hose stream be less than 250 gpm. The fire protection system shall be designed to achieve a
minimum 10 percent or 10 psi safety factor, whichever is greater. M.I.T. maintains data on
hydrant flow tests and available water pressure at various campus locations which may be used
for preliminary calculations. The project manager will supply this information on request. The
final contractor calculations must be based on hydraulic flow data from an independent testing
firm and that data must be less than one year old. The test data must be taken with properly
calibrated FM Approved gauges and in accordance with the procedures outlined in FM Global
Property Loss Prevention Data Sheet 3-0.

Sprinkler densities and minimum k-factors must be based on both NFPA 13 and FM Global
requirements. Sprinkler densities for both NFPA 13 and FM Global must be shown on the plans.
The contractor shall be required to submit hydraulic calculations based on the more demanding
of the FM Global and NFPA 13 requirements. It should be noted that FM Global has many different
requirements for densities depending upon the particular hazard including but not limited to:
storage, non-storage, flammable liquids etc., that must be consulted. The designer shall pay
particular attention and care to fully understand the FM Global and M.I.T. requirements to avoid
significant redesign late in the project. An example of such design requirements is illustrated
below:

```
   DENSITY (GPM/FT²)  0.10  1500
   NFPA 13 HAZARD CLASSIFICATION
   LIGHT HAZARD
   HC-T
   FM GLOBAL NO. OF SPRINKLERS @ PSI (IF APPLICABLE)
   X @ Y
```

Sprinkler systems shall be designed in accordance with the density/area method in accordance
with NFPA 13 and FM Global requirements. The sprinkler system shall be designed to produce
the required pressures and flows over a minimum area of 1,500 square feet. Decreases are not
permitted. The room design method may be considered in certain applications only when
specifically reviewed with the M.I.T. Fire Protection Engineer.

In addition to the NFPA 13 working plan requirements, the designer shall require that all shop
drawings describe the necessary settings that the contractor must set in the field and settings that
are manufacturer specific or preset in the factory. These settings may include air compressor cut
in and cut out pressures, normal air pressure to set the air maintenance device, and activation of
the supervisory air pressure switch.
Due to the varying quality of shop drawings and hydraulic calculation formats that are often received, the designer shall require the following in addition to the NFPA 13 hydraulic calculations:

1. Detailed riser diagram showing a schematic of system supply, supply connection, devices, valves, pipe and fittings. Hydraulic nodes shall also be indicated on the riser diagram.
2. Hydraulic calculations shall be computer generated by a listed program. The name of the hydraulic calculation program shall be provided by M.I.T. at the appropriate time. Methods using Microsoft excel or other spreadsheet program will not be accepted.
3. Shop drawings shall be required to include details specific to the installation including but not limited to:
   a. Hanger installation.
   b. Seismic bracing installation.
   c. Dry pipe and deluge valves.
   d. Compressor and air maintenance details.
   e. Floor control assembly details.
   f. Typical sprinkler installation details to convey the installation intent including sprinklers with respect to obstructions, sprinklers above open grid ceilings etc.
   g. Fire stopping.

3.3 Wet Pipe Systems Design Criteria

Where the sprinkler system is served by multiple risers, the system shall be hydraulically calculated to deliver the required demand through the hydraulically most remote riser. Splitting flows through multiple risers is not permitted.

Combined automatic sprinkler and standpipe risers should not be interconnected by sprinkler system piping. In sprinkler systems where the risers are interconnected on a floor, control valves shall be located on both sides of the check valve and a sign shall indicate that the systems are interconnected. No hydraulic credit may be taken for interconnected systems.

The NFPA 13 exception for the elimination of sprinklers in electric rooms is not acceptable to M.I.T. and must not be used. All electrical rooms shall be protected with high temperature sprinklers equipped with listed guards. Upright sprinklers are preferred in rooms where a ceiling is not installed. A supervised control valve shall be provided outside of electrical rooms to isolate the electrical room sprinklers only for electric rooms protected with more than one sprinkler, and any room that contains equipment where the voltage is greater than 600 V. An auxiliary drain shall be provided outside of electrical rooms and all piping shall be sloped to facilitate drainage to the auxiliary drain.

1. High voltage rooms with power greater than 600 volts (transformer vaults, primary
switchgear, etc.) are to be protected with a pre-action sprinkler system. The protection of these rooms shall be reviewed with the M.I.T. Fire Protection Engineer. Most high voltage rooms on campus are owned by M.I.T. In some instances the electrical Utility owns the vault. The protection of high voltage rooms shall be reviewed with the M.I.T. Fire Protection Engineer and the utility company.

Automatic sprinklers should not be installed in elevator machine or control rooms or at the top or bottom of hoistways where the hoistway is of rated construction in accordance with the Massachusetts State Building Code.

Where dry sprinklers are attached to wet systems, the designer shall be responsible for providing the temperature criteria to avoid freezing due to conduction. The minimum permitted temperature on the heated side is 50 deg F. Designers should assume an exterior design temperature of at least -10 deg F. The designer is required to confirm design temperatures of the protected space.

Sprinkler Waterflow Alarm-Initiating Devices:

1. Waterflow detectors shall be vane type with retard.
2. A main waterflow switch shall be provided.
3. The main waterflow switch should be set to activate between 45 and 60 seconds, and the floor or zone waterflow switch should be set to activate between 30 and 40 seconds.

3.4 Dry Pipe Systems Design Criteria

All dry systems must be designed to meet a maximum water delivery time in accordance with NFPA 13 and FM Global requirements. Accelerators should be avoided wherever possible and their use should be reviewed with the M.I.T. Fire Protection Engineer. In locations where an accelerator is required, an electric type should be specified. In no case shall a mechanical accelerator be utilized.

The dry pipe valve shall be located in a heated enclosure. Wherever practical the valve shall be located as close as possible to the area being protected to limit system volume size. The designer shall require the contractor to submit water delivery time calculations based on the fabrication drawings for all dry pipe systems larger than 500 gallons. For all water delivery calculations, the calculations shall indicate water will be delivered within 50 seconds (includes a 20 percent safety factor to account for changes in the field). The designer may specify a minimum size for the dry pipe valve, however the designer must make the contractor responsible for final sizing of the dry pipe valve and associated piping to comply with NFPA, FM Global and specific M.I.T. requirements.

The M.I.T. standard dry pipe valve is the Tyco DPV valve.
All dry systems must use seamless hot-dipped galvanized pipe and fittings. Weld-o-lets are not allowed.

In small areas such refrigerators, loading docks, etc. the design should consider dry pendent or sidewall sprinklers.

Riser mounted compressors should be provided with a listed reservoir and air pressure maintenance device to prevent short cycling of the compressor. A tank mounted compressor and air pressure maintenance device is to be specified. Pressure maintenance devices shall be installed in accordance with manufacturer’s recommendations. Compressors with desiccant dryers shall be specified for dry systems serving freezers and other similar protected areas. The dryers shall be used to remove water vapor from the compressed air system. Compressors shall also be specified with a listed external motor starter compatible for the compressor to maintain equipment warranty and prevent damage to the motor. The motor starter must be specified with the necessary contacts to be monitored by the fire alarm system. The fire alarm system is required to monitor that power is present after the disconnect and that the starter has not been overloaded.

### 3.5 Pre-Action Systems Design Criteria

Pre-action systems may only be specified for special applications where there is irreplaceable equipment or where conventional systems pose a life safety hazard. The use of pre-action systems must be approved by the M.I.T. Fire Protection Engineer. Where pre-action systems used, they must be single interlocked.

Double interlocked systems are not allowed. All pre-action systems are to be electric actuation. M.I.T.’s preferred valve is the Reliable DDX deluge valve with solenoid valve trim.

The releasing service control unit for the pre-action system is required to comply with the ‘Fire Alarm Releasing Service Control Units’ section in this document.

### 3.6 Antifreeze Systems Design Criteria

Antifreeze systems are not acceptable and are not to be designed. Existing antifreeze systems where discovered should be replaced with dry pipe systems or dry type sprinklers wherever practical. Where impractical to replace existing antifreeze systems, and systems served directly from the city water supply, such systems shall be equipped with reduced pressure backflow preventers in accordance with Massachusetts cross-connection regulations, and expansion chambers as required to comply with NFPA 13 and FM Global requirements. Such systems are to be reviewed with the M.I.T. Fire Protection Engineer.
3.7 Deluge Systems Design Criteria

Deluge systems are for special application only and must be approved by the M.I.T. Fire Protection Engineer. If allowed, the design must provide testing capability.

3.8 Special Systems Design Criteria

The specification of FM-200, FE-13, Inergen, Mist and other similar systems require approval of the M.I.T. Fire Protection Engineer. Clean agent extinguishing systems are considered supplemental fire extinguishing systems and are not to be installed in place of a sprinkler system. Carbon dioxide extinguishing systems are not permitted to be installed unless they protect spaces that are not normally occupied such as machinery spaces.

It is M.I.T.’s intent that kitchen fire suppression systems be specified in Division 11 and by the kitchen consultant but coordinated and reviewed by the fire protection engineer of record. These systems shall be wet chemical type designed in accordance with NFPA 17A. Foam and CO2 systems are not acceptable. When hoods are protected by separate extinguishing systems and are connected to a common exhaust duct, a dedicated extinguishing system is required to be provided to serve the common exhaust duct. Drawings are to be developed for each system that include an isometric drawing of the piping, nozzle sizes and locations with respect to the hazard protected, and agent and gas cartridge tank sizes. All wet chemical extinguishing systems are required to be designed by a NICET Level 4 certified fire protection specialist contractor. Laminated as-built drawings are to be located within the enclosure assembly.

3.9 Fire Alarm Releasing Service Control Units Design Criteria

UL listed and FM Approved Fire Alarm Releasing Service Control units shall be provided by the fire alarm contractor and installed by the fire protection contractor. Coordination between the designers of the two systems will be required. The following text, while providing information for the fire alarm system designer is inserted here as information for the fire protection system designer and to facilitate the necessary coordination. If releasing service control units and associated equipment are provided by the sprinkler system contractor, the design documents need to incorporate listed M.I.T. fire alarm requirements.

The releasing service control unit is required to be an addressable control unit designed for releasing purposes. The system designer must specify that the battery capacity provides a minimum 90 hour standby duration followed by 10 minutes of releasing power per FM Global requirements. The designer must specify that the solenoid releasing valves are listed for use with the control unit. Interfacing outputs from the releasing panel to the fire alarm control unit need to be included in the design drawings. At a minimum the following points are required to be interfaced with the building fire alarm system:

1. Discharge (if applicable).
2. Waterflow (if applicable).
3. Automatic alarm.
4. Automatic pre-alarm.
7. Trouble and new trouble.

When activation of a special suppression system is by smoke detectors, a minimum of two smoke detectors are to be installed in each protected space. At least two detectors must activate before the solenoid is released.

3.10 Fire Pumps Design Criteria

The preliminary system hydraulic calculations will assist in determining whether a fire pump is required. These calculations must be performed during the SD phase so that space and a location for the fire pump can be determined as early as possible in the project. High rise buildings on the campus may require an onsite secondary water supply based on site soil conditions. Please consult the Seismic section of these Guidelines for additional information. The need for the onsite secondary water supply must be determined in the SD phase. Discuss the preliminary hydraulic calculations and the need for a fire pump or a secondary water supply with the M.I.T. Fire Protection Engineer and Project Manager. Fire pumps manufactured by Peerless, Aurora, and A-C Xylem are acceptable. FM Data Sheet 3-7 gives detailed requirements for both electric and diesel fire pumps, these requirements must be followed.

Electric pumps are preferred; diesel pumps are allowed in existing buildings where there is insufficient electric capacity. Discuss this issue with the M.I.T. Fire Protection Engineer and Project Manager.

Electric pump motors shall have a synchronous speed of no greater than 1800 rpm.

The use of pressure reducing valves at each floor is not permitted. Master PRV assemblies are permitted in certain applications and shall be reviewed with the M.I.T. Fire Protection Engineer. All efforts to avoid the use of pressure reducing valves including, high and low pressure zones, and variable speed fire pump controllers shall be explored. A means shall be provided for testing all PRV valves.

Due to the varying city water pressures within the city of Cambridge and M.I.T. campus loops, all electric fire pumps should be equipped with a variable speed fire pump controller whenever the churn pressure of the fire pump is greater than 165 psi. If a variable speed controller is used insure that the fire pump motor is rated for inverter duty. All diesel fire pumps shall be equipped with a pressure-limiting diesel driver listed for fire pump service whenever the churn pressure of the fire pump is greater than 165 psi.

Additional requirements pertinent to the fire pump installation shall be included in the specification as follows:
1. Pump is laser aligned.
2. Full coordination shop drawings of the pump room layout including all system piping, controllers, valves, other building systems etc., shall be provided. The contractor is required to provide 3D drawings of the fire pump room.

3.11 Fire Pumps Controllers Design Criteria

All fire pump controllers (electric or diesel) shall be manufactured by MasterControls.

1. Variable speed electric fire pump controllers shall be provided with a soft start and across the line bypass in the event the VFD fails.
2. The fire pump system shall be monitored by the fire alarm system in accordance with the requirements stated in the Fire Alarm section. The designer should note and coordinate with the fire alarm system the following outputs from the fire pump:
   a. Fire pump running.
   b. Loss of phase (electric only).
   c. Phase reversal (electric only).
   d. Controller connected to alternate source (electric only).
   e. Controller main switch is turned off or to manual position (diesel only).
   f. VFD failure.
   g. VFD bypass.
   h. VFD overpressure.
   i. Common pump trouble (electric) to indicate, high pump room temperature, under voltage, overvoltage, phase unbalance.
   j. Common pump trouble (diesel) loss of output of battery charger, battery failure or missing battery, battery charger failure, low air or hydraulic pressure, system overpressure, ECM selector switch in alternate ECM position, fuel injection malfunction, low fuel level, low engine temperature.
   k. Relief valve discharge, monitored through a pressure switch.
   l. High discharge water pressure, monitored through a pressure switch.

Jockey pumps shall be provided for all fire pumps. Jockey pump controllers shall be variable speed, and manufactured by MasterControls. The fire alarm system shall monitor the following jockey pump conditions:

1. Loss of power.
2. Phase failure.
3. Switch not in Auto.
4. Fail to start.
5. Overload.
6. VFD failure.
7. Jockey pump running – status only.

Circulation test loops with listed flow meters shall be provided on all fire pump installations.

Fire pump rooms that open directly to the exterior are to be provided with low temperature sensor that is monitored by the fire alarm system.

3.12 **Transfer Switch Design Criteria**

Automatic transfer switches are to be housed separately from the fire pump controller. M.I.T.’s standard automatic transfer switch is by Russ Electric. Refer to the Electrical section and Division 26 requirements for specific requirements on transfer switches. An additional contact is required to be provided to interface with the building fire alarm system.

3.13 **Standpipes Design Criteria**

The connected hose stations shall have a 2-1/2 inch valve with a 1-1/2 inch reducer and cap without hoses with NH threads to match the Cambridge Fire Department. Cambridge Fire Department requirements may be different from those in other jurisdictions. The following sentences summarize those requirements:

1. The hose stations must be located on main and not intermediate landings.
2. The distance from fire department hose valve to the seat of fire cannot exceed 150 feet.
3. When calculating the 150 feet, the engineer must take into account corridor turns and obstructions which may be present in a building including stairs, chairs, stationary equipment and travel distance to interior spaces such as offices or mechanical rooms.
4. The hose stream may not be calculated into the equation i.e. 150 feet of hose plus 50 feet of water stream does not meet CFD’s requirement.
5. Supplemental fire department hose valves must be added on the floor, if the 150-foot distance to the seat of the fire cannot be obtained. The maximum distance between hose valves in a building must be no greater than 200 feet.

The designer should note that pressure gauges and air relief valves are to be installed at the top of all standpipe risers.

Roof manifold connections are to be provided in accordance with NFPA 14. Valves controlling roof manifolds need to be readily accessible from the roof through the use of post indicator valves or other approved means. Valves interior to the building are not acceptable.

3.14 **Fire Department Connections Design Criteria**

Fire department connections shall be UL listed and FM Approved. All fire department connections shall have 2-1/2” NH threaded fittings. M.I.T. and Cambridge fire have agreed that
Storz connections will not be used on campus. Each fire department connection shall have an inlet for every 250 gpm of flow required.

Fire department connection locations shall be reviewed and coordinated with the M.I.T. Fire Protection Engineer.

The number of fire department connections for each building shall be reviewed with the M.I.T. Fire Protection Engineer. Site conditions, accessibility to the building and the size of the building may warrant additional fire department connections.

Hydraulic calculations shall be provided for each fire department connection serving standpipes in accordance with NFPA 14. When multiple fire department connections are provided, flows shall not be permitted to be split between fire department connections.

4. UNDERGROUND & SERVICE PIPING REQUIREMENTS

4.1 General Requirements

Mechanical pipe fittings are required, push on connectors are not acceptable

Designing fire protection piping under building slabs should be avoided with all practicality. Fire protection piping shall run under slabs for no more than five feet.

Piping penetration into building shall be by Link-Seal fittings.

Plastic piping is not to be used for underground pipe service.

All new incoming fire mains into buildings shall be equipped with a Post Indicator valve. The valve shall be equipped with a tamper switch and port to be monitored by the fire alarm system. Provide Mueller post indicator valves or approved equal.

The M.I.T. Fire Protection Engineer is to be present for all flushing tests.

Refer to the following sketch for the design intent of valve locations:
4.2 M.I.T. Campus Fire Mains

All piping shall comply with NFPA 24 and American Water Works Association (AWWA) requirements.

Piping shall be minimum thickness class 52 ductile iron pipe, cement lined and tar coated per AWWA for fire main use.

M.I.T. uses a special square curb box on all underground valves for the campus fire mains. These special curb boxes can be obtained from M.I.T.

Backflow preventers are not required on incoming services connected to the campus fire main, however, an alarm check valve shall be provided within the building upstream of any further equipment or connections within the building.

4.3 Cambridge Public Water

All piping shall comply with Cambridge Water requirements.
A backflow preventer shall be installed on all incoming fire service mains in accordance with Cambridge Water and Massachusetts, 310 CMR requirements.

Double Check Valve Assemblies installed horizontally are required. M.I.T. uses the Watts 709 backflow preventer with OS&Y valves.

5. **ABOVE GROUND PIPING REQUIREMENTS**

System Risers System risers, i.e., the aboveground horizontal or vertical pipe between the backflow preventer and the mains (cross or feed) that contains a control valve, pressure gauge, drain and water flow alarm device (floor control assembly) are required to be schedule 40 black steel piping with roll-grooved ends and couplings.

5.1 **Wet Pipe Sprinkler System**

All new piping 2 inch and smaller is to be schedule 40 with threaded fittings. Piping larger than 2 inch shall be schedule 10 or schedule 40 with roll-grooved ends and couplings. Schedule 40 pipe is required for all garages, mechanical room and generator rooms as well as in the Central Utility Plant. All gasket couplings shall be listed for the application. Rolled grooved fittings are to be American made, imported fittings are not acceptable. Cut grooved fittings may be permitted where reviewed and discussed with the M.I.T. Fire Protection Engineer.

1. The designer shall include in the contract documents, requirements for the contractor to provide a quality assurance plan that all grooves in piping cut onsite and offsite comply with the applicable tolerance standards. The designer shall note in the contract documents that the contractor may be required to remove couplings in the field to demonstrate compliance.

5.2 **Dry Pipe and Pre-Action Sprinkler System**

All new piping 2 inch and smaller is to be seamless galvanized schedule 40 with galvanized threaded fittings. Piping larger than 2 inch shall be seamless galvanized schedule 40 with galvanized grooved ends and couplings. Grooved fittings are to be American made, imported fittings are not acceptable. Couplings shall use flush sealed gaskets or similar in accordance with manufacturer’s recommendations. Schedule 10 piping is not permitted for dry-pipe or pre-action sprinkler systems. In accordance with FM Global data sheet 2-0 recommendations, galvanized pipe should not be used where the ambient temperature could exceed 130 deg F unless the pipe is specifically FM Approved for use in such conditions. If this situation arises, black steel pipe with an inert gas shall be utilized.

Provide nitrogen system if the system has more than 6 sprinklers.
Provide supervisory control valves upstream and downstream of the dry/pre-action control valves.

Provide a low-pressure air switch and alarm.

Provide 'AC Power Lost' alarm for air maintenance devices.

5.3 Other General Piping Requirements

Other general piping requirements include:

1. Where mechanical T fittings are used, solid back strap only fittings shall be permitted. Snap-on and strapless fittings are not allowed.
2. Beam clamps or drop in anchors are permitted as a means of fastening to the structure. Powder actuated fasteners and concrete screws are not permitted.
3. Factory shop welded outlets are permitted.
4. Plastic piping shall not be permitted except for transitions to anechoic chambers or similar spaces where specifically reviewed with the M.I.T. Fire Protection Engineer.
5. Copper piping is permitted for wet pipe sprinkler systems. Copper piping shall be Type K hard pipe (thickness L or M shall not be specified). Fittings shall be brazed, or FM listed pressure seal fittings. Hangers used on copper piping shall be felt lined or listed for copper applications.
6. Flexible sprinkler fittings and drops are not permitted.
7. M.I.T.’s preferred coupling and fitting manufacturer is Victaulic.
8. All system drains are to be schedule 40 galvanized pipe.
9. Seismic bracing may be required, see the Guidelines section on Seismic for further information.

6. SYSTEM DRAINAGE AND TEST CONNECTIONS

Many of M.I.T.'s buildings are directly accessible to public sidewalks. Wherever feasible fire protection system drains shall discharge to areas that will not disturb the public. System drains discharging to the interior shall indirectly discharge to an open hub drain/receiver or sump sized accordingly to handle the anticipated sprinkler flow. In no case, shall this open hub drain be smaller than 4-inches nominal diameter.

Special permission must be obtained for the sprinkler system to drain to the exterior. All exterior sprinkler drain locations shall be approved by the M.I.T. Fire Protection Engineer. Sprinkler drains that must discharge to the exterior should be equipped with a minimum 2 inch downward turning elbow. The drains should discharge to M.I.T. owned property wherever feasible and should limit disruption to the public.
A remote inspector’s test connection is to be provided at the end of the most hydraulically remote area on every floor. The piping from the remote test connection should be piped back to the drain riser. In many instances electric solenoid valves that can be remotely operated by the fire alarm system will be required at the test connections. This should be reviewed with the M.I.T. Fire Protection Engineer.

Exterior test connections or other approved means shall be provided for anything requiring flow greater than 500 gpm including backflow preventer tests, fire pump test headers etc. Test connections shall be listed, properly identified and equipped with 2-1/2 inch male NH threads to allow test valves and hose to be connected. All test connections shall be located on the building exterior. Normally closed and supervised valves shall be provided on test header piping. Test connections shall discharge to M.I.T. owned property wherever feasible and shall be coordinated with exterior storm drains and hard surfaces. Test connections shall not discharge to surfaces such as grass, mulch, dirt, pedestrian walkways etc.

6.1 Sprinklers

All sprinklers must be UL listed and FM Approved. It is important for the designer to specify FM Approved sprinklers and to be aware that many variations of sprinklers depending upon the k-factor, finish, hazard protection etc., may affect listings.

UL listed and FM Approved residential sprinklers may be used inside dormitory rooms. Use of the “small room rule” is not permitted. Standard spray sprinklers are to be used elsewhere in residential occupancies. This approach is acceptable to FM Global.

Concealed sprinklers are not FM Approved as quick response sprinklers and are not to be used in light hazard occupancies.

Locations of high temperature and intermediate temperature sprinklers are often overlooked by contractors in the field. The designer needs to coordinate high temperature sprinklers with heat sources in accordance with NFPA 13. Identify locations on the contract documents where higher temperature sprinklers are required. Above and beyond NFPA 13 requirements, M.I.T. requires the following minimum sprinkler temperature classifications:

1. Mechanical Rooms: Intermediate.
2. Electrical Rooms: High Temperature.
4. AHU Filter Enclosures: High Temperature.

6.2 Miscellaneous Components and Requirements

Each sprinkler system by a city water source shall be equipped with a pressure switch located before the backflow preventer to indicate low city water pressure. This pressure switch shall be a Potter Signal switch equipped with a bleeding valve and pressure gauge assembly. The switch
shall be accessible for maintenance and calibration. All pressure switches used in other parts of
the building shall also meet these requirements.

1. The designer needs to specify the required supervisory pressure setting is to be
determined by half the normal pressure plus 10 psi.

Normally closed butterfly valves where used shall be listed for such application. Normally open
butterfly valves shall not be permitted to be used for normally closed applications such as test
headers.

Water flow detectors shall be vane type with retard.

Each floor control assembly is to be labeled to identify the location served by each floor control
assembly. The signage is required to be installed prior to fire alarm testing, the fire alarm
contractor will use this information to program the fire alarm system. For systems connected to
two risers, the sign is required to identify the location of the second riser. All signs are to be
engraved or laser printed, white on red or red on white with a minimum character size of 1/2 inch.

A main waterflow switch shall be provided. Where the water velocity is expected to exceed the
listing of a paddle type water flow switch (dry pipe system or pre-action systems for example) an
alarm check valve is to be provided on the incoming water supply.

The designer needs to note that the sprinkler contractor will be required to coordinate sprinkler
zones with the programming of the fire alarm system. Flow switches need to be programmed on
the fire alarm system to indicate the area where water would be flowing and tamper switches to
be programmed to indicate the location of the valve.

All control valves including remote inspector’s test connections in the building need to be
accessible. NFPA 13 defines accessible as not needing to be accessed by the use of equipment
such as a portable ladder. Control valves should be located between 7 and 8 feet above the
finished floor level where practical. Where this cannot be accomplished valves should be
equipped with chain operated hand wheel, fixed ladder or other means reviewed with the M.I.T.
Fire Protection Engineer.

All sprinkler control valves are required to be installed with locks and chains in addition to
electrical supervision. The contractor will be required to provide the chains and install the locks
provided by M.I.T.

The designer needs to note that all signage as stipulated in NFPA 13 is required to be provided.
Specifically hydraulic design signs, general information signs, sprinkler identification signs and
signs for every control valve and auxiliary drain valve need to be provided. Where multiple risers
serve the same floor signage needs to indicate that all valves on the floor must be shut off.

Supervised control valves are to be located at the base of each sprinkler riser.
7. EXISTING BUILDING CONDITIONS

Renovations may identify or change the hazard classification of the area protected by the sprinkler system. Deficiencies are to be corrected as part of the renovation project. If sprinklers within the work area are more than 40 years old, the sprinklers are to be replaced to minimize disruption to occupants in the future. The contractor should be directed to notify the M.I.T. Fire Protection Engineer if any other deficiencies are identified during construction such as obstructed piping.

8. ACCEPTANCE TESTING

Sprinkler system acceptance tests are required to be conducted in accordance with NFPA 13, 14, 20, 24, 25 and section 2.8 of FM Data Sheet 2-0. The system designer has the following responsibilities with regard to the tests:

1. Verify that FM plan review recommendations have been satisfactorily addressed.
2. Ensure that the system has been installed according to the approved plans.
3. Witness a hydrostatic test. Require that adequate notice be given for such tests. M.I.T. may choose to witness the tests and will coordinate with the engineer.
4. Witness an incoming fire service main flushing test.
5. Witness a trip test of all pre-action and dry pipe systems to verify that the required water delivery times are met.
6. Verify that all required equipment identification tags are present. Hydraulic design data information signs are required by section 24.5 of NFPA 13 but are frequently not installed. This data is valuable for future renovation work and the designer is requested to call out this requirement in the documents and to ensure that the signs are installed.

In addition to the required contractor’s material and test certificates per NFPA 13, 14, 20 and 24, the specifications must require that the contractor complete and provide M.I.T. a copy of FM85A, Contractors Material and Test Certificate for Automatic Sprinkler Systems.

The specification must require that the contractor complete and provide M.I.T. a copy of FM999C, Contractor’s Hydraulic Analysis Certificate for Automatic Sprinkler Systems.
The specifications must require that the contractor to test all valve tamper alarms and verify that all valves, whether monitored or not, are open.

Design documents shall require the contractor to support the testing of the fire alarm system for the contractor and third party acceptance testing. All sprinkler components will be operated during this testing. Sprinkler contractor will be required to adjust flow switch retard times, tamper switches and pressure switches as necessary.

9. PRACTICES AND PROCEDURES

Require that the contractor follow NFPA 241, Standard for Safeguarding Construction, Alteration, and Demolition Operations during construction. As mentioned above, this will require an impairment plan for renovations or additions and the M.I.T. shutdown notification procedure shall be followed whenever any fire protection system is to be impaired. The contract documents must clearly spell out these requirements.

The sprinkler system designer must prepare a design narrative as required by the Massachusetts State Building Code, Section 903 for all fire protection systems.

9.1 Additional Fire Protection Guidelines

Cooling towers shall be protected with an automatic sprinkler system where required per FM Global data sheet 1-6 and NFPA 214. Non FM Approved cooling towers shall be equipped with automatic sprinkler protection.

FM Global data sheet 1-45 shall be consulted during the design of protection for air conditioning and ventilation systems. Sprinklers may be required in air handling units. This shall be reviewed on a case by case basis with the M.I.T. Fire Protection Engineer.

Generator enclosures shall be protected by a pre-action system activated by infrared and heat detectors.

There are no special M.I.T. requirements for fire protection in lab hoods.

9.2 Areas Where M.I.T. Requirements May Differ from Common Practice

These differences must be understood by the designer and must be clearly spelled out in the contract documents. Failure of the contractor to understand these differences and a consequent bid and schedule based on common practice will result in delays, RFI’s and potential change orders.

1. The contractor must provide adequate allowance of time and cost for testing of fire protection systems as described above. Each project will have different requirements and
M.I.T. should be consulted to estimate the testing duration based on previous experience.

2. Due to the increased maintenance and additional likelihood of failure, the use of clean agent, antifreeze and pre-action systems need to be specifically reviewed with the M.I.T. Fire Protection Engineer before being utilized. These systems may only be used in special applications where reviewed with the M.I.T. Fire Protection Engineer.

3. The contractor must maintain fire protection equivalency during renovations and demolition. This will generally require submission of an impairment plan for M.I.T.’s approval. The designer must discuss this need with M.I.T. prior to completion of the contract documents. This is strictly enforced by M.I.T. but many owners do not require such a plan.

4. The designer must state design densities for each area of the project at the SD phase. These may differ from those used in past projects and for other owners. The FM Global sprinkler coverage chart contains this information and is referenced in the above sections.

5. The design must provide an inspectors test station, piped directly to the drain, at the hydraulically most remote point of every sprinkler system including wet sprinkler systems. Determination of that point must be confirmed with M.I.T. System designers frequently leave this to later in the design and finding a suitable drain can be problematic.

6. The designer must provide fire protection in all concealed spaces that contain combustible material or the potential for combustible materials, such as wiring closets. Any areas proposed to be left non-sprinkler protected must be confirmed with M.I.T. and should be pointed out in the narrative.

7. The designer should not meet with the Cambridge Fire Department without M.I.T. approval. Generally a representative of M.I.T.’s Systems Engineering Group will arrange for and be present at such meetings. This will be coordinated through the project manager.

END OF DOCUMENT
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APPENDIX A: SCHEMATICS

A: Plumbing Waste Water

B. Plumbing Water Supply
1. M.I.T. PLUMBING SYSTEMS GOALS

It is our mission to provide safe, reliable and efficient plumbing systems that are designed to conserve water, energy and the environment. To achieve these goals, we commit ourselves to adhere to pertaining codes, regulations and industry standards. We will provide redundancy where necessary to achieve uninterrupted service and minimize downtime. We will provide sufficient design flexibility to allow for future expansion. As an institute of technology, we will keep an open mind to design proposals that incorporate new technology and innovative approaches to plumbing engineering.

1.1 Top Ten List of Common Plumbing Design Issues (not prioritized)

1. During renovations and for new construction, provide back water valves at grade level and basement level floor drains (sanitary) and area drains (storm) to prevent back-charging of water. Correct existing conditions as required. Do not treat as existing to remain or “grandfathered.”

2. Provide in-line check valves on hot and cold supplies to all plumbing fixtures.

3. Existing lead-lined piping shall be replaced as it is discovered during renovations.

4. Drain valves at bottom of risers 2-1/2 inch and larger shall be 1-1/2 inch size with 1-1/2 inch threaded fire hose connection.

5. Potable and non-potable water heaters shall be low pressure (15psi) steam semi-instantaneous with double wall 90-10 cupro-nickel alloy jacket and bundle.

6. Condensate from air conditioning coils shall be collected as reclaim water or piped indirectly to storm.

7. Domestic water booster pumps shall be vertical, multi-stage with variable speed drives and all wetted parts shall be 304 stainless steel. Control panels are to display inlet pressure, discharge pressure, flow, totalized flow, and pump status. Pressure and flow shall be displayed through the Building Management System (BMS).

8. Valves in chases are to be installed to be accessible for repair and replacement with access panels installed if needed.

9. When possible, the first three to four floors of a building shall be fed potable water directly from street pressure. A pressurized express main shall feed upper floors.

10. Irrigation water is to be metered by independent city meters to facilitate sewer abatements. Irrigation (non- sewer) meter shall be installed per Cambridge Water Department standard.
2. DESIGN REVIEW CHECKLIST

The Design Consultant is responsible for filling out, signing, and submitting this checklist at each phase of design as a guide for review by M.I.T. Facilities.

2.1 Schematic Design (SD) Phase

1. Review of applicable codes, regulations, and standards.
2. System descriptions (Basis of Design).
3. Alternative design concepts.
4. Outline specifications.
5. Equipment cut sheets.

2.2 Design Development (DD) Phase

1. Risers diagram for all systems
4. Piping and metering of irrigation water.
5. Design of split water distribution system, as applicable.
6. Variable speed drive domestic booster pumps, as applicable.
7. Calculations of water distribution pressure and flow.
9. Hot water storage temperature, as applicable.
10. Tempered water system design.
11. Chase wall sizes coordinated between plumbing and architectural.
12. Natural gas systems including:
   a. Natural gas load calculations.
   b. Natural gas loads filed with the gas company.
   c. Elevated gas pressure permit filed, as applicable.
13. Flushing water including:
   a. System design, as applicable.
   b. Flushing water variance application filed, as applicable.
   c. Flushing water load calculations.
   d. Flushing water pressure calculations. End fixture pressure not to be less than 20 psig and not greater than 30 psig. Provide pressure control valves as necessary to attain design pressure limits.
14. Controlled Flow roof drain design, as applicable.
   a. System design, as applicable.
   b. Include roof drain areas serving for each roof drain and indicated on the riser diagrams.

15. Location of emergency showers and eyewashes.
   a. Emergency shower and eyewash locations to be reviewed with M.I.T. EHS.

16. Location of sanitary vent terminals with respect to HVAC fresh air inlets. Provide minimum 25 feet away from any fresh air intakes.
17. Piping of HVAC condensate to storm drain system.
18. Trap primers shall be provided for all floor drains and are installed where required.
19. Coordination of plumbing with HVAC.
20. Coordination of plumbing with electrical.
21. Sprinkler drains and compressed air service supplied to fire protection systems.
22. Garage waste, sand, and oil interceptor design reviewed with plumbing inspector.
23. Grease interceptors design shall be reviewed with plumbing and sanitary inspectors.
24. Updated fixture and equipment cut sheets provided.
25. Reclaimed water systems application for variance filed with Cambridge and reviewed with Plumbing Inspector.
26. Coordinate with the Architect to provide moisture resistant gypsum board in plumbing chases and wet walls to the greatest extent possible.
27. Provide sleeves for all pipe penetrations in wet wall and laboratories.
28. Provide cleanout at the end of a ganged water closets sanitary header. Cleanout shall be higher than flood rim of water closets.

2.3 **90% Construction Documents and Construction Documents (CD) Phase**

1. List of design changes from the Design Development issue.
2. Updated fixture and equipment cut sheets.
3. Natural gas loads and permits approved by Gas Company or State Board.
4. Flushing water system approved by local Authority having jurisdiction.
5. HVAC condensate coordinated with storm water system.
6. Electrical loads coordinated with electrical drawings.
7. Variances approved by responsible authorities.
8. Review of specification sections.
9. Coordination with other trades (mechanical, electrical and fire protection)

2.4 **Shop Drawing Phase**

1. Ensure that the shop drawing submittals comply with all aspects of the contract
documents; note in writing any deviations for discussion with M.I.T. or provide written certification that shop drawing submittals are compliant.

2.5 Record Drawing Phase

1. Review record drawings and final submittals for compliance. Provide a written report of compliance or deviations.
2. Record drawings shall include all isolation valves location, valve tags, equipment location and schedules.

3. PLUMBING SYSTEMS DESIGN CRITERIA

3.1 City Water Metering Requirements

Provide Cambridge Water Department preferred meters for city water metering including:

1. Refer to MIT Utilities Water Meter Section for meters specification.
2. Provide meters for buildings cooling towers feed and blowdown.
3. Provide a full size valve up to 2-1/2 inch with threaded hose connection at the outlet side of the city water meter to use for meter calibration, temporary feed to the building, and system draining.
4. All city water meters shall read in cubic feet.
5. With the exception of irrigation and cooling tower make-up meters, The City of Cambridge Water Department will supply water meters for services 2 inch and smaller, typically Neptune meters, AWWA C700.

Provide an electrical outlet for all meters requiring remote reading.

All meters shall be provided with manufacturer’s remote registration hardware including a wall-mounted accessory pad for communications.

Fire protection services are not to be metered.

Install dedicated water meters for cooling tower make-up, cooling tower blowdown and in-ground irrigation systems. Dedicated meters are not sub-meters to a main meter, and shall be fed directly from the water service entry, separate from the rest of the building, upstream of the domestic water meter. Dedicated meters are used to facilitate sewer rebate tracking with the city.

Meters inside the building shall be installed in accessible locations. Exterior meter pits or vaults are not allowed.

Wherever possible, remove existing meters in exterior pits and vaults and relocate inside the nearest building.
Water used at a construction site shall be metered by the contractor and billed to the respective construction project account.

3.2 Backflow Prevention

Refer to “Plumbing Products” table below for acceptable backflow device manufacturers.

All backflow devices, 4 inch and under, shall have ball valves for isolation. Ball valves 2½ inch to 4 inch and smaller shall be American Valve 3700V (series). 2 inch and smaller shall be lead free bronze body valves. Specify gate valves for sizes 6-inch and larger.

Project specifications shall include the following under Part 3 – Execution:

“Flush water lines prior to backflow testing to clear piping of sediment. Test all backflow devices and provide written record of each test result to M.I.T. Facilities. A third-party certified tester shall perform all tests. Rectify all test discrepancies prior to M.I.T. acceptance. Provide one spare parts kit to M.I.T. for each size backflow device.”

Backflow devices with flange or body material dissimilar to the connected piping shall be installed with a dielectric kit supplied by the backflow device manufacturer.

All backflow devices shall be supplied with a 20-mesh strainer at the inlet.

Unless a fire pump is installed, strainers are not required for double check valves in fire protection services.

Where fire pumps are installed, provide a 20-mesh strainer body and strainer for fire pump testing and certification. This strainer is required to prevent foreign matter frequently present in new services from fouling the fire pump. After certification, remove the strainer element from the strainer body.

For sizes 2-inch and smaller, provide Watts LF909 QT-S. For hot water, provide Watts LF909 HW-QT-S. (210°F)

For 2-1/2-inch and larger, provide Watts LF909 QT-S.

Provide air gap and indirect waste. Run waste pipe to nearest floor drain.

All backflow preventer assemblies over 2-1/2-inch shall be epoxy coated cast iron.

Backflow preventers shall be approved by the Cambridge Water Department.

Provide one (1) set of repair kit.

2 inches and smaller shall have a soft seat check valve upstream and downstream of device.

Provide pressure gauges upstream and downstream of backflow preventers.
3.3 Booster Pumps

Water pressure on campus can vary significantly from day to night and from season to season. Pressure ranges from 40 psig to 60 psig.

Buildings over 40 feet shall have a booster pump system to maintain pressure.

Split Systems: The basement through fourth floor shall be fed off of street pressure when practical. An express main from the booster pumps will feed the upper floors. This is to conserve energy by avoiding pressurizing water above 80 psig only to subsequently reduce pressure through a pressure-reducing valve to feed lower floors.

All domestic water booster pumps shall be vertical, multi-stage with variable speed drives. Control panels are to display inlet pressure, discharge pressure, flow, totalized flow, and pump status. Pressure and flow should be displayed through the building’s BMS and MIT PI System.

Provide 3/4-inch shutoff valve with threaded hose connection at upstream of hydrocumulator tank. Provide pressure gage at hydrocumulator tank with shutoff valve.

Provide a full size by-pass with shutoff valve.

Provide BACNET output for booster pump interface.

3.4 Water Heaters, Master Mixing Valves and Circulator Pumps

Water heaters in academic buildings shall be semi-instantaneous medium pressure (60 psi) steam fired whenever possible with double wall 90-10 cupro-nickel alloy jacket and tube bundle.

Instantaneous water heaters shall not be used on potable hot water systems:

1. Instantaneous water heaters are defined as heat exchangers where the water to be heated is in the coil and the steam is in the jacket.
2. Semi-instantaneous water heaters are defined as heat exchangers where the water to be heated is in the jacket and the steam is in the coil. With an internal thermostatic control, these heaters are far more accurate.

Where a reduced pressure zone backflow preventer is installed in the domestic water supply, an expansion tank shall be installed in the cold water feed to the potable water heaters.

When storage type water heaters are used, storage temperature shall be from 140 deg F to 150 deg F to inhibit bacterial growth. This requirement is especially important in dormitory buildings and buildings with shower facilities where occupants can be exposed to aerosolized hot water.

Hot water heater steam control valves should be pneumatically controlled. Pilot operated steam valves should be used only in situations where compressed air is not available.
Thermostatic mixing valves shall be used to convert to hot water storage temperature to
distribution temperature. Hot water distribution temperature shall be between 110 deg F to 120
deg F for academic buildings and 120 deg F to 130 deg F for residencies. Thermostatic valves
shall be listed as lead free and be certified ASSE 1017. Hot water temperature should be displayed
on the building’s BMS.

1. For peak flow ranges 30 gpm and lower, specify Leonard, Lawler or Watts approved
equal ASSE 1017 valves with 0.5 gpm minimum flow.

2. For peak flows from 30 to 120 gpm, specify ASSE 1017 digital response thermostatic
mixing valves. Powers Intellistation LFIS (series) or Armstrong “The Brain” DRV
(series) with 0.5 gpm minimum flow.

3. For all valve types, follow manufacturer’s written instructions for hot water
recirculation piping configuration and balancing. Manufacturer instructions shall take
precedence over Construction Document details which are typically generic and
schematic.

4. Provide a full size tee at the discharge of hot water mixing valve to enable load for
mixing valve setting.

Provide drain port for thermostatic mixing valve cleaning and inspection. Provide a ¾” ball valve
with threaded hose connection between the valve outlet and main shut-off valve to assist in testing
and temperature adjustment.

Hot water circulation pumps shall be in-line centrifugal pumps with close-coupled variable speed
drive motor and on-board temperature and flow instrumentation. Grundfos Alpha or Grundfos
Magna 3. Connect temperature, flow and status points to the building BMS.

On large distribution systems such as in a laboratory or residence hall (i.e. for return flow rates
about 5 gpm and higher), overnight or weekend shut-down of the circulation system is not
allowed. Doing so will result in excessive time to restore temperature throughout the distribution.
For smaller distribution systems, overnight shutdown provided by a timer is permitted.

### 3.5 Hose Bibbs and Wall Hydrants

Interior hose bibbs shall be provided in each toilet room with more than one flushing fixture and in
each mechanical room.

Hose bibbs in toilet rooms shall be polished chrome plated with threaded hose connection, integral
vacuum breaker and removable tee handle. Equal to Chicago 952-1/2CP.

Hose bibbs in mechanical rooms and other unfinished spaces such as trash rooms, storage rooms,
etc. shall be rough chrome plated with threaded hose connection, integral vacuum breaker and
removable tee handle. Equal to Chicago 998-RCF.
Exterior hydrants shall be self-draining, non-freeze configuration with integral vacuum breaker. Wherever possible, specify hydrants with flush access door with removable tee handle. J.R. Smith 5509QT or equal.

Exterior hydrants shall be located 2 feet above finished grade.

Provide wall hydrants every 100 feet along the perimeter for residential buildings.

On roofs with mechanical equipment such as air handlers with heating/cooling coils and cooling towers or on vegetated roofs provide non-freeze roof mounted hydrant(s) with ASSE 1052 backflow device and threaded hose connection. Hydrant shall be capable of being mounted to the roof deck with flashing and counter flashing. Provide a hydrant drain piped over to the closest acceptable receptor such as a janitor sink or trapped and vented floor drain.

### 3.6 Floor Drains, Roof Drains and Area Drains

Provide trap primers and trap guards for all floor drains, either automatic or mechanical. Automatic one shall work for 3 psi differential. Similar PPP or Wade.

Provide floor drains in toilet rooms with more than one flushing fixture and in mechanical rooms. Locate mechanical room floor drains as required to receive discharge and/or drain down by mechanical and plumbing equipment. All RPZ backflows shall be piped indirectly to a floor drain. All floor drains not regularly receiving process water waste shall be provided with an automatic trap primer similar to Precision Plumbing Products (PPP) Model MP-500-115V (1 to 4 outlets with distributor) or PTS (series) manifold multi-outlet units.

Mechanical room floor drains shall be specified with removable sediment buckets. Provide with water dam floor drains for clean water waste (condensate drain discharge).

Roof drains shall be ASME A112.6.4 (latest adopted edition) general duty cast iron body with flashing ring, gravel stop and polyethylene dome strainer. Specify under deck clamps, sump receiver and other accessories as needed to mount to roof deck system.

Secondary overflow drains shall have a perimeter water dam approximately the same diameter as the drain flashing ring. Interior standpipe drains are not permitted. Water dam height shall be 2 inches minimum but not more than permitted by the loading factor of the roof system.

Provide bronze or stainless steel overflow drain outlet with insects screen.

### 3.7 Pressure Gauges, Temperature Gauges and Related Instruments

Pressure gauges, switches and transmitters shall have 1/4 inch isolation valves (or size as required by the instrument’s process connection size).
Provide pressure gauges at the inlet and outlet of each pump, backflow preventer and pressure-reducing valve.

Provide temperature gauges at the inlet and outlet of each water heater, thermostatic valve, and circulation pump.

Pressure gauges shall be liquid filled.

3.8 Drinking Fountains

Recess drinking fountains in alcoves. Do not project into corridors. Coordinate with the Architect as required.

Provide dual height units as required to meet barrier-free accessibility requirements.

Units should be electric water cooled with bottle fillers.

3.9 Toilet Room Fixtures

Residence hall water closets, lavatories, public urinals, and public/private showerheads shall be EPA Watersense® certified.

Wall hung lavatories are preferred for commercial (i.e. non-residence) toilet rooms. Avoid the use of countertops.

Where countertops are used, specify an under-mount bowl to eliminate any lip or dam at the sink edge.

Lavatory selection and design shall be easy to wipe clean and prevent trapped water outside the sink bowl. Provide with overflow drain for public use and pop-up drain for residential use.

Public lavatory faucets shall be 0.5 gpm electronic sensor faucets. Faucets shall be battery powered with recharging technology (e.g. solar or turbine regeneration). Public lavatory faucets shall be specified with ASSE 1070 thermostatic temperature limiting valves set at 110°F outlet temperature. Provide one (1) single handle manual operated faucet on public bathrooms.

Residence hall lavatory faucets shall be 0.5 gpm with manual control. In residence hall units designated ADA, provide ASSE 1070 thermostatic temperature limiting valves set at 110°F outlet temperature.

Public water closets shall be wall hung flush valve fixtures, 1.28 gallons per flush. Flush valves shall be sensor operated, battery powered with recharging technology (e.g. solar or turbine regeneration).

Urinals shall be wall hung flush valve fixtures, 0.128 gallons per flush. Flush valves shall be sensor operated, battery powered with recharging technology (e.g. solar or turbine regeneration).
Residence hall water closets shall be tank-type, floor mounted, 1.28 gallons per flush or dual flush with fewer gallons per flush.

Shower valves shall be single handle, ASSE 1016 pressure balance, thermostatic or combined anti-scald units. Shower heads shall be maximum 1.5 gpm.

Provide in-line checks on both hot and cold supplies.

Water closets and flush valves shall be the same manufacturer, do not mix and match.

Provide water closet carriers with a 4-inch coupling (3-inch is not acceptable) and 500 pound load rating.

### 3.10 Janitor Sinks

Janitor sinks shall be floor mounted mop receptors constructed of terrazzo with bumper guards and 304 stainless steel wall splash guards. Faucet shall be two handle, wall mounted with polished or rough chrome plated finish, integral check valves, integral vacuum breaker and pail hook with bracket.

Minimum drain and trap size shall be 3 inch.

Hot and cold water supplies feeding janitor sinks shall be protected by ASSE 1013 reduced pressure zone backflow prevention. Point of use backflows are not preferred due to the number of assemblies required to be registered, maintained and tested, therefore consolidation is encouraged. A central RPZ with separate electric storage water heater feeding only the janitor sinks is ideal where recirculation is required due to distance from the hot water source to the furthest outlet. Non-potable hot water shall not be recirculated back to the potable hot water system or heaters.

### 3.11 Natural Gas

Determine the current gas supply company. As of Year 2016 contact Eversource.

File total connected load for new gas consumption with the gas company in writing. Review the preliminary gas system load with the gas provider early in the design process and update regularly thereafter.

The gas company will make the connections to the gas main and will provide the service branch to the building. M.I.T. may be back-charged for this expense.

The gas company typically furnishes and installs the gas meter assembly.

Provide swing joints at buildings as required by code and standards to account for building settlement.

Refer to laboratory services sections of the M.I.T. Guidelines for laboratory gas requirements.
Install emergency shut-off valves outside the labs with tee handles and on to the path of egress. Provide signage “master gas shutoff valve”.

For pressure less than or equal to 0.5 psi (14 inch water column):

1. Pipe Sizes 2 inch and Smaller: Schedule 40 black steel pipe with malleable iron screwed fittings.
2. Pipe Sizes 2-1/2 inch and Larger: Schedule 40 black steel pipe with welded joints.
3. Gas pipe shall be painted yellow with labels.
4. Exterior gas piping and piping exposed to the elements including all piping in open parking structures shall be polymer coated and joints shall be painted yellow with epoxy paint.

Natural gas to commercial kitchen cooking equipment shall be provided with an automatic shut-off, manually reset solenoid valve in addition to the manual shut-off and hood fire suppression automatic shut-off valve. The solenoid valve shall be controlled by a carbon monoxide and natural gas (methane) monitor connected to two (2) carbon monoxide detectors and two (2) methane detectors located in the room. The detectors shall be mounted as recommended by the detector/controller manufacturer, generally 3 to 5 feet above the floor and greater than 10 feet away from the cooking equipment or hood. Twin detectors are intended to provide redundancy. If one detector activates, the system goes into “alarm” mode with local alarm notification. If a second detector activates, the system goes into “shut down” mode which closes the natural gas solenoid and initiates a remote alarm notification to the building fire alarm system. The solenoid valve may not be automatically reset. It shall require manual reset at the controller to re-open.

### 3.12 Sewage Ejectors and Sump Pumps

All sewage ejectors and sump pumps in basins deeper than 4 feet shall be specified with rail removal systems.

Provide duplex pumps with an automatic alternating control panel.

Provide air cooled (no oil lubricated) pumps.

All sewage ejector high alarms shall be connected to the building management system (BMS).

Provide alarm indicator light outside the Mechanical Room.

### 3.13 Emergency Showers and Eyewash Systems

ANSI Z358.1 (latest edition) and 527 CMR 10.02 shall be followed in all respects when installing emergency showers and eyewashes on campus. MIT requires the tempered water system to support minimum of two (2) safety showers (40 GPM) on new laboratories buildings and one (1) safety shower and one (1) safety eyewash on existing laboratory building renovations.
Supply water to emergency showers and eyewashes shall be tempered in a range between 70°F and 90°F with a preferred temperature of 85°F with emergency thermostatic mixing valves.

Thermal Storage:

1. Whenever possible, tempered water shall be supplied through a semi-instantaneous steam-fired water heater(s). This heater may be the potable water heater for the building. The intent is to minimize thermal storage required for ANSI flushing water supply requirements.
2. When semi-instantaneous heaters are not possible, M.I.T. prefers the use of dedicated electric storage water heaters to meet 15 minute tempered water requirements of ANSI.
3. Storage water heaters shall have a minimum combined storage capacity of 220 gallons at a storage temperature of 150 deg F to meet one shower and one eye wash requirements.
4. Storage temperature requirements are intended to mitigate Legionella pneumophila proliferation in stagnant water supplies. Higher temperature also allows a higher specific enthalpy thereby reducing storage volume.

Emergency shower mixing valves to comply with ANSI Z358.1 to provide 20 gpm of tempered water with positive hot water shutoff and cold water bypass bronze body, dual independent elements, stainless steel piston and liner. Thermostatic mixing valves shall be set for 85°F and designed to provide full cold-water bypass on failure of the hot water supply.

Thermal storage shall be sized for one emergency shower and one emergency eyewash flowing for 15 minutes for existing buildings; two showers for new construction. Minimum delivery temperature shall not be less than 70 deg F after fifteen minutes.

Flushing water supply pressure to emergency showers and eyewashes shall not be less than 20 psig and shall not exceed 30 psig. Where water supply pressure is inadequate to supply the 20 psig minimum residual at design flow include a booster pump in the tempered water system.

Pipe sizing shall be based on two emergency showers flowing simultaneously without regard to delivery temperature including:

1. Minimum main distribution shall be 2 inch diameter.
2. Branch distribution to a floor shall be not less than 1-1/2 inch diameter.
3. Feeds to individual equipment shall follow ANSI requirements.

Continuous flushing of tempered water line to prevent stagnation, as required by Mass Plumbing Code, should be done by tying to a bathroom fixture (preferred connected to the cold water feed of urinals or water closets) or other approved means. Comply with the “5 foot rule” for dead legs.

Emergency eyewash models should be dual stream and the swing arm type is preferred. Drench hose units mounted next to laboratory sinks are prohibited. If used as supplemental equipment, such drench hose units shall be located 6 feet or more away from laboratory sinks and fume hoods.
Safety showers shall be specified with the manufacturer’s flow switch package for connection to the BMS. Refer to controls sections for addressable monitoring by room number. Only located in common areas.

Safety showers do not require floor drains. Free standing eyewash units do not require hard piped waste, trap or vent. However, specify and detail that recessed pull-down eyewash units have the drain piped to the provided “daylight” outlet.

Tempered water distribution piping is not required to be insulated per ASHRAE 90.1 and the IECC.

Provide lockable line size full port shutoff valve on hot and cold water feed to the emergency mixing valve. Service valves in the tempered water distribution shall be locked open or have the operating handle removed and zip-tied to the pipe for use as needed for maintenance shut-downs.

Provide testing certification for all emergency equipment which include emergency shower/eyewash stations, emergency showers and emergency eyewash stations. Testing procedures for certification shall comply with ANSI ISEA Z358.1.

3.14 Lab Waste Neutralization

M.I.T. uses centralized pH neutralization for the campus. Buildings without stand alone systems collect their lab waste in the basement and transfer it to the nearest neutralization system for neutralization.

Neutralization by the use of limestone chip tanks is not permitted, even in cases of “temporary” provisions. All lab waste shall be treated by means of a fully automated pH adjustment system.

Pumped lab waste piping should be Schedule 80 high density polyethylene (HDPE) with butt fusion or socket joints use socket fusion joints only when field fabrication of a butt fusion joint is not practical. Equivalent Standard Dimension Ratio (SDR) pipe wall thickness rating is SDR 11. Piping color should be black.

Gravity lab waste piping should be flame-retardant polypropylene (PPFR) with fusion joints and mechanical joints in laboratory casework. Piping color should be blue, pale green or dark green.

Point of Use Lift Stations:

Provide point of use lab waste lift station at lab sinks if lab waste cannot flow by gravity to the lab waste system.

Lab waste lift station package system shall be a UL listed and Mass approved product.

Practical Applications Inc. is the MIT preferred vendor for lab waste lift stations.
In certain locations on campus, laboratory sinks may still have limestone chip tanks below sinks without automatic pH treatment downstream. If such chip tanks are present, new infrastructure for laboratory waste transfer or treatment must be provided to comply with City of Cambridge and MWRA regulations.

In some locations on campus, some laboratory sinks may have limestone chip tanks installed but downstream piping is laboratory waste materials and waste is either treated or transferred to an appropriate treatment system. If such chip tanks are present, they should be remove and replaced with a new polypropylene (PPFR) p-trap. Legally dispose of chip tanks, p-traps and piping as hazardous waste if heavy metals or other contaminants are discovered. Testing to be done/verified by MIT EHS.

Lab Waste Transfer Stations:

Welded seam polypropylene basin with reinforcing ribs. Basins shall include 1 ½ inch low point drain valve, access manway, and threaded or flanged nozzles as required for pumps, inlet, outlet, vent and level sensors. Basin shall be air tight to prevent odors.

RF Admittance technology continuous level sensors for level measurement and pump on/off control. Point level sensors for high-high alarm and pump start permissive level. Equal to AMETEK Drexelbrook Universal or Intellipoint.

Duplex stainless steel housing and impeller centrifugal, end-suction pumps with suction flexible connections. Preferred pump configuration is floor mounted exterior. Submersible pumps may be considered on a case-by-case basis due to space restraints. Goulds or equal.

Discharge electromagnetic flow sensor capable of displaying and transmitting instantaneous flow and totalized flow. ABB or equal.

pH probe located in basin capable of transmitting pH to control panel.

Minimum of two (2) sample ports at pump discharge for grab and composite sampling at an accessible height without the use of ladder.

Control panel with local power disconnect and touchscreen operator interface. Controller shall be a programmable logic controller (PLC) capable of receiving operating inputs and providing display or control of the following parameters:

Pump status: On/off/auto (user selected)
Pump run indication
Basin Level
Alarm: high level, pump failure, etc.
Discharge pH
Discharge flow (gpm) and totalized flow (gallons)
The controller shall be connected to the BMS system for remote monitoring of the parameters above.

Centralized pH Neutralization:

Welded seam polyethylene contact tanks with reinforcing ribs. Tanks shall include 1 ½ inch low point drain valve, access manway, and threaded or flanged nozzles as required for chemical injection, mixers, inlet, outlet, vents and sensors.

Tank-mounted pH probes capable of transmitting signal back to the main controller.

Tank or shelf-mounted metering pumps with concentrated 98% sulfuric acid and 50% sodium hydroxide reagent tanks. Although proper mixing should provide adequate pH response during treatment, assess the need to provide Calcium Carbonate solution and metering pump where influent waste is predominantly deionized to buffer the pH response of the treated solution. Include reagent tank low level switches.

Tank-mounted marine style mixers capable of completing a full tank turn-over in one minute or less. For example, a 500 gallon contact tank shall be mixed at a rate of 500 gallons per minute.

Discharge p-trap with in-line final pH sensor and MWRA required sample port and three additional MIT sample ports for grab and composite sampling.

Discharge electromagnetic flow sensor capable of displaying and transmitting instantaneous flow and totalized flow. ABB or equal.

Circular chart recorder to continuously record for 7 days minimum the discharge pH.

Control panel with local power disconnect and touchscreen operator interface. Controller shall be a programmable logic controller (PLC) capable of receiving operating inputs and providing display or control of the following parameters:

Metering Pump status: On/off/auto (manual user selected)  
Pump run indication  
Alarm: pH level out of limits, reagent tank low, pump failure, etc.  
Discharge pH  
Discharge flow (gpm) and totalized flow (gallons)

The controller shall be connected to the BMS system for remote monitoring of the parameters above.

3.15 Minimum Insulation Requirements for Hot and Cold Water

Applies to both potable and non-potable water distribution systems. Insulation shall meet the requirements of ASHRAE 90.1 (latest adopted edition).
Cold Water: Minimum 1/2 inch insulation thickness.

Tempered Water (70°F to 90°F): Insulation not required.

Circulated Service Hot Water (100°F to 140°F):

1-1/2 inch and smaller: 1 inch minimum insulation thickness at maximum conductivity of 0.28 BTU/in x ft2 x °F.

2 inch and larger: 1-1/2 inch minimum insulation thickness at a maximum conductivity of 0.28 BTU/in x ft2 x °F.

Circulated Hot Water (141°F and higher):

1-1/2 inch and smaller: 1-1/2 inch minimum insulation thickness at maximum conductivity of 0.29 BTU/in x ft2 x °F.

2 inch and larger: 2 inch minimum insulation thickness at a maximum conductivity of 0.29 BTU/in x ft2 x °F.

Non-Circulated Service Hot Water:

All Sizes: 1 inch minimum insulation thickness at a maximum conductivity of 0.27 BTU/in x ft2 x degrees F.

3.16 Interceptors, Separators, and Holding Tanks

Food Preparation/Service Areas

Comply with 248 CMR, Mass Plumbing code where such drains must be provided. As a minimum the following are recommended:

- Cafeterias;
- Dining areas where food is prepared and served;
- Commercial kitchens;
- Restaurants;
- Medical facilities; and
- Where substantial amounts of fats, oil, and grease have the potential to enter the buildings drainage system or cause obstructions in sewage lines.

Residential Areas

Grease traps and interceptors are not required for residential buildings, structures, dwellings, dwelling units, or any private residence. Floor drains are required at ADA showers.

Cafeterias or Commercial Cooking Areas
Grease traps and interceptors are required in buildings deemed “residential” (e.g. Dormitories, graduate student apartment buildings) that include cafeterias or commercial cooking areas (i.e., dining halls).

The fats, wax, oil, and grease contents of a grease trap or interceptor shall not be discharged to the sewer system.

Chemical, biological, or physical means shall not be used to release fats, wax, oil, or grease into the sewer, bypass the trap or interceptor, or otherwise make the trap or interceptor operate less effectively. Only MWRA approved chemical or biological agents can be used in a grease trap or interceptor may be added to a trap or interceptor to convert the fats, wax, oil, and grease in a trap or interceptor to a substance not regulated by 360 CMR 10.021 through 10.024 if the resulting discharge from the trap or interceptor will not cause or contribute to an obstruction or blockage in the sewer or otherwise violate 360 CMR 10.021 through 10.024.

Central and point of use grease interceptors shall be provided per 248 CMR, Section 10.09. Provide testing port for central grease interceptor located downstream of the discharge.

Vehicle Maintenance Areas

Ensure that the floor drain shall be equipped with an approved sediment and sand control basket, or the floor drain shall discharge through a sand interceptor. Discharge of multiple floor drains into one sand interceptor is acceptable.

4. PIPE AND VALVE IDENTIFICATION

Provide color-coded pipe identification markers on all installed piping.

Pipe markers shall be plastic tape type protected by clear acrylic coating. Refer to “Plumbing Products” below for approved manufacturers.

Provide valve tags for all valves and locations shall be indicated on record drawings.

Provide pipe labels with direction of flow.

4.1 Labeling

Label mains as follows:

1. at all points of entrance and exit from mechanical rooms,
2. adjacent to each valve,
3. on each riser between each floor,
4. at each tee fitting,
5. at points of entrance and exit from building,
6. at least once each room,
7. at intervals no longer than 20 feet.

For pipe 4 inch and larger, legend shall be 2 inch high. For pipe 3 inch and smaller, use 1/2 inch high legend.

Install arrow markers with each identification marker to indicate direction of flow. If flow can be in either direction, use double-headed arrow marker.

Reclaimed water piping shall be painted along its entire length in yellow enamel paint prior to insulation. Pipe shall then be stenciled in black paint “Toilet and Urinal Flushing Only.” After insulation, provide pipe label as specified in the table below. This procedure is mandatory; deviation shall require special approval of the State Board of Examiners of Plumbers and Gas Fitters.

Markers shall have band colors and legend as indicated in the following table:

<table>
<thead>
<tr>
<th>Service</th>
<th>Legend</th>
<th>Band Color</th>
<th>Legend Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold Water</td>
<td>Potable Cold Water</td>
<td>Green</td>
<td>White</td>
</tr>
<tr>
<td>Hot Water</td>
<td>Potable Hot Water</td>
<td>Green</td>
<td>White</td>
</tr>
<tr>
<td>Hot Water Return</td>
<td>Potable Hot Water Return</td>
<td>Green</td>
<td>White</td>
</tr>
<tr>
<td>Non-Potable Cold Water</td>
<td>Non-Potable Cold Water</td>
<td>Green</td>
<td>White</td>
</tr>
<tr>
<td>Non-Potable Hot Water</td>
<td>Non-Potable Hot Water</td>
<td>Green</td>
<td>White</td>
</tr>
<tr>
<td>Non-Potable Hot Water Return</td>
<td>Non-Potable Hot Water Return</td>
<td>Green</td>
<td>White</td>
</tr>
<tr>
<td>Tempered Water</td>
<td>Tempered Water</td>
<td>Green</td>
<td>White</td>
</tr>
<tr>
<td>Purified Water</td>
<td>RODI</td>
<td>Green</td>
<td>White</td>
</tr>
<tr>
<td>Sanitary Drain</td>
<td>Sanitary Sewer</td>
<td>Green</td>
<td>White</td>
</tr>
<tr>
<td>Sanitary Vent</td>
<td>Sanitary Vent</td>
<td>Green</td>
<td>White</td>
</tr>
<tr>
<td>Rainwater</td>
<td>Storm Drain</td>
<td>Green</td>
<td>White</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>Natural Gas</td>
<td>Yellow</td>
<td>Black</td>
</tr>
<tr>
<td>Garage Waste</td>
<td>Garage Waste</td>
<td>Green</td>
<td>White</td>
</tr>
<tr>
<td>Garage Vent</td>
<td>Garage Vent</td>
<td>Green</td>
<td>White</td>
</tr>
<tr>
<td>Reclaimed Water</td>
<td>Gray Water</td>
<td>Purple</td>
<td>White</td>
</tr>
<tr>
<td>Flushing Water</td>
<td>Flushing Water</td>
<td>Yellow</td>
<td>Black</td>
</tr>
<tr>
<td>Irrigation Water</td>
<td>Non-Potable Water</td>
<td>Yellow</td>
<td>Black</td>
</tr>
<tr>
<td></td>
<td>Gray Water</td>
<td>Purple</td>
<td>White</td>
</tr>
</tbody>
</table>
4.2 Valve Tags

Stamped or engraved with 1/4-inch (6.4-mm) letters for piping system abbreviation and 1/2-inch (13-mm) numbers. 1 ½” diameter with smooth edges.

Tag Material: Brass, 0.032-inch (0.8-mm), 0.032-inch (0.8-mm) minimum thickness, and having predrilled or stamped holes for attachment hardware.

Fasteners: Brass wire-link or beaded chain; or S-hook.

Valve Schedules: For each piping system, on 8-1/2-by-11-inch (A4) bond paper. Tabulate valve number, piping system, system abbreviation (as shown on valve tag), location of valve (room or space), normal-operating position (open, closed, or modulating), and variations for identification. Mark valves for emergency shutoff and similar special uses.

Valve-tag schedule shall be included in operation and maintenance data.

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>Description</th>
<th>Color</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler/CHW Make-up</td>
<td>Non-potable Water</td>
<td>Yellow</td>
<td>Black</td>
</tr>
<tr>
<td>Pure Water Make-up</td>
<td>Non-potable Water</td>
<td>Yellow</td>
<td>Black</td>
</tr>
<tr>
<td>Laboratory Air</td>
<td>Compressed Air</td>
<td>Blue</td>
<td>White</td>
</tr>
<tr>
<td>Laboratory Vacuum</td>
<td>Laboratory Vacuum</td>
<td>Blue</td>
<td>White</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>Nitrogen</td>
<td>Green</td>
<td>White</td>
</tr>
<tr>
<td>Oxygen</td>
<td>Oxygen</td>
<td>Yellow</td>
<td>Black</td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>Carbon Dioxide</td>
<td>Blue</td>
<td>White</td>
</tr>
<tr>
<td>Argon</td>
<td>Argon</td>
<td>Blue</td>
<td>White</td>
</tr>
<tr>
<td>Helium</td>
<td>Helium</td>
<td>Blue</td>
<td>White</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>Hydrogen</td>
<td>Yellow</td>
<td>Black</td>
</tr>
</tbody>
</table>

4.3 MEP Equipment Naming Standards

Design drawings should include equipment designations in their schedules and plan views which are unique and do not duplicate existing equipment. Contact the MIT Systems Engineering Group to determine which equipment names are available.

Equipment names should conform to the following standard:
XXX_XXXXXXX

Examples:
Building 76, Air Handling Unit 12A would be:
M76_AHU12A
Buildings which have no letter prefix assigned in the MIT naming convention (Buildings 1, 2, 3, etc.) will be preceded with an “M”.

Building E17, Chilled Water Pump 2 would be:
E17_CHWPMP02

Note that system, equipment, and number are combined as one text string.
The following is the standardized list of system, equipment, and other abbreviations:

<table>
<thead>
<tr>
<th>System/Equipment</th>
<th>Abbreviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Handling Unit</td>
<td>AHU</td>
</tr>
<tr>
<td>Exhaust Air Handling Unit</td>
<td>EAHU</td>
</tr>
<tr>
<td>Exhaust Fan</td>
<td>EF</td>
</tr>
<tr>
<td>Return Fan</td>
<td>RF</td>
</tr>
<tr>
<td>Pump</td>
<td>PMP</td>
</tr>
<tr>
<td>Air Cooled Condensing Unit</td>
<td>ACCU</td>
</tr>
<tr>
<td>Heat Exchanger</td>
<td>HX</td>
</tr>
<tr>
<td>Heating Converter (shell and tube)</td>
<td>CV</td>
</tr>
<tr>
<td>Chilled Water</td>
<td>CHW</td>
</tr>
<tr>
<td>Process Chilled Cooling Water</td>
<td>PCHW</td>
</tr>
<tr>
<td>Hot Water</td>
<td>HW</td>
</tr>
<tr>
<td>Condenser Water</td>
<td>CND</td>
</tr>
<tr>
<td>Domestic Hot Water</td>
<td>DHW</td>
</tr>
<tr>
<td>Domestic Cold Water</td>
<td>DCW</td>
</tr>
<tr>
<td>Supply</td>
<td>S</td>
</tr>
<tr>
<td>Return</td>
<td>R</td>
</tr>
<tr>
<td>Temperature</td>
<td>TEMP</td>
</tr>
<tr>
<td>Pressure</td>
<td>PRESS</td>
</tr>
<tr>
<td>Flow</td>
<td>FLOW</td>
</tr>
</tbody>
</table>

For example, Domestic Hot Water Return Temperature in Building 2 would be:
M02_DHWRTTEMP

5. PRODUCTS

5.1 General Requirements

All plumbing products shall be Massachusetts approved. Refer to contract requirements to verify if the “Buy American Act” applies.
Refer to 248 CMR, Section 10.15 (10) Table 5 for determine the capacity of sewage ejectors.

Provide stainless steel variable frequency drive hot water circulators.

5.2 Fixtures and Equipment

All plumbing products shall be Massachusetts approved. Refer to contract requirements to verify if the “Buy American Act” applies.

Refer to 248 CMR, Section 10.15 (10) Table 5 for determine the capacity of sewage ejectors.

Provide stainless steel variable frequency drive hot water circulators.

5.3 Preferred Manufacturers

<table>
<thead>
<tr>
<th>Item</th>
<th>Preferred Manufacturers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TOILET ROOMS</strong></td>
<td></td>
</tr>
<tr>
<td>Lavatories</td>
<td>American Standard</td>
</tr>
<tr>
<td>Lavatory Faucets</td>
<td>TOTO</td>
</tr>
<tr>
<td></td>
<td>Sloan</td>
</tr>
<tr>
<td></td>
<td>Chicago</td>
</tr>
<tr>
<td></td>
<td>Symmons (Commercial Grade for Housing)</td>
</tr>
<tr>
<td></td>
<td>Delta (Commercial Grade for Housing)</td>
</tr>
<tr>
<td>Hose Bibs</td>
<td>Watts</td>
</tr>
<tr>
<td></td>
<td>Chicago</td>
</tr>
<tr>
<td></td>
<td>T &amp; S Brass</td>
</tr>
<tr>
<td>Shower Units</td>
<td>Best Bath</td>
</tr>
<tr>
<td>Shower Valves</td>
<td>Symmons Safety Mix</td>
</tr>
<tr>
<td>Water Closets</td>
<td>TOTO</td>
</tr>
<tr>
<td></td>
<td>Sloan</td>
</tr>
<tr>
<td>Urinals</td>
<td>TOTO</td>
</tr>
<tr>
<td></td>
<td>Sloan</td>
</tr>
<tr>
<td>Flush Valves</td>
<td>TOTO EcoPower</td>
</tr>
<tr>
<td></td>
<td>Sloan Solar Power</td>
</tr>
<tr>
<td>Supplies and Stops</td>
<td>McGuire Manufacturing</td>
</tr>
<tr>
<td>Shower and Toilet Room Floor Drains</td>
<td>J. R. Smith</td>
</tr>
<tr>
<td></td>
<td>Zurn</td>
</tr>
<tr>
<td></td>
<td>Watts</td>
</tr>
<tr>
<td>SINKS</td>
<td></td>
</tr>
<tr>
<td>Janitor Sink Basins</td>
<td>Fiat</td>
</tr>
<tr>
<td>Equipment</td>
<td>Manufacturer(s)</td>
</tr>
<tr>
<td>----------------------------</td>
<td>------------------------------------------</td>
</tr>
<tr>
<td>Terrazzo</td>
<td></td>
</tr>
<tr>
<td>Janitor Sink Faucets</td>
<td>Chicago</td>
</tr>
<tr>
<td>Kitchen Sink</td>
<td>Just</td>
</tr>
<tr>
<td></td>
<td>Elkay</td>
</tr>
<tr>
<td>Kitchen Sink Faucets</td>
<td>Chicago</td>
</tr>
<tr>
<td></td>
<td>Symmons (Commercial Grade for Housing)</td>
</tr>
<tr>
<td><strong>EQUIPMENT</strong></td>
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<tr>
<td>Drinking Fountains</td>
<td>Elkay</td>
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<tr>
<td></td>
<td>Oasis</td>
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<tr>
<td></td>
<td>Halsey Taylor</td>
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<tr>
<td>Floor Drains, Roof Drains,</td>
<td>J. R. Smith</td>
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<tr>
<td>Area Drains, Planter Drains</td>
<td>Watts</td>
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<tr>
<td></td>
<td>Josam</td>
</tr>
<tr>
<td></td>
<td>Zurn</td>
</tr>
<tr>
<td>Wall Hydrants</td>
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<td></td>
<td>Watts</td>
</tr>
<tr>
<td>Grease Traps</td>
<td>Guardians</td>
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<td></td>
<td>Schier-Great Basin</td>
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<td></td>
<td>Zurn</td>
</tr>
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<td></td>
<td>Rockford</td>
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<tr>
<td>Gas and Sand Interceptors</td>
<td>Rockford</td>
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<tr>
<td>Pipe Markers</td>
<td>Seton “Setmark”</td>
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<tr>
<td>Emergency Showers/Eyewashes</td>
<td>Guardian</td>
</tr>
<tr>
<td></td>
<td>Speakman</td>
</tr>
<tr>
<td></td>
<td>Haws</td>
</tr>
<tr>
<td></td>
<td>Water Saver</td>
</tr>
<tr>
<td>Insulation</td>
<td>Owens Corning</td>
</tr>
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<td></td>
<td>Manville</td>
</tr>
<tr>
<td></td>
<td>Certain-Teed</td>
</tr>
<tr>
<td>Backflow Preventers</td>
<td>Watts</td>
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<tr>
<td>Pressure and Temperature Gauges</td>
<td>Ashcroft</td>
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<tr>
<td></td>
<td>U.S. Gauge</td>
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<td></td>
<td>Trerice</td>
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<tr>
<td>Booster Pumps</td>
<td>Synchhroflo</td>
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<tr>
<td></td>
<td>Grundfos</td>
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<td></td>
<td>VC System &amp; Controls</td>
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<tr>
<td>Sewage Ejectors</td>
<td>Weil</td>
</tr>
<tr>
<td>Category</td>
<td>Brands</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td><strong>Zoeller Sump Pumps</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Water Heaters</strong></td>
<td></td>
</tr>
<tr>
<td>Water Heater Steam</td>
<td>Patterson-Kelly Armstrong</td>
</tr>
<tr>
<td>Gas Water Heaters</td>
<td>Patterson-Kelly Aerco Lochinvar</td>
</tr>
<tr>
<td>Electric Water Heaters</td>
<td>A.O. Smith Hubbell Bosch (point of use)</td>
</tr>
<tr>
<td><strong>Valves</strong></td>
<td></td>
</tr>
<tr>
<td>Tempering Valves</td>
<td>Leonard Lawler Powers</td>
</tr>
<tr>
<td>Emergency Shower Valves</td>
<td>Leonard Lawler Powers</td>
</tr>
<tr>
<td>Ball Valves</td>
<td>Apollo (Conbraco) Watts Nibco</td>
</tr>
<tr>
<td>Gate, Butterfly and Check Valves</td>
<td>Nibco Stockham Milwaukee Victaulic</td>
</tr>
<tr>
<td>Thermostatic Mixing Valves</td>
<td>Lawler Leonard Powers Armstrong Watts</td>
</tr>
<tr>
<td><strong>Water Meters</strong></td>
<td></td>
</tr>
<tr>
<td>Services 2 inch or less</td>
<td>Refer to MIT Utilities Water Meter Specification</td>
</tr>
<tr>
<td>Services 2 inch or larger</td>
<td>Refer to MIT Utilities Water Meter Specification</td>
</tr>
<tr>
<td>Irrigation (non-sewer)</td>
<td>Refer to MIT Utilities Water Meter Specification</td>
</tr>
</tbody>
</table>
5.4 Pipe, Fittings and Valves

Soil, Waste, Vent and Storm Systems:

1. Buried piping:
   a. Epoxy coated service weight hub and spigot cast iron drainage piping in accordance with ASTM A75. Gasket in accordance with ASTM C564.
   b. Buried piping 10 feet or more below elevation of high water table: Ductile iron Class 56 with push-on joints.

2. Above-ground piping:
   b. Waste and vent piping 3 inches and smaller: Standard weight galvanized steel pipe with galvanized cast-iron drainage fittings or Hub-less cast-iron pipe and fittings or Type “L” copper with cast brass drainage fittings and solder joints.
   c. Vent Piping: Epoxy hub-less cast iron pipe and fittings or standard-weight galvanized steel pipe with galvanized cast-iron drainage fittings.

3. Hubless Piping Couplings:
   a. Heavy-Duty Couplings: ASTM C 1540 heavy-duty stainless steel hubless piping couplings equal to Anaco Husky Series 4000, Tyler Wide-Body, Mission Heavyweight C-series or Clamp-All.
   b. 1-1/2 inches to 4 inches in size: 4 bands.
   c. 5 inches and larger in size: 6 bands.
   d. Regular-Duty Couplings: CISPI couplings may be used on vent piping and 3-inch and smaller waste branches.

Garage Waste Piping:

1. Refer to waste and vent piping.

Pumped Waste Discharge, (Force Main): For storm or sanitary piping systems:

1. Above Grade: Standard weight galvanized steel pipe with threaded or mechanical couplings joints with galvanized cast iron drainage fittings.

2. Buried: Class 52 cement-lined ductile iron pipe and fittings with push-on joints.

Indirect Waste Piping:

2. Type "L" copper with sweated connections.

3. Exposed -1/2 inches and smaller: chrome plated brass, threaded connections and fittings.

Under Slab and Foundation Drainage:

1. PVC Schedule 40 perforated piping with sealed joints.

Cooling Tower Waste:

1. From the drain receptor down to the point of connection to the sanitary stack. Standard weight galvanized steel pipe with threaded or mechanical couplings joints with galvanized cast iron drainage fittings.

Laboratory Waste and Vent Pipe and Fittings

1. Manufacturers:
   a. Enfield,
   b. Asahi,
   c. Orion,


7. Do NOT use this pipe material or fittings for pressurized service (force mains).

Laboratory Waste Force Main


2. Fittings: Identical to pipe material. Molded fittings per ASTM D 3261. SDR 11 (Schedule 80). Fittings may be field or shop fabricated following ASTM D 3261
procedures. 45 degree miter and 45 degree lateral only. Butt fusion end connections. Socket fusion end connections only for connections in field not possible with butt fusion equipment.

3. Joint: Butt fusion methods in accordance with ASTM D 3261. Threaded or solvent bonding of polyethylene materials is forbidden.


6. Ball Valves: For 3 inch and smaller. Polypropylene body, Viton seals, flanged or union end connections.


9. Piping shall be continuously supported in V-channel with V-channel clevis hangers every 5 feet on center.

Water Systems, Potable and Non-Potable:

1. Above ground piping, 2 inches and smaller:

   Hard drawn ASTM B 88, Type L copper with ASME B16.22 wrought copper fittings. ASTM B 32 solder filler material, 95-5 lead-free solder joints. ASTM B 813 liquid or paste flux. Viega ProPress gasketed press joint system.

   Mechanical Joints: Cast copper alloy unions, lead free, hexagonal stock with ball and socket joint, solder ends. ASME B16.18.

   Ball Valves: All bronze, lead-free, full port. Equal to Apollo 77CLF-A series. ProPress ball valves are not acceptable as they are made of brass and not compatible with the Cambridge water chemistry.

   Check Valves: Lead-free bronze body and clapper, solder ends, 200 WOG. Equal to Nibco S-413-Y-LF or Apollo 61Y.

   Balancing Valves: Lead free bronze, PTFE seats, EPDM O-ring, solder end connections. 125 psig WOG. Equal to Nibco S-1810-LF.
Drain Valves: Lead free bronze, 2 piece, RPTFE seats, thread x solder end connections. 600 psig WOG. Hose thread adapter with cap and chain. Equal to Nibco 66-LF-HC.

2. Above ground piping, 2 -1/2 inches and larger:

Hard drawn ASTM B 88, Type L copper pipe with ASME B16.22 wrought copper fittings. ASTM B 32 solder filler material, 95-5 lead-free solder joints or:

Ductile iron coupling with copper alkyd enamel paint coating, ASTM A 536. Grade “EHP” EPDM elastomer gasket, ASTM D 2000. Equal to Victaulic Style 607 coupling. ASTM B 75, B 152 or B 16.22 copper alloy fittings. UNS C89836 or C92200 grooved end cast bronze fittings. Or:

Viega “Pro-Press.”

Mechanical Joints: ANSI Class 150 flange adaptor equal to Victaulic Style 641 for connections to flanged equipment or valves. ANSI B16.1 dimensions.

Butterfly Valves: 300 CWP, Brass casting, grooved ends. Aluminum-bronze offset disc, Grade “CHP” Fluoroelastomer pressure-responsive seat, bubble-tight and bidirectional shutoff and dead-end rated to full rated pressure. Victaulic Style 608N.

Ball Valves: Class 125, cast iron body, epoxy coated. Full port, flanged or roll-groove ends, PTFE coated ball and stainless steel blowout proof stem. ANSI B16.1 flange dimensions. Equal to American Valve 3700V (series).


Drain Valves: Minimum 1 ½” lead free bronze body ball valve with threaded end connection for 1 ½” canvas fire hose.

3. Buried piping, 3 inches and smaller:

Type K annealed (soft) copper with wrought copper fittings and brazed connections.

4. Buried piping, sizes 4 inches and larger:

Class 56 cement-lined ductile iron pipe and fittings with restrained mechanical joints.


6. Polypropylene Pipe: ASTM F 2389, SDR 7.3 socket or electrofusion fittings; and fusion-welded joints piping and fittings to be MA Board approved for all applications and pressure rated to 220 psi at 140 degrees water temperature. Pipe materials shall be PP-R. The manufacturer of the product shall be capable of documenting more than 50 project installations involving PP-R materials in North America.
7. Piping in shafts and concealed spaces shall be welded or soldered joints. No mechanical couplings are permitted.

Reclaim Water Piping

1. Pigmented ASTM F 2389 and CSA B137.11 polypropylene-random copolymer (PP-R) piping. SDR 11. NSF 14 certified. Equal to Aquatherm “Lilac” purple pipe or Niron with heat-fusion fittings.

Trap Primer Piping:

1. Buried: Type K, soft copper with wrought copper fittings and soldered joints with no buried joints. Install Armaflex closed cell neoprene insulation on buried copper tubing.
2. Above Grade: Type L, soft copper with wrought copper fittings and soldered joints

Natural Gas and Gas Train Vent

1. Pipe: ASTM A 53/A 53M, black steel, Schedule 40, Type E or S, Grade B.
3. Fittings:
   2” and Smaller: Threaded. ANSI/ASME B16.3, Class 150. Malleable iron, standard pattern. ANSI/ASME B1.20.1 threads with approved pipe dope or Viega Megapress
   2-1/2” and Larger or Greater than 0.5 (14” w.c.) Pressure: Welded or flanged. ASTM A 234/A 234M for butt welding and socket welding. ANSI/ASME B16.9. AWS D10.12/D10.12M for welding materials.
4. Unions:
   2” and Smaller: Malleable iron. ASTM A182. Class 150.
   3” and Larger: Use flange.
5. Flanges:
6. Ball Valves:
   2” and Smaller: All bronze ASTM B 584, one piece, standard port, RPTFE seats, threaded end connections per ASME B1.20.1. Blowout proof stem design. Chrome plated ball. Steel tee handle. 600 psig CWP. WOG indicated on body. UL-listed for natural gas service. Fed Spec WW-V-35C, Type II, Composition BZ, Style 3. Apollo 70-100-07 series or approved equal.
3” and Larger: Use Plug Valves

2” and Smaller: All bronze ASTM B 584 or iron, bronze plug, threaded end connections per ASME B1.20.1. WOG indicated on body. UL-listed for natural gas service. A. Y. McDonald Mfg. Co. or approved equal.

3” and Larger: Cast iron ASTM A 126, Class B. Bronze plug, flanged end connections, WOG indicated on body. Square head or lug type, tamperproof. A. Y. McDonald Mfg. Co. or approved equal.

8. Dielectric Fittings: Combination fitting of copper alloy and ferrous materials with threaded, brazed-joint, plain, or welded end connections that match piping system materials. 150 psig minimum operating pressure.

9. Coating, Exterior Piping: Shop applied pipe coating shall be adhesive-thermoplastic resin coating (Fed Spec L-C-530, Type I), thermosetting epoxy coating (Fed Spec L-C-530, Type II), or field applied for repairing damaged areas (Fed Spec L-T-1512, Type I), 10 mil nominal thickness for pipe joints and 20 mil nominal thickness for coating repairs.

10. Exterior buried: Polyethylene gas pipe and fittings in conformance with ASTM D 2513 identified as “Gas” and “ASTM D 2513”. Provide electronically detectable yellow warning tape equal to Terra Tape identified as “Gas Piping Below” buried 12 inches to 15 inches above piping.

Purified Water Piping System:

1. Pretreatment, from RPZ outlet to RO skid pump suction:

   Pipe: Chlorinated Polyvinylchloride (CPVC), Type I manufactured per ASTM D 1784. Schedule 80.

   Fittings: CPVC complying with ASTM F 439. Socket or threaded.


   Flange: ANSI B16.5, Class 150 pattern of identical pipe material.

   Ball Valves: CPVC, Type 1, ASTM D 1784 body and ball. PTFE seats and Viton O-rings. Standard “T” operating handle. Union or solvent cemented socket end connections. Blow-out proof stem. Equal to Georg Fischer Type 546.

   Check Valves: CPVC, Type 1, ASTM D 1784 body and check cone. PTFE seats and stainless steel spring. Body to be capable of being installed in any position. Union or solvent cemented socket end connections. Equal to Georg Fischer Type 562.
2. RO permeate through supply and return distribution:

Pipe: Type II copolymer, virgin and unpigmented polypropylene manufactured per ASTM D 4101, SDR 11 for 2 inch and smaller. SDR 17.5 for 3 inch. Equal to Georg Fischer PROGEF high purity piping system.

Fittings: Same material as pipe with bead and crevice free (BCF) fusion joints of the same manufacturer.

Joints: Heat fusion. Comply with ASTM D 2657 procedures and manufacturer’s written instructions. Use fusion joining equipment supplied by the pipe and fitting manufacturer. Fusion inserts and prefabricated coil fittings are prohibited.

Flange: ANSI B16.5 Class 150 pattern of same material with stainless steel backer rings. For connection to flanged nozzles and equipment. EPDM elastomeric gasket equal to Garlok Style 370, FDA compliant ingredients.

Diaphragm Valves: Type II copolymer, virgin and unpigmented polypropylene body and bonnet manufactured per ASTM D 4101. PTFE diaphragm.

Pressure Reducing Valves: Type II copolymer, virgin and unpigmented polypropylene body manufactured per ASTM D 4101. PTFE diaphragm. Spigot end connections. Equal to Georg Fischer PROGEF Type V782 for 1 ½ inch and smaller. Type V82 for 2 inch to 3 inch.

Pressure Reducing Valves: Type II copolymer, virgin and unpigmented polypropylene body manufactured per ASTM D 4101. PTFE diaphragm. Spigot end connections. Equal to Georg Fischer PROGEF Type V86.

Laboratory Gas Piping, Fittings and Valves

High Purity Copper Tube

Applies to concealed piping for general service laboratory gases requiring high chemical purity but not sensitive to small levels of particulates. Representative gases include:

Laboratory Air
Laboratory Vacuum
Argon
Carbon Dioxide
Helium
Hydrogen
Nitrogen
Oxygen
1. Tube: Seamless copper tube, medical oxygen grade, drawn temper, Type L. ASTM B 819. Include standard color marking "OXY," "MED," or "OXY/MED" in blue for Type L tube. ACR tubing is not permitted.

2. Fittings:
   1/8” to ½”: Copper Alloy barstock, threaded joints. ASTM B16, ASTM B453. Swagelok or equal.
   ½” and larger: Wrought copper, solder-joint. ASME B16.22.

3. Joints:
   1/8” to ½”: Threaded. ISO 7/1, DIN 2999, BSP TR, and JIS B0203 for tapered pipe threads.
   ½” and larger: ANSI/AWS A5.8 brazing filler material, BCuP series. No flux.

4. Mechanical Joints:
   ½” to 2”: Cast copper alloy unions, hexagonal stock with ball-and-socket joint, solder joint ends. ASME B16.18.
   3” and larger: ANSI Class 150 flange, ASME B16.24. ANSI B16.1 flange dimensions.


6. Needle Valve: For 1/8” to 1/2”. Brass body, 316 SS packing gland, stem and seat, PFA packing. Phenoloc handle. Whitey 0, 1, or 18 series.

7. Ball Valves:
   1/8”: Nickel-copper alloy body, ball and stem, ASTM B164. Viton o-rings. Whitey 60 series or equal.
   3/8” and larger: All bronze, 3 piece, full port, PTFE seats, stainless steel ball, solder end connections. 600 psig WOG. Apollo 82-200-57, Watts B-6801.

8. Check Valves:
   1/8” to ½”: Brass body and poppet, BUNA-N elastomeric O-ring and PTFE-coated aluminum gasket. Stainless steel spring. Whitey 4C or equal.
   ½” to 2”: Class 125, bronze body, bronze disc, solder end connections. Milwaukee 1509, Jenkins 4093, Stockham B-309.
2 ½” and larger: Class 125, cast iron body, bronze disc, flanged end connections. ANSI B16.1 flange dimensions. Milwaukee F-2974.


11. Valves shall be by a single manufacturer. Valves, fittings, components and each length of tube shall be factory cleaned and suitable for oxygen service in accordance with CGA Pamphlet G-4.1 and ASTM G93 Level C. They shall be permanently labeled and delivered plugged, capped, bagged or otherwise sealed. Plugs caps or other seals shall remain in place until final assembly. Plugs caps or other seals shall remain in place until final assembly.

12. Brazers shall be qualified in accordance with the requirements of NFPA 99. Joints and piping shall be continuously purged with a positive flow of Grade M, CGA Pamphlet G-10.1 oil-free, dry nitrogen per ANSI/AWS B2.2 and NFPA 99 procedures.

13. Valves and other lubricated components shall use non-hydrocarbon lubricants.


16. Source Quality Assurance: Valves shall be by a single manufacturer. Valves, fittings, components and each length of tube shall be factory cleaned per the applicable pipe standard. They shall be permanently labeled and delivered plugged, capped, bagged or otherwise sealed. Plugs caps or other seals shall remain in place until final assembly.

17. Joints and piping shall be continuously purged with a positive flow of Grade M, CGA Pamphlet G-10.1 oil-free, dry nitrogen per ANSI/AWS B2.2 procedures.

High Purity Stainless Steel Tube

Applies to high purity gases requiring very low to zero particulate content. Also used for exposed piping on walls or to ceiling mounted outlets/equipment. Also used for gas tubing down stream of local sub-micron filtration or locally/bench generated gases. Representative gases include:

- Argon
- Helium
- Hydrogen
- Nitrogen
- Oxygen
- Methane and other Flammables
Anhydrous Ammonia and other noxious/irritants
Pyrophorics

1. Tube: AISI 316L austenitic stainless steel, ASTM A 269. Comply with applicable requirements of ASTM A 450. UNS S31603 alloy. Welded seam by TIG weld process. Heat treated per ASTM A 269. Tube wall thickness as follows:
   a. 1/8 inch – 0.028 in (0.71 mm).
   b. ¼ inch to ⅜ in - 0.065 in (1.65mm)
   c. 1 inch – 0.083 in (2.11 mm)
   d. 1 ¼ inch – 0.120 in (3.05 mm)
   e. 1 ½ inch – 0.134 in (3.40 mm)
   f. 2 inch – 0.188 in (4.78 mm)

   ID Surface Finish: Mechanically polished to 240 grit (elecropolish to 20 Ra as required for higher purity applications as required by the User).
   OD Surface Finish: Bright annealed.
   Marking: Per ASTM A 450. Include “welded” and surface finish to marking.


3. Weld: Tungsten inert gas (TIG) arc welding process with automatic orbital welding equipment. Comply with AWS procedures by certified personnel.


8. Manufacturer Cleaning and Passivation: Clean and descale tube and parts per ASTM A 380. Passivate tube and parts in citric acid solution and test for free iron per ASTM A 967. Rinse with 18 megOhm deionized water and dry with filtered, oil-free dry compressed air or nitrogen.
9. Manufacturer Packaging: Package in vacuum-sealed inner bags to protect the fitting from contamination caused by fitting movement and to prevent it from cutting the bag. Do not use lubricants on wetted components. Cover end connections of each assembled valve and tube to prevent contamination during shipment. Individually box each double bagged part.

10. Methane and other Flammables, Anhydrous Ammonia and other noxious/irritants, Pyrophorics shall be piped in coaxial stainless steel tubing with vacuum monitoring. Any service valves outside of cylinder cabinets shall be enclosed in ventilated valve cabinets.

5.5 Insulation

1. Manufacturers

   Johns Manville; Micro-Lok.
   Knauf Insulation.
   Manson Insulation Inc.
   Owens Corning; Fiberglas Pipe Insulation.
   Approved equal.

3. Mineral fiber, preformed pipe insulation. Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 547, Type I, Grade A with factory applied all-service jacket (ASJ-SSL) with white kraft paper with integral vapor barrier and self-sealing lap. Pre-cut fiberglass inserts with molded PVC covers secured with glass fabric tape. Maximum thermal conductivity of 0.29 BTU/in x ft^2 x °F.

4. Fire Safety: Insulating materials as described above or approved equal materials shall meet Fire and Smoke Hazard Classification ratings on a COMPOSITE basis in accordance with NFPA 155 and UL 723. These products shall not exceed a flame spread and developed smoke rating minimum. Fitting covers shall not exceed maximum toxicity ratings.

5. Insulation Jacket, Exterior, Exposed

   Stainless-Steel Jacket: ASTM A 167 or ASTM A 240/A 240M.

   a. Sheet and roll stock ready for shop or field sizing.
   b. Type 304, smooth 2B finish with Z-shaped locking seam. 0.024 inch (0.61 mm) thick.
   c. Moisture Barrier for Outdoor Applications: 3-mil- (0.075-mm-) thick, heat-bonded polyethylene and kraft paper.
   d. Factory-Fabricated Fitting Covers:
      1) Same material, finish, and thickness as jacket.
      2) Preformed 2-piece or gore, 45- and 90-degree, short- and long-radius elbows.
      3) Tee covers.
      4) Flange and union covers.
5) End caps.
6) Beveled collars.
7) Valve covers.
8) Field fabricate fitting covers only if factory-fabricated fitting covers are not available.

5.6 Heat Tracing

1. Manufacturers:

   BH Thermal Corporation,
   Delta-Therm Corporation,
   Raychem,
   Tyco
   Approved equal.

2. Freeze Protection:

   Self-Regulating, Parallel-Resistance Heating Cables

   a. Heating Element: Pair of parallel No. 16 AWG, nickel-coated stranded copper bus wires embedded in cross-linked conductive polymer core, which varies heat output in response to temperature along its length. Terminate with waterproof, factory-assembled non-heating leads with connectors at one end, and seal the opposite end watertight. Cable shall be capable of crossing over itself once without overheating.

   b. Electrical Insulating Jacket: Flame-retardant polyolefin.

   c. Cable Cover: Tinned-copper braid, and polyolefin outer jacket with UV inhibitor.

   d. NEMA 4X connection kits for power, splice/tee and end seals.

   e. High temperature, glass filament tape for attachment of cable to piping. Cable ties are prohibited.

   f. Provide warning labels every 10 feet on exterior of insulation on opposite sides of the pipe.

3. Controller

4. **Basis of Design:** Raychem XL-Trace heating cable with RayClic connection kits and DigiTrace 910 (series) digital controller.

5. **Temperature Maintenance, Service hot water.**
   
   Not permitted. Provide mechanical circulation.

6. **Provide label "Heat Trace" on insulation cover.**

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### 6. **GREEN DESIGN**

#### 6.1 **Reclaimed Water**

Reclaimed water shall include:

1. Whenever practical and economical, consideration shall be given to collecting storm water for recycled use as irrigation water or toilet flushing.
2. Reverse osmosis (RO) reject water shall be reclaimed whenever possible to be used as irrigation, toilet flushing or non-potable water.
3. Reclaimed water systems shall not be employed in childcare facilities.
4. Reclaimed water systems shall comply with 248 CMR.

For new construction and substantial renovations, pipe water closets, urinals, process equipment and other non-potable water uses in reclaimed water piping (e.g. Aquatherm Lilac) whether or not reclaimed water is to be collected. The pre-separated system will allow for future reclaimed water system(s) to be installed without further disturbance to the building distribution.

#### 6.2 **Sustainable Design Strategies**

Additional sustainable design strategies include:

1. Low flow consumption fixtures (i.e. EPA Watersense).
2. Controlled flow roof drainage.

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### 7. **OPERATIONS**

#### 7.1 **(Section to be added)**

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### 8. **ENVIRONMENTAL HEALTH AND SAFETY**
Water Labeling: Refer to pipe identification above.

Emergency Shower and Eyewash Systems: Consult with M.I.T. Emergency Health and Safety (EHS) for the location of all emergency first aid equipment including emergency eyewashes and showers.

9. INSTITUTE SPACES Art, Architecture, and Preservation

9.1 (Section to be added)

10. LABORATORY SERVICES

10.1 Water

Hot and cold water to laboratory sinks and equipment shall be supplied from central, duplexed reduced pressure backflow preventers after the containment backflow preventers at the water service entrance and distributed as a parallel (separated) piping system. In existing buildings where a separated water system is not provided, local RPZ’s may be considered on a case-by-case basis or separation of the building will be required.

Laboratory hot water shall be generated by a dedicated set of water heaters supplied protected water from the backflow preventers.

Laboratory faucets shall be specified with integral spout vacuum breakers. Provide the appropriate level of backflow prevention at equipment connections.

10.2 Laboratory Waste and Vent

Laboratory waste shall be collected by a dedicated waste and vent system. Pipe materials shall be as specified above.

Provide “V” channel between hangers to continuously support HDPE force main piping to prevent sagging.

Provide mechanical joints for laboratory sink waste and trap.
10.3 Laboratory Compressed Air

Laboratory compressed air systems shall not be used to serve utility equipment, such as pneumatic doors, HVAC controls, etc.

Design compressed air equipment and piping distribution to deliver 45 to 50 psig at the most remote outlet(s) with a distribution pressure drop not to exceed 5 psi. Add 25% to calculated peak flow to allow for future expansion. Use 1 scfm per laboratory outlet and apply the following diversity factors for sizing distribution piping. Note that the table below includes a 25% increase in load to accommodate future expansion.

### Laboratory Air Diversity Factors

<table>
<thead>
<tr>
<th>Number of Outlets</th>
<th>Diversity Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-3</td>
<td>1.0</td>
</tr>
<tr>
<td>4-7</td>
<td>0.80</td>
</tr>
<tr>
<td>8-13</td>
<td>0.66</td>
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<tr>
<td>14-25</td>
<td>0.40</td>
</tr>
<tr>
<td>26-63</td>
<td>0.30</td>
</tr>
<tr>
<td>64 and up</td>
<td>0.20</td>
</tr>
</tbody>
</table>

Equipment shall be located with adequate access space for regular monitoring and servicing. Provide floor drain adjacent to equipment pads.

Compressed air quality delivered to laboratory users shall meet or exceed ISO 8573-1:2010 Class 2 for particulates, Class 2 for moisture (−40°F dewpoint), and Class 1 for oil/hydrocarbon. Where central/plant compressed air is not available (either physically or in capacity), provide multi-plexed oil-free compressors. Whether plant air is used or local compressors are used, include an appropriately sized air receiver, auto-regenerative desiccant dryers, and final sub-micron particulate filters.

Locate air compressor system intake for breathing air systems outdoors above roof level. The air intake may extend through exterior wall and terminate below roof level when approved by MIT EHS. Air compressor system intake terminals shall be located at least 25 feet (may require more depending upon prevailing wind direction and velocity) from all exhausts, vents, vacuum system discharges or any anticipated source of odor or particulate matter. Air that is filtered for breathable ventilation system use may be considered an acceptable source of intake air when approved by MIT EHS. Combined air intakes must be sized for no restriction while flowing maximum intake.
possible, and shall be provided with an isolation valve at the header for each compressor served. Intake piping for air compressors shall be sized using the total SCFM for the system (both lead and lag pumps) and the total developed length of run. Coordinate with air compressor system technical representative and verify that proposed sizing of intake piping complies with manufacturer’s recommendations.

Laboratory air compressors shall be multiplexed with receiver tanks and sized such that 100 percent of the design load is carried with the largest single unit out of service. Increase the calculated (SCFM) load by 25 percent to accommodate future system expansion.

Design air dryers, filters and pressure regulators for the laboratory air system in duplex, each sized for 100 percent of the load using duplex twin tower desiccant dryers. Include continuous line dewpoint and carbon monoxide (as required) monitoring with sample connections on the discharge piping downstream of the filters and regulators. Locate monitors at, or integral with, the control panel.

10.4 Laboratory Vacuum

Design vacuum source equipment and piping distribution to deliver 19 inches Hg vacuum level at the most remote inlet(s) with a distribution pressure drop not to exceed 5 inches Hg. Add 25% to calculated peak flow to allow for future expansion. Use 1 scfm per laboratory inlet and apply the following diversity factors for sizing distribution piping. Note that the table below includes a 25% increase in load to accommodate future expansion.

<table>
<thead>
<tr>
<th>Number of Outlets</th>
<th>Diversity Factor</th>
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</thead>
<tbody>
<tr>
<td>1-3</td>
<td>1.0</td>
</tr>
<tr>
<td>4-7</td>
<td>0.80</td>
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<tr>
<td>8-13</td>
<td>0.66</td>
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<tr>
<td>14-25</td>
<td>0.35</td>
</tr>
<tr>
<td>26 and up</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Equipment shall be located with adequate access space for regular monitoring and servicing. Provide floor drain adjacent to equipment pads. Floor drains serving vacuum pumps shall be provided with smooth, acid resistant interior coating. Provide a hose bib within the mechanical room.
Terminate laboratory vacuum exhaust discharge outdoors above roof level. Exhaust may extend through exterior wall and terminate below roof level when approved by MIT EHS. Laboratory vacuum exhaust shall terminate at least 25 feet horizontally (may be more depending upon prevailing wind direction and velocity) from all air intakes, doors, windows, louvers or any other building openings. Combine exhaust from each laboratory vacuum pump into one discharge pipe, sized for no restriction while flowing maximum discharge possible, and shall be provided with an isolation valve at the header for each pump served. Exhaust piping for vacuum pumps shall be sized using the total SCFM for the system (both lead and lag pumps) and the total developed length of run. Exhaust piping shall be sized and arranged to prevent moisture and back-pressure from entering pump. Provide valved drip-leg at base of exhaust stacks. Coordinate with vacuum pump system technical representative and verify that proposed sizing of exhaust piping complies with manufacturer’s recommendations.

Laboratory vacuum pumps shall be multiplexed with receiver tanks and sized such that 100 percent of the design load is carried with the largest single unit out of service. Increase the calculated (SCFM) load by 25 percent to accommodate future system expansion.

10.5 Natural Gas

Natural gas pressure to laboratory outlets shall be not less than 4 inches w.c. and not more than 7 inches w.c. Size distribution piping in accordance with accepted practices. Indicate on plans or riser diagrams the total equivalent length of piping to the most remote outlet(s) and the gas load for each intermediate section of piping back to the gas meter or regulator. Use the appropriate tables from NFPA 54 to determine pipe sizes based on diversified connected loads.

Use 5 CFH (MBH) per laboratory gas outlet with the following use diversity factors. Note that the table below incorporates a 25% increase to peak flows to accommodate future expansion.

<table>
<thead>
<tr>
<th>Number of Outlets</th>
<th>Diversity</th>
<th>Maximum Diversity</th>
</tr>
</thead>
<tbody>
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<tr>
<td>8-13</td>
<td>0.75</td>
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<tr>
<td>14-25</td>
<td>0.60</td>
<td>0.90</td>
</tr>
<tr>
<td>26-88</td>
<td>0.40</td>
<td>0.75</td>
</tr>
<tr>
<td>89-188</td>
<td>0.30</td>
<td>0.56</td>
</tr>
<tr>
<td>189 and up</td>
<td>0.20</td>
<td>0.50</td>
</tr>
</tbody>
</table>
Laboratory gas outlets in rooms with pressurized gas outlets (e.g. compressed air, nitrogen, argon, etc.) shall have integral check valves provided to prevent back pressurization of the natural gas system.

Provide master gas shutoff valve cabinet outside of the laboratory doors

10.6 Gas Detection

For laboratories gas detection level, refer to MIT EHS Gas Detection Guidelines and recommendation.

Ensure that appropriate gas detection monitors, controllers and alarm devices are installed in rooms with gas storage and gas use for occupant safety.

For oxygen displacement gases such as nitrogen, argon, helium, carbon dioxide, etc. provide oxygen sensors to alarm if oxygen levels fall below 19.5%. For gases heavier than air, provide sensors 10 to 12 inches above the floor as well as at the breathing zone.

For rooms with oxygen storage, provide oxygen sensor(s) to alarm if oxygen levels go above 22%.

For flammable gases, provide appropriate lower explosive limit (LEL) sensors both low and high as required.

Provide gas detection within ventilated gas safety cabinets.

10.7 Laboratory Gases

Provide two-stage pressure regulating manifolds for laboratory gases as required by space programming provided by the lab planner or architect. For systems requiring continuous and uninterrupted service, provide automatic switch-over manifolds.

Provide sufficiently sized, properly ventilated and constructed room for laboratory gas cylinder storage and manifold systems in accordance with NFPA 99. Coordinate with the designated MIT representative to determine space required for storage of additional non-manifolded cylinders. Gas cylinder storage rooms shall be located at ground level with at least one exterior wall and be provided with a minimum 42 inch door opening to the outside. Localized gas cylinder storage rooms may be provided at other locations within the building when approved by MIT.

Acceptable manufacturers for gas manifolds are Beacon Medaes, Linde, Concoa, Swagelok or approved equal by MIT.

10.8 Purified Water

Centrally produced, stored and distributed purified water (commonly referred to as RODI) quality shall be water quality level produced through processing tap water or clean reclaimed water
through pre-treatment unit operations, product-staged reverse osmosis with pharmaceutical grade polysulfone membranes, 185 nanometer ultraviolet lamp, followed by two stage, mixed bed deionizing vessels (primary / polishing). The resulting quality after the mixed bed outlet will be free of total dissolved solids, total organic carbon, and bio-burden but may contain some dissolved gases.

Reverse osmosis equipment shall be sized without consideration of tempered water make-up. Sized based on winter ground water temperature, typically 40°F.

Provide sampling valves before and after each unit operation through the entire treatment train.

RODI product shall be stored in a polypropylene or polyethylene cone-bottom tank with inlet nozzle, return stream spray ball and hydrophobic vent filter. RODI water conductivity will increase as carbon dioxide is absorbed by the water in the tank and will typically settle out to 1.3 μS/cm (0.77 megΩ-cm) at 25°C when carbon dioxide absorption comes to equilibrium. All other water quality parameters including type and concentration of dissolved solids, TOC, pH, alkalinity, etc. will be considered as indirectly satisfied through maximum conductivity levels as determined by in-line instrumentation. Further treatment to achieve higher resistivity levels will be performed at the point of use with polishing units provided and maintained by the laboratory Users.

Water conductivity/resistivity shall be monitored with a tank wall mounted conductivity cell and transmitter for display at the master control panel user interface screen. Water conductivity/resistivity 10% above/below specified levels requires intervention to determine what sources of contamination exist. Offline testing for specific contaminants may be required.

Storage tank(s) shall be sized to store one day’s worth of estimated RODI water consumption. Tanks shall be configured to minimize development of bio-film and to aid in chemical sanitization of the system.

Distribution system configuration shall allow for the continuous flow of water in the piping by means of recirculation. Size pumps to provide full turbulent flow conditions throughout the distribution system with target flow velocity of 5 to 7 feet per second. Distribution pumps shall be duplexed and on VFD’s to allow for one to be taken off line with the other capable of providing the full circulation flow. Normally, both pumps shall run at reduced capacity to allow for run time of both pumps and prevent stagnant zones.

Perform detailed hydraulic calculations to assess supply pressure and flow requirements, losses through the system including pressure reducing valves for multi-story installations and (most importantly) pressures after back pressure valves to verify adequate pressures in return piping to avoid cavitation. Provide multiple zones or loops as required to control return line pressures.

Provide sampling valves at the storage tank and the return stream.

Provide “V” channels as part of RODI piping to prevent sagging.
Dead legs more than 6 pipe diameters (i.e. “6D”) are not allowed on RODI water services to lab benches or sinks.

Distribution polishing equipment shall include 185 nanometer ultraviolet lamp for disinfection and TOC reduction and duplex 0.1 micron final filters. Mixed bed deionization may be employed if determined that the serviced laboratories require a high level of resistivity.

In-line analytical devices on the return piping shall include at a minimum:

- Flow,
- Pressure before and after back pressure valve(s),
- Conductivity (resistivity),
- pH (temperature compensated),
- Temperature.

All or part of the return stream shall pass through a tank head mounted spray ball.

Include in the design provisions to collect and re-use RO reject water either within the building or in other buildings. Keep in mind DEP does not want RO reject waste to go directly to storm without constant water analysis and MWRA does not want clear water waste going directly to sanitary.

**11. EXECUTION**

1. Provide hot water systems balancing, balancing shall be performed by the approved Balancing Agency.

2. Provide disinfection of water systems

3. Provide disinfection and cleaning of purified water systems.

4. Provide 3rd party cross connection protection and approval.

5. Grooved joint piping systems shall be installed in accordance with the manufacturer's guidelines and recommendations. All grooved couplings, fittings, valves, and specialties shall be the products of a single manufacturer. Grooving tools shall be of the same manufacturer as the grooved components. The gasket style and elastomeric material (grade) shall be verified as suitable for the intended service as specified. Gaskets shall be molded and produced by the product manufacturer. Grooved end shall be clean and free from indentations, projections, and roll marks in the area from pipe end to groove for proper gasket sealing. A factory-trained field representative shall provide on-site training for contractor's field personnel in the proper use of grooving tools, verification of groove
and installation of grooved piping products. Factory-trained representative shall periodically review the product installation. Contractor shall remove and replace any improperly installed products.
APPENDIX A: SCHEMATICS
PLUMBING: WASTE WATER
MIT
Design Standards

DIVISION 23 — HVAC

May 2018
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I.  BUILDING STEAM PRV STATION MECHANICAL LAYOUT
1. **MIT HVAC SYSTEM GOALS**

HVAC system design and equipment selection should presume an operating life of 40 years. In cases where access is difficult, longer lasting equipment is appropriate.

Equipment location and housing should provide easy access for maintenance, repair, replacement and day-to-day operations.

As an institute of technology, MIT is particularly receptive to HVAC design innovations which reduce cost and maintenance and improve safety and sustainability.

HVAC designs and installations at MIT should provide an acceptable level of air quality and comfort, minimize energy use, and be manufactured of materials that are safe for the environment.

It is not the intent of these design standards to limit designs or creativity, but to provide guidance for consultants and contractors to follow, and to stimulate discussions, questions, and exchange of information.

The requirements for new building systems versus renovations in existing building systems may vary significantly. To reduce economic and practical inefficiencies associated with renovations, in many instances, MIT has undertaken long term master planning which may include provisions to prioritize certain HVAC systems and building components. Therefore, design teams should always review project requirements to determine whether such priorities for expansion provisions exist. Systems presented in this document are suggested and should be tailored to meet specific project requirements.

### 1.1 List of Common HVAC Design Issues

1. Verify coordination with Architecture, Structure, and among HVAC, Plumbing, Fire Protection, Fire Alarm and Electrical disciplines including the following. (This list is not prioritized):
   
   a. Confirm that systems will fit and provide appropriate capacities.
   b. Confirm that make-up water is supplied to humidifiers, cooling towers, closed systems, and similar systems.
   c. Confirm that electrical power is supplied to HVAC equipment that requires power including:
      
      1) Appropriate electrical power voltage and phase are supplied and listed correctly in HVAC and electrical schedules.
      2) Disconnects are provided, fused or otherwise, as appropriate to HVAC equipment.
3) Emergency power or optional standby power as appropriate

d. Confirm that plumbing system components are supplied to HVAC equipment that requires plumbing including:

1) Appropriate plumbing devices are supplied and listed correctly in HVAC and plumbing schedules.
2) Appropriate drains are provided.
3) Make-up water connections where required.
4) Cooling coil condensate drains are directed to the storm system not sanitary drainage.
5) Gas service is provided where required.
6) Auxiliary contacts are supplied for MIT Building Automation Systems control interfaces.

2. Verify that all project consultants (not only other MEP consultants) have reviewed project documents, have submitted comments, and have received responses to their comments, including architecture, interiors, acoustics, building code, kitchen consultants, sustainability and energy consultants, commissioning agents, and structural engineers.

3. Provide a complete code review confirming all required provisions required by code including, but not limited to:

a. Fire dampers, smoke dampers, smoke detectors, etc.
b. Hi-rise/smoke proof enclosures.
c. Elevator and stairwell pressurization.
d. Atria including requirements for exhausting atria.
e. Electrical rooms including any ductwork or piping conflicts.
f. Hazardous Exhaust (Fume Hoods) including:

   1) Ducts must remain inside defined fire zone or laboratory unit.
   2) A fire-rated dedicated shaft to roof is provided.

g. Sprinklers are provided above CPVC ducts and at tops of duct shafts. No sprinkler heads may be provided inside fume hood exhaust ductwork.
h. Grease/commercial kitchen exhaust.
i. Laundry facility dryer exhaust (dormitories).
j. Ventilation.
k. Energy Code and if applicable, the Stretch Energy Code.
l. Elevator cooling and venting.

4. Undertake a complete review of engineering calculations and assumptions including the following and Required Engineering Documents in Division 01 – General Requirements:

a. Outside air/ventilation.
b. Steam.
c. Chilled water.
d. Power demand.
e. Campus medium temperature hot water demand (if applicable)

5. Review MEP space layouts and service access including:
   a. Shaft space.
   b. Mechanical/electrical rooms and penthouses.
   c. Areas with large ductwork.
   d. Public spaces.
   e. Ceiling spaces and wall cavities.
   f. IS&T rooms including space necessary to locate cooling equipment outside but adjacent to the room.
   g. Service and Code mandated clearances.
   h. Valve, damper, cleanout access.
   i. Provide guardrails or enclosures around equipment and paths with proper fall restraint to equipment when 4 feet or more above roof decks or when roof decks as a whole do not meet OSHA fall protection with parapet walls or perimeter rail systems.

6. Undertake a complete review of control sequences required for new equipment including:
   a. “Safeties” including freeze protection.
   b. Smoke control and smoke evacuation.
   c. Fume hood exhaust sequences for air side balance.
   d. Smoke dampers and actuation including integration with fire alarm systems.
   e. Interface with MIT Building Automation Systems.
   f. Alarm points.
   g. Interface with pneumatic and electric actuation. Use pneumatic actuation only where absolutely necessary because of harsh environments, (proximity to very hot steam piping) speed of response (fast opening or closing) or force requirements.

7. Undertake a complete review of riser and flow diagrams including:
   a. Air flow diagrams.
   b. Chilled water system.
   c. Steam systems and hot water systems flow diagrams and valve locations.
   d. Focus on known problem areas such as chilled water pumps.

8. Verify new equipment is accessible and provides adequate clearance for maintenance. This includes drains, power supplies, and all components which must be accessed for preventive maintenance or repair. If lifts are required for maintenance there must be a clear pathway to
move them into position and a flat location available so they can be deployed for maintenance. In some cases hoisting beams may be required within air handlers or mounted to structure above other equipment to allow for the use of chainfalls. In some cases hatches may be necessary to remove and replace equipment if no other access is available.

9. Verify utilities and infrastructure including:

a. Chilled water systems:

   1) Appropriate building pump station capacity and differential pressure are available. See section 3.4 for additional guidance.
   2) Appropriate pump operation schedule and sequence.
   3) Differential pressure without pumps. Evaluate possible energy savings and opportunities to improve system operation.
   4) Confirm a check valve bypass assembly is between the suction and discharge sides of automated pump stations.

b. Steam systems:

   1) Be certain that year-round steam sources are available for hot water reheat systems and central station air handling systems.
   2) Confirm operating pressures and temperatures.
   3) Building perimeter steam heating systems may be low cycled off above a certain outdoor temperature.

c. Heating hot water systems:

   1) Operating temperatures including reset schedules based on outside temperature.
   2) Operating schedules.
   3) Capacities.

d. Ventilation systems:

   1) Operating schedules.
   2) Capacities for expansion.

e. Fume hood supply and exhaust air handling systems:

   1) Fume hood types and requirements.
   2) Capacities for expansion.

f. Compressed air system for temperature controls:

   1) Operating pressure.
2) Capacity.

10. Undertake a complete review of compliance and design within MIT departments including:
   a. Equipment will be appropriately labeled and nomenclature conforms to MIT standards including:
      1) Pipe and duct identification.
      2) Equipment identification.
      3) Valve tags.
   c. Central utilities (see Division 33000 for additional guidance.
      1) Utility operations.
      2) Utility metering (includes building level consumption of power, chilled water, campus steam, and campus heating hot water).
   d. SEMO and insurance underwriter.
   e. The Industrial Hygiene Office within EHS.
   f. Repair and Maintenance or CSG as appropriate.
   g. Facility Information Systems.
   h. Department, Lab, or Center client team.

2. DESIGN REVIEW REQUIREMENTS

The Design Consultant is responsible for filling out, signing, and submitting this information at each phase of design as a guide for review by MIT Facilities. The following sections outline the items which are expected to be submitted at each phase of the design process.

2.1 Schematic Design (SD) Phase

1. Review of applicable codes, regulations, and standards.
2. Identify major equipment.
3. Identify space requirements.
4. System descriptions (Basis of Design).
5. Alternative design concepts.
6. Outline specifications.
7. Equipment cut sheets.
8. Statement of probable costs (vendor assistance may be required).
9. Submit preliminary calculations for:
   a. Cooling loads.
b. Heating loads.
c. Ventilation loads.
d. Air system pressure drop and flow.
e. Chilled water and steam.
f. Hydronic system pressure drop and flow.
g. Outside air.
h. Supply air.
i. Annual load profiles

10. Systems considered include:
   a. All air.
   b. Combination systems.
   c. Types of heating systems.
   d. Energy recovery options.
   e. Written narrative of systems proposed.

11. Obtain approval of design comfort level (heating and cooling operating standards) from MIT Systems Engineer.

12. Energy Analysis: A thorough energy analysis of the complete HVAC system including associated electricity, chilled water, and steam utilities is required for all projects. For large capital projects and major renovations MIT retains a specialty consultant to study sustainability and energy performance. For smaller scale projects the MEP Design Engineer is expected to use MIT’s “Energy and Emissions Impact Calculator” to estimate the net change in energy and GHG performance. See “Sustainability “ thematic folder elsewhere in the Standards. System recommendations must be submitted to MIT and their Energy/Sustainability consultants for review prior to design development drawings.

13. The ventilation air change rate and other aspects of the ventilation system must be reviewed with MIT Systems Engineer, Project Management, and EHS during the design phase.

2.2 Design Development (DD) Phase

1. Finalize system selection.
2. Equipment schedules and sizes.
3. Agree on basis of design and acceptable manufacturers.
4. Finalize space requirements, architectural and related building systems coordination including:
   a. Major shaft sizes and locations.
   b. Louver sizes and locations.
   c. Mechanical room block layouts and services.
5. Flow diagrams of major systems including quantities and pipe sizes.
6. Control descriptions including diagrams.
7. Verification of energy code compliance.
8. Bound copy of updated engineering calculations.
9. Bound copy of specifications unless otherwise indicated in Division 01.

### 2.3 90% Construction Documents and Construction Documents (CD) Phase

1. General:
   a. List of changes and deviations from Design Development.
   b. Drawing List and Specifications Table of Contents.
   c. Drawings coordinated with project specifications.
   d. Drawings marked for Progress, GMP, Bid or Construction.
   e. Final drawings (prints) sealed and embossed per State requirements.
   f. All HVAC components shown on the drawings.
   g. Existing and new work clearly labeled.

2. Calculations:
   a. Complete calculations for pumps, fans etc. including the following:
      1. Flow rates, pressures, and consumption rates.
      2. Pressure drop calculations which align with pipe and ductwork sizes and fittings indicated on the floor plans. Include pressure drop for control valves, isolation valves, dampers, louvers, equipment and similar items as indicated on the schedules.
      3. Marked up floor plans associated with the pressure drop calculations included as a diagram.
   b. Cooling and heating load calculations associated with scheduled equipment.
   c. Pipe expansion and anchor load calculations.

3. Flow Diagrams:
   a. Diagrams depict engineering of the HVAC system.
   b. Arrangement of equipment is similar to actual conditions in a schematic format.
   c. All major equipment shown, identified and coordinated with scheduled sheets.

2. Floor Plans:
   a. Ductwork and piping sizes as well as fittings indicated on plans which align with pressure drop calculations.
   b. Control valves and major isolation valves indicated on plans.
   c. HVAC drawings for complete chilled water, steam or hot water systems to HVAC equipment.
   d. HVAC drawings for complete ductwork system drawings including supply, exhaust, return, and specialty exhaust from the distribution point to the air entry/exit point.
e. All areas heated, ventilated or air conditioned as required.

f. Supply, return and exhaust air balance.

g. Location of thermostats, humidistats, duct smoke detectors, CO₂ sensors and firestats.

h. Access provided where needed including:

1) Controls (including all field devices such as air flow measuring stations, etc)
2) Coils.
3) Fans.
4) Dampers.
5) Valves.
6) Filters.
7) Cleanouts.

d. Heat trace is indicated where necessary and coordinated with electrical drawings. In some applications optional standby power may be appropriate. Critical heat trace applications must be alarmed for loss of power and low temperature.

e. Labels indicated on all ductwork, piping, equipment etc.

f. Confirmation that pipes will fit into the available space and do not interfere with ducts, lights, or structural members. Take into account any piping that is required to be sloped for coordination with other trades. Coordination should include runouts to room terminal units. Routing to conform to accepted design practices.

g. Piping system to have adequate expansion loops and anchors. Locations and sizes should be detailed on plans.

h. Confirmation that ductwork will fit into the available space and does not interfere with piping, lights, or structural members. Routing to conform to accepted design practices and minimize system pressure drop. Space coordination should also account for any duct sloping requirements (grease exhaust etc.).

i. Architectural door schedule coordinated with the HVAC plans. Door schedule to indicate doors requiring ventilation openings with adequate undercut or louvered free area. If doors do not have undercuts/louvers transfer ducts should be provided as needed.

j. HVAC drawings to include all room names and numbers and column numbers.

k. Air outlets are indicated and do not interfere with lights or other devices.

l. Coordination of headroom available for ceiling hung units such as unit heaters with architectural plans.

m. Airflows show room by room balance and room totals against flow shown on air handling units and fans.

n. Fire dampers, smoke dampers, and fire-smoke dampers clearly shown in accordance with relevant codes and ordinances, floor-by-floor where required. Access doors are provided.

o. Sound traps have been provided to meet required sound attenuation as required to meet the project acoustical requirements.
p. Volume dampers located.

3. Mechanical Equipment Rooms Plans:
   a. Equipment locations and layout allows for access and maintenance, coil removal, heat
      exchanger (steam-water converters) tube bundle pulls, damper, valves, controls, future
      equipment replacement etc.
   b. Floor drain locations are coordinated with plumbing plans for coils and plenums.
   c. Pumps:
      1) Drains and vents are properly located.
      2) Flexible connections, vibration isolation, and sound isolation connections are
         indicated where needed (expansion joints, equipment on isolators).
   d. Piping unions at unit, thermometer wells, pressure gauges, trap drainage, and traps on
      cooling coil condensate drains.
   e. Outside air intake and exhaust opening sizes including:
      1) Proper velocity to prevent snow carryover.
      2) Height above ground and recessed from building wall to prevent snow
         intrusion.
      3) Plenums should be drained.
   f. Building service connections coordinate with HVAC equipment.
   g. Freeze protection has been provided for cooling coils, cooling tower sump, etc.
   h. Adequate combustion air openings have been provided for boiler rooms, boilers, hot
      water heaters and other fuel burning equipment.
   i. Flue sizes and heights are properly sized for adequate draft and suitable discharge
      considering the effect of adjacent building.
   j. Insulate ductwork between fans and condensate areas.
   k. Ceiling clearances in adjacent areas have been coordinated with the architect for duct
      connection between mechanical rooms and floors served.
   l. Provide at least one section of each mechanical room.
   m. Control dampers are indicated on plans.
   n. Mechanical rooms are properly ventilated.

4. Schedules:
   a. Schedules to be project specific. Notes provided on schedules should align with
      information in project specifications.
   b. Electrical data is complete and coordinated with electrical department and electrical
      engineering including coordination of all emergency and standby power requirements.
   c. All equipment is scheduled, properly labeled and coordinated with the floor plans.
   d. Scheduled data for major equipment including AHUs, pumps, chillers, expansion
      tanks, etc. align with the load calculations and static pressure calculations.
e. Verify equipment pressure ratings are adequate for the static height of each building.

f. Acoustical information provided for review by an acoustical consultant. Acoustical review should be completed prior to CD issue.

g. Air devices selected for appropriate airflow, pressure drop, noise level, throw and neck velocity.

5. Standard Details:

a. Provide details that only apply to each specific project.

b. Provide details which are customized for each specific project.

c. Provide custom AHU are details with components, dimensions, plans, and elevations.

d. Details to be properly cross referenced on detail sheet and plans.

e. Equipment hook-ups to be detailed but not dimensioned.

6. Controls:

a. Confirm electrical control requirements coordinated with other departments and disciplines.

b. Confirm equipment is covered under a sequence of operation.

c. Confirm system operations for start-up, shutdown, summer, winter, and intermediate seasons.

d. Review needs of special equipment, dampers, heaters, and etc.

e. Review control points for adequate control and monitoring.

f. Confirm control points are defined and adjustable.

2.4 Shop Drawing Phase

Ensure that shop drawing submittals comply with all aspects of the contract documents; note in writing any deviations for discussion with MIT or provide written certification that shop drawing submittals are compliant.

2.5 Record Drawing Phase

Record drawings must be high-quality, easily-readable, produced by carefully and accurately revising the Contract Documents to show clearly deviations from the original Contract Drawings, precise location of each item of work, and field changes. Record Drawings must be submitted to and approved by MIT as a prerequisite to final payment. Please refer to the thematic folder “BIM/CAD Standards” elsewhere in the MIT Design Standards.
3. HVAC SYSTEMS DESIGN STRATEGIES

3.1 MIT Facilities Drawings and Standard Details

MIT CAD Documents
MIT may have CAD documents, depending on the project location and scope, of facility related information and standard details, which may be of value to the designer for integration into project Construction Documents. To determine the availability of these documents, contact MIT’s Facility Information Systems (FIS) group through the MIT Project Manager. The designer shall be responsible for determining the usability and appropriateness of MIT documents to a particular project.

3.2 MEP Equipment Naming Standards

Design drawings should include equipment designations in their schedules and plan views which are unique and do not duplicate existing equipment. Contact the MIT Systems Engineering Group to determine which equipment names are available.

Equipment names should conform to the following standard:
XXX_XXXXXXX

Examples:
Building 76, Air Handling Unit 12A would be:
M76_AHU12A

Buildings which have no letter prefix assigned in the MIT naming convention (Buildings 1, 2, 3, etc.) will be preceded with an “M”.

Building E17, Chilled Water Pump 2 would be:
E17_CHWPMP02

Note that system, equipment, and number are combined as one text string.
The following is the standardized list of system, equipment, and other abbreviations:

<table>
<thead>
<tr>
<th>System/Equipment Description</th>
<th>Abbreviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Handling Unit</td>
<td>AHU</td>
</tr>
<tr>
<td>Exhaust Air Handling Unit</td>
<td>EAHU</td>
</tr>
<tr>
<td>Exhaust Fan</td>
<td>EF</td>
</tr>
<tr>
<td>Return Fan</td>
<td>RF</td>
</tr>
<tr>
<td>Pump</td>
<td>PMP</td>
</tr>
<tr>
<td>Air Cooled Condensing Unit</td>
<td>ACCU</td>
</tr>
<tr>
<td>Heat Exchanger</td>
<td>HX</td>
</tr>
<tr>
<td>Heating Converter (shell and tube)</td>
<td>CV</td>
</tr>
<tr>
<td>Chilled Water</td>
<td>CHW</td>
</tr>
</tbody>
</table>
Process Chilled Cooling Water PCHW
Hot Water HW
Condenser Water CND
Domestic Hot Water DHW
Domestic Cold Water DCW
Supply S
Return R
Temperature TEMP
Pressure PRESS
Flow FLOW

For example, Domestic Hot Water Return Temperature in Building 2 would be:
M02_DHWRETEMP

3.3 Design Criteria for HVAC Systems

Temperature Standards
Basic comfort temperature standards are 70 deg F for heating and 74 deg F for cooling. Specific uses and applications may require different comfort guidelines. Proposed design temperature and humidity must be agreed upon by the project design team early in the design phase.

Critical Environments:

When designing air systems for critical environments, (such as vivaria, and other places where stable controlled humidity is critical) follow ASHRAE 99.6% guidelines or better for outdoor heating conditions and 0.4% or better dehumidification peak loads - 0.4% dehumidification dewpoint with mean coincident drybulb (MCDB) condition.

1. Heating:
   a. Outside Temperature: 8 deg F

2. Cooling:
   a. Outside Dewpoint Temperature: 73 deg F.
   b. Outside MCDB Temperature: 81 deg F.

Typical Environments:

For typical office environments, follow ASHRAE 99.0% guidelines or better for outdoor heating conditions and 1% or better dehumidification peak loads - 1% dehumidification dewpoint with Mean Coincident Dry Bulb (MCDB) condition.
1. Heating:
   a. Outside Temperature: 13 deg F.

2. Cooling:
   a. Outside Dewpoint Temperature: 72 deg F.
   b. Outside MCDB Temperature: 79 deg F.

**Campus Chilled Water**

Design around a winter peak chilled water supply temperature of 50 deg F. During summer, the CUP will strive to deliver chilled water at 42 deg F utilizing mechanical cooling. The following wet bulb and dry bulb conditions are the control points utilized for chilled water reset:

<table>
<thead>
<tr>
<th>Wet Bulb</th>
<th>Outside Air Temperature</th>
<th>Chilled Water Supply Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 42 F</td>
<td>Does not control</td>
<td>50 F or less</td>
</tr>
<tr>
<td>42 F to 55 F</td>
<td>Does not control</td>
<td>45 F or less</td>
</tr>
<tr>
<td>Above 55 F OR</td>
<td>Higher than 70 F</td>
<td>42 F or less</td>
</tr>
</tbody>
</table>

For critical applications, use a summer chilled water design supply temperature of 43 deg F or higher.

**Ventilation Air**

Ventilation rates should be maintained within acceptable parameters established by ASHRAE 62.1 and building codes. For dense occupancies within office environments (conference rooms, meeting rooms) space CO2 sensing and VAV box override may be an effective control strategy. For laboratory applications, refer to section 3.12 below.

**3.4 Design Strategies for Areas without Active Mechanical Ventilation Systems**

There are a number of buildings and areas on campus without active ventilation systems. Some systems have older, inoperable components, both moving and static; other areas were never provided with mechanical ventilation systems because they were not required.

1. Recommendations:
   a. A workable approach for renovating spaces without active ventilation has been to install new systems which draw in a constant amount of outside air and distribute that air to renovated areas. This arrangement allows future projects to provide the outdoor air component from a new central source.
   b. Spaces with operable windows no longer technically comply with code ventilation
requirements without mechanical ventilation systems. Installing small total heat recovery ventilators has been an effective strategy for specific locations.

2. Often when a ventilation system is included for this reason, it is extended to serve the windowed spaces also. Types of spaces that can be accommodated by the strategy above include:

   a. High occupant density areas such as classrooms, lecture halls, conference rooms.
   b. Laboratories which require make-up ventilation because of specialized exhaust requirements.

3.5 Design Strategies for Chilled Water Piping Systems

There are many various arrangements of chilled water systems within MIT buildings depending on the area of campus and the vintage of the chilled water system including the following variations:

1. No pumps (Building E14 as an example).
2. One or more pumps and no check valve bypass (Buildings 3, 5, and 10 for example).
3. One or more pumps and a check valve bypass (E60, Building 13 for example).
4. Pumps, when present, are usually controlled to make a constant differential pressure available from pump discharge to building return (across the building loads).
5. Some pumps in a multiple pump station may be constant speed “backup” pumps intended to only run during repairs to the controlled pump(s).
6. Some buildings, especially on the East Campus, may only have control valves at the building entrance which are controlled to make a constant differential pressure available for the building loads.
7. Some buildings have control valves at the building entrance and pumps to boost differential when necessary. These are a product of history and the control valves are not operable in some cases (Building 37 for example) or they may still be part of the published sequence of pressure control in the building (Building 35 for example). Whether they are truly active or not should be challenged.

Many buildings on campus have chilled water pumping stations with two or three pumps. These pumps are in parallel with each other and in series with plant pumps. These pumps may also be in parallel with other pumping stations in the same building that provide service to other buildings (Building 13 for example). If a pump station is required to provide differential to a campus building, the station must include a bypass line from suction to discharge with a check valve. This allows water to flow past the pump station when there is adequate differential for the building with the pumps off. Without this bypass, the water must flow through the pump body which causes a loss of available differential pressure. Also, when transitioning to pump minimum speed (15 hz), there is a large increase in the differential available to the building as the pumps go from being a restriction to assisting with flow.
If chilled water pumps are required, they must be fitted with VFD’s for controllability. The campus chilled water distribution system at times can have low differential as a result of heavy demand. Building pumps can adversely affect campus return pressures if operated inappropriately or not equipped with check valve bypasses. Campus practice has been to enable the building pumps, only when absolutely necessary, to provide adequate differential for the building load. This must be accomplished by using the balancing process to measure the actual differential required at the point of differential pressure sensing to achieve design flow through the building. Buildings which are closer to the chilled water plant will have a higher differential pressure available than those buildings which are further away. When designing a chilled water distribution system for an existing or new building verify with MIT Systems Engineer and the Utilities Group if there is a true need for a building pumping station at the project location. It is important to make this determination early in the design process, preferably before schematic design is started.

Most loads on the chilled water system can be adequately served by the differential available from the central plant and additional pumps are unnecessary. Always design new systems with low pressure drop in mind.

Whenever a secondary loop is used (either with a heat exchanger or a bleed-in valve and recirc pump) it is beneficial to elevate the loop temperature as much as practically possible. This increases the return water temperature to the CUP and helps campus delta T. Applications include process cooling, chilled beams and valence units. Future consideration should be given to fan coil and air handler circuits.

Generally, chilled water distribution piping within buildings shall be sized for an average pressure drop of 1.5 feet of head per 100 feet of pipe. Where applicable, design and size the piping distribution systems with consideration for future expansion.

Properly selected pressure independent flow control valves with fixed upper limits shall be used to prevent excess flow during times of strong or rapidly increasing pressure differentials. As a result, these valves keep the whole building delta T from being eroded by excess flow through coils and heat exchangers. Use of this valve type shall be reviewed with the MIT Systems Engineer. This type of valve eliminates the need for balancing valve at the individual piece of equipment, as manufacturer’s literature advises against using a separate balancing valve with these products.

Typically, strainers shall be provided at water pumps. Do not provide strainers at terminal equipment.

Automatic air vents can be beneficial for system start-up. The installation must include an isolation ball valve and contractors must be instructed to close the isolation valve after system start-up. The auto air vent should be installed at an elbow and the piping extended to a fitting “looking down” with a hose bib and chained cap. The cap shall be heavy brass rated for 75 psig.

At start-up (during cleaning and flushing) systems shall be filled using city water. Thereafter, closed and independent piping systems requiring make-up water typically shall be designed to have water made up automatically from the chilled water distribution system, which in turn is made up at the
CUP. This avoids the need for an additional building back flow preventer and the associated testing and maintenance.

### 3.6 Design Strategies for Steam and Hot Water Systems

MIT does not use steam as the perimeter heating medium for newer buildings due to limited controllability. For new buildings or fully renovated buildings, hot water heating systems are used as the heating distribution in the building, including the AHU’s. Steam should be used at AHU’s only in small renovations and replacement in kind projects. Other process loads such as autoclaves always require steam. The type of system to be provided should be reviewed with the MIT Systems Engineer early in the design. Hot water heating systems should be selected at the lowest temperature possible, and enabled to operate at the lowest temperature necessary based on outdoor air temperature. We have been able to reduce the peak design heating water temperature to 140 degrees F in recent projects.

Many older buildings at MIT have existing low pressure perimeter steam heating systems which are cycled on and off throughout the heating season. Where perimeter radiation lacks control, it is the strategy of MIT to provide DDC control or self-contained control valves. Where possible, shut off valves on steam supply and return lines to radiators, within renovation area, should be provided for routine maintenance and to avoid building wide shut downs. For larger renovation projects, we strongly prefer removing the perimeter steam heating system and replacing it with a hot water system. The long range strategy of MIT is to replace perimeter steam systems with hot water systems.

Campus steam distribution supply pressures to buildings are either 200 psig or 60 psig. At times of high load, these distribution pressures can be lower at the building entrance due to system losses. Please discuss your requirements with the Systems Engineering Group (SEG).

When connecting to these steam systems for renovations which might include air handling units, year round hot water reheat systems, or domestic hot water heaters, a firm (year round) steam source must be confirmed early in the design process. Review the requirements for steam with the MIT Systems Engineer. Provide pressure reducing stations and specialties per the MIT standards.

Steam supply to heating coils for air handling units shall not be tied into perimeter house steam heating system which may cycle on and off during the heating season. Check with MIT personnel and connect to year round steam source. Provide pressure reducing station as required. Steam pressure to coils shall be minimum 10 psig.

Determine whether condensate return system within the building is or shall be a wet return, dry return or vacuum return system. Use the appropriate steam coil detail for wet / dry or vacuum return. Verify that the vacuum return has proper water seal or equalizing line and eliminate vacuum breaker.

In condensate return systems, do not specify or detail bypass piping and valves to bypass flow around steam traps. These bypasses are not necessary. They can only result in unregulated steam flow into the condensate system, where it can damage traps, condensate pumps, and other building components.
Condensate pumps, where required, should be sized to overcome system back pressures. Review required discharge pressure with the MIT Systems Engineer and perform an Engineering study as required. It is preferred to pump to existing vented large receivers on campus where possible.

There is an existing medium temperature hot water (MTHW) circuit on campus which originates in NW14 and serves a few buildings nearby. In the future, additional heating hot water circuits may be available from the CUP as additional heat is scavenged from the gas turbine flue gas and supply/return lines are extended into additional campus areas. This source may be available for building heat as well as domestic hot water production. In winter the projected supply temperature is 200°F and building heat exchange equipment should be selected to provide a 170°F return water temperature. We expect that the lowest temperature for this system (summer) is likely to be 180°F, with the system designed for a 30 degree delta T. It is therefore desirable to design hydronic heating systems and domestic hot water systems which can provide summer design capacity with 180 deg. F supply water and return water to the plant at 150°F. The building heat exchangers and associated primary piping must be designed to tolerate temperatures as high as 230°F. These parameters are also valid for connection to the existing campus MTHW system.

Typically, strainers shall be provided at water pumps. Do not provide strainers at terminal equipment.

If hot water heating coils are used in a 100% outside air application (i.e. heat recovery preheat coils) they must be served with glycol protected water. Hot water heating coils in mixed air systems must have a local circulating pump and check valve in the bypass between coil supply and return. This pump must run when the outside air temperature is 35 or lower to protect the coil from freezing by assuring flow and even distribution through the coil. A 2-way modulating valve can be used to return water to the heating plant downstream from the branch that connects to the pumped bypass. If the pump is commanded to run by the BMS systems or the outside air temp is below 35 and the pump status is “off” then the entire air handling unit shall trip off and dampers /valves will go to the same positions as they would if the hard wired freeze stat had tripped.

3.7 Design Strategies for Air Handling Units

The entire air handling system, including without limitation, air handlers, ductwork, coils, filters and other components must be designed for appropriate static pressures, optimum operating efficiency, and other considerations.

The merits of heat recovery shall be considered for 100 percent outdoor air applications and where required by Code. These shall be carefully studied and reviewed with MIT facilities staff. See section on “Strategies for Heat Recovery” below in this document.

Housekeeping pads for AHU’s shall be designed with adequate height to accommodate a correctly sized P trap considering the maximum anticipated operating static pressure of the drain pan section. Maximum filter loading must be considered for draw-through units.
When belt driven fans are used, fixed pitched sheaves shall be installed. Adjustable pitch shall be used at start-up only, then replaced with fixed pitch. Provide multiple belt-type sheaves.

Direct drive fans are preferred for most (non lab exhaust) applications on campus. Individual drives shall be provided for each fan motor See Division 26 for additional guidance on approved VFD manufacturers and harmonic mitigation strategies.

Carefully design the entire air handler to meet the project’s noise and vibration requirements. The unit shall have a vibration analysis performed at the factory and any corrective action shall be taken as necessary to meet project requirements.

Vertical or horizontal steam coils with integral face and bypass dampers may be used. For variable air volume systems allow increased distance between these heating coils and cooling coils to allow for full mixing of bypass air and heated air during low turndown. During lower airflows, air may still be destratified causing nuisance tripping by freeze-stat mounted on face of cooling coil. In these cases, provide turbulators or mixing baffles down stream of steam coils to increase mixing.

A spacer section must be provided between steam preheat coil and cooling coils for service access, installation of freeze stats and proper mixing of air before cooling coil. Provide an access door on both sides if possible.

When designing 100% outside air system for ventilation only with steam heat (typically lab ventilation), use vertically oriented steam coil tubes with integral face and bypass control. The engineer must specify manufacturers that accept the use of modulating steam valves with their equipment (Control Air and AeroFin are examples of this. Wing does not warranty installations with modulating valves and recommends against it) . Integrated face and bypass assemblies must be fitted with mixing baffles and a perforated mesh screen downstream of the coil/damper assembly to enhance mixing.

For mixed air systems when steam is the appropriate heating medium a full face steam heating coil can provide some level of freeze protection for a chilled water coil located downstream. However, malfunctioning steam traps can put both coils at risk of freezing. Vertical tube orientation is generally better than horizontal, but in some AHU configurations this is not possible. If a full face heating coil is necessary, the best freeze protection for both coils is to use a glycol protected hydronic heating loop with adequate distance between heating and cooling coils.

If air handling units are on emergency power, the glycol circulating system and heating source must also be supported by emergency generators. The current practice in Facilities (circa 2016) is that ethylene glycol is the appropriate freeze protection additive. Pay attention to and design for the heat transfer penalty and pump de-rating imposed by using a glycol solution.

100% outside air units which utilize hot water heating coils shall be served by glycol protected water and the design must include circulating pumps for good heat transfer and even coil temperature
distribution. These preheat coil circulating pumps are generally only required to run if the outside air temperature is above 40 F.

100% outside air units with heat wheels and hot water coils and all other hot water heating coils in air handlers must have a local circulating pump and check valve in the bypass between coil supply and return. This pump must run when the outside air temperature (OAT) is lower than 40 degrees F to protect the coil from freezing by assuring flow. It also establishes even distribution through the coil under low load to prevent stratification. A 2-way modulating valve can be used to return water to the heating system downstream from the branch that connects to the pumped bypass. Once the valve has been signaled to greater than a 60% open value, the pump shall be commanded off. If the valve modulates below 50% (and the OAT remains below 40 degrees F), the pump shall be commanded on until the OAT rises to 40. If the pump is commanded to run by the BMS system and the pump status is "off" then an alarm shall be generated. Chilled water cooling coils shall be sized for five foot maximum pressure drop and 16 deg. F water temperature rise. Multiple coils shall be used as required. Campus chilled supply water temperatures are 42 deg. F summer, 50 deg. F winter. See section 3.2 for more detail on the transition from free cooling to mechanical cooling.

Cooling coil connections must be detailed so that coils can be drained and winterized by the following procedure:

1. Close isolation valves.
2. Open vent.
3. Open drain and drain chilled water.
4. Connect barrel of glycol/water solution to coil and circulate solution through coil from bottom to top, returning solution to barrel.
5. Stop pump.
6. Disconnect upper connection and leave connection open.
7. Allow water to drain back to barrel by gravity.
8. Connect compressed air line to top coil connection and blow remaining residue back to barrel.
9. Disconnect compressed air hose and barrel drain line.
10. Leave upper and lower valves for vents and drains open during winter operation. Residual solution at low points in coil will help protect the tubes from freezing.

Humidification is typically not included. See section elsewhere “Design Strategies for Humidification”.

Filters may be provided in various locations within air handlers for differing reasons.

ASHRAE Standard 52.2, “Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size” (ASHRAE, 2007) provides complex testing and rating procedures for filters. Test results are reported as the minimum efficiency reporting value (MERV) in 20 grades grouped into four categories. Tested filters are referred to by MERV number, MERV 1 being the least efficient.
Fresh air intakes should have adequate filtration to protect the downstream coils and equipment from heavy particulates in the outdoor air. This is often accomplished with a 2 stage filter bank consisting of MERV 8 and MERV 13 filters in series. Provide access doors on both sides of casing unless the filter compartment is a walk-in or the unit is small enough to be serviced from one side.

A V-bank arrangement should be used for pre-filters where space is available. This will increase filter surface area, decrease pressure drop, and increase filter life (250 feet per minute maximum recommended velocity). Final-filters shall have maximum velocity of 500 feet per minute.

When a heat wheel(s) or an energy recovery coil is in an AHU, the return air stream must be filtered to protect the wheel(s) or coil. These filters must meet or exceed the heat wheel manufacturer’s recommendations. MERV 8 would be typical.

Requirements for sprinklers and smoke detection within the units must be carefully examined and coordinated to meet MIT requirements. Dry sprinkler systems in the filter section and VESDA detection systems are often required.

Condensate drains shall be piped to clear water drains, storm or grade to meet MWRA requirements.

### 3.8 Design Strategies for Airside Heat Recovery

**Air to Air Energy Recovering Equipment**

The following systems are considered in general, however, the list below should not be restrictive. The design team is encouraged to exceed minimum energy recovery effectiveness as required by code and submit new concepts for MIT project teams and EHS for consideration:

**Run Around Loops**

MIT has decades of experience with glycol run-around heat recovery loops in laboratory systems. These systems have the desirable feature in lab applications of having no risk of air side cross-contamination. The energy penalties include the pump energy and pressure drop across the coils. The coils must be constructed to suit the environment and operating conditions to which they are exposed. The effects of condensable and corrosives may require specialized materials or coatings. MIT Facilities and EHS consultation is needed for construction materials and coatings.

**Heat Wheels**

To allow maximum heat recovery potential, heat wheels should be installed before a cooling coil in the air-handling system and installed in a “blow through” mode, i.e., the supply fan blows air through the heat wheel and the return fan draws through the heat wheel. This allows any air leakage around the heat wheel to be only from uncontaminated supply air to the exhaust side. Heat wheels can be successfully applied to 100% outside air systems and the ventilation component of economizer
systems, but only where the exhaust stream is not contaminated or hazardous. Fume hood exhaust is not acceptable for heat wheel recovery.

A heat wheel is a rotating mechanical piece of equipment, which means components such as the electric motor, wheel deflection, bearings, belt, and drives require careful selection and maintenance. The air seal design should be carefully evaluated to meet the design criteria. See “products” section for recommended manufacturers.

**Heat Pipes**

The heat-pipe heat-exchanger device, also called a thermosiphon, provides a full separation of exhaust and supply air stream. This is an approved concept at MIT for 100% outside air lab systems. Care must be taken that appropriate refrigerant is used in the heat pipe otherwise heat recovery potential is lost. The choice between “tilting” and “fixed coil” designs should be carefully considered.

An additional heat pipe application is a “wrap around” coil which has the chilled water coil between the two sections of refrigerant coils. This provides reheat downstream of the cooling coil by moving heat from upstream to downstream of the coil. The airside pressure penalty is present at all times, and should be considered in the design. Space needs to be made available between the refrigerant coils and the chilled water coils for maintenance and repair access. If there are active controls for the refrigerant coil they should be provided by the BMS vendor, not by the coil manufacturer. This also assures that the coil can be deactivated by the BMS when conditions are unfavorable.

**Static Plate Total Energy Recovery Heat Exchangers**

We are beginning to use heat exchangers with a corrugated resin core for office and general ventilation applications. The primary advantage of this device is the elimination of many moving parts and complexity of control required for heat wheels. Fume hood exhaust is not acceptable for static plate energy recovery.

**Chemical Regenerators**

This system consists of chemical spray headers installed in both supply and exhaust air streams. The chemical (the heat-transfer medium) is usually lithium bromide (LiBr). It is very maintenance intensive due to the corrosive nature of the chemical and is not recommended for MIT applications.

**3.9 Design Strategies for Air Intakes**

Outside air intakes must be located so as to avoid bringing contaminated air into the building air-supply systems. Examination of likely contaminant sources, such as air exhaust stacks, should be conducted before outside air intake locations are selected. The ANSI Z9.5 standard on laboratory ventilation recommends that a risk assessment of exhaust discharge location in relation to the air intake be conducted.
MIT prefers a minimum distance of 30 ft (9 m) from specialty exhaust discharge (including diesel generators, vacuum discharges, etc.) to air intakes (or greater if required by code) to reduce re-entry problems. It is good practice to design for the maximum feasible separation. The plumbing code requires a minimum of 25 feet of separation from air intakes to plumbing stack vents.

MIT has experienced that outside air intakes located at ground level are subject to contamination from automobile and truck fumes, whereas air intakes at roof level are susceptible to contamination from laboratory exhaust stacks or high stacks serving off-site facilities in the vicinity. Such design is to be avoided.

If a building contains more than 10 stories, A/E team should consider locating the air intakes at the midpoint of the building. In addition, the AHU entry should be separated from the building face by a horizontal distance of 10 feet or more. This will minimize snow buildup on the pre-filters and subsequent structural failure of the filter rack and/or unit trip on low static at fan suction.

Air intakes located at the face of a building shall be designed for a maximum velocity of 300 fpm.

When outside air intakes are in a “drywell”, A/E team shall ensure that the bottom of the air intakes are set at a minimum of 24 inches above the floor of the areaway.

For difficult project locations such as those surrounded by higher buildings A/E team should consider wind tunnel tests to investigate the fume reentry problem under simulated conditions. Alternatively, with permission of MIT PM and MIT EHS office, A/E team may use computer-modeling programs to assist in stack-discharge design and air-intake location. A/E team should perform this study for all new buildings constructed as well as those undergoing major renovations.

### 3.10 Design Strategies for Humidification

Typically, humidification is not provided for spaces at MIT. If humidification is required for specific program needs, do not use chemically treated CUP boiler steam directly for humidification. The types of spaces which may be humidified on campus include animal facilities, cleanrooms, archival storage of valuable cellulose-based materials (rare books and artworks), musical instrument storage, and certain art galleries.

Where humidification is required, create a clean steam source for the project by using CUP steam and a steam-to-steam heat exchanger. Certain applications may require that the clean steam is generated from purified water. Deionized water is very aggressive and should not be used for clean steam generation. For clean steam generation use RO water as the feedstock to the heat exchanger. In all cases pay special attention to the materials of construction in the system and the makeup water for the clean side of the heat exchanger. The heat exchanger must have appropriate materials of construction. Typically CuNi tube bundles and stainless steel shell heat exchanger construction is best when softened water is used as the feedstock. For applications using RO water only, a stainless tube bundle may be used as the CuNi is not required. Stainless steel piping is used as the piping material for the
feed to the steam dispersion tubes. Stainless steel ductwork should be used 2 feet upstream and 10 feet downstream of the dispersion tube. The stainless steel section shall be pitched to a drain located just downstream of the dispersion tube. The steam condensate piping which returns the condensate to the generator should be threaded stainless steel pipe.

Central systems are recommended for entire buildings or large laboratories. Special humidity control systems with additional dispersion tubes in duct branches may be needed for very precise humidity regulation within individual spaces. As these systems are costly, complex and difficult to maintain, the performance characteristics need to be carefully examined with the Project Manager and the representative of the Department, Lab or Center.

Typically, clean steam at atmospheric pressure is introduced directly into the air to be humidified. Duct-installed humidifiers need to be carefully designed to avoid condensation and carryover inside ducts. The persistent or intermittent presence of liquid water can initiate and sustain the growth of fungi and bacteria that degrade air quality. When condensation is persistent, water may drip from air outlets. The location of the dispersion tube is critical for optimum safe performance and effective maintenance. In addition to the manufacturers’ recommendations, the dispersion tubes must be installed so they can be easily accessed for removal and replacement without disturbing the lab or otherwise occupied space. EHS office review is needed for all installations.

Atomizing humidifiers introduce a fine mist of water directly into the air, where the water evaporates. The ability of air to evaporate all the mist depends on air temperature, air velocity, and entering RH. A major problem with water atomization is the potential risk of bacteria growth in the supply water reservoir and the nozzle itself. MIT does not accept atomizing humidifiers for these reasons.

A wet pad and fan system where air flow evaporates water from the pad is prohibited for several reasons including poor control and the potential for growth of fungi and bacteria. MIT does not accept wet pad systems for these reasons.

Small humidifiers installed in or near the occupied spaces may be able to provide humidification for small areas of application. Care must be taken in their selection and placement because uniform dispersion of water vapor is often difficult to achieve. The unit may discharge direct to the room or may have a duct mounted dispersion tube. In this application, MIT prefers the self-contained, wall mounted disposable cartridge style of unit.

### 3.11 Design Strategies for Air Handling System Zones

Air handling systems (supply and exhaust) should be zoned to serve areas of similar use and occupancy schedules where possible. If this is not possible, occupied/unoccupied VAV terminals should be provided to shut down areas not in use.

In new building designs, air handling systems and duct distribution should not cross building lines. Air handling systems shall be dedicated only to the building they serve.
Unfortunately, there are a number of areas on campus where air handling units serve more than one building and cross building demising walls. During system shut downs, this makes it very difficult to notify user groups in advance of shut downs due to the difficulty of defining all of the areas the unit serves. This results in a user group not being notified and a potential valuable loss of research time. In these areas, it is the strategy of MIT to separate building systems, utilities and services. These systems, which do cross building demising walls and are within the project renovation area and beyond, must be evaluated and reviewed with the MIT Systems Engineer. The systems should be separated by dedicating the air handling unit to one building only, and if necessary, adding an air handling unit and distribution system to the other building. In order to facilitate shutdowns and reduce complexity, the utility services to the AHU (power, steam, chilled water etc.) should come from the building it serves. Cost implications may limit the feasibility of this approach and design. Be aware that if an AHU is NOT located in the building is serves, the normal power service (per NEC) must come from the building it is located in on. This allows firefighting personnel to open the building’s normal power disconnect and be confident that all normal power in the building is de-energized.

For roof mounted equipment, provide guardrails or enclosures around the equipment including the path of travel to the equipment which will satisfy OSHA requirements unless high parapets are provided. Provide lighting and service outlets. Maintain proper clearances to permit space to service and replace equipment.

3.12 Design Strategies for Terminal Units

MIT believes that all “waste water” cooling units (units which use domestic water for condenser heat removal) have been eliminated from the campus. However, if a renovation project has a waste water unit, the unit should be removed and its capacity replaced as necessary with alternate equipment by the project.

Verify that adequate spare capacity is available when tying into existing heating, cooling, and process cooling systems.

MIT prefers fancoils with electrically commutated motors over chilled beams for most locations. All chilled beams require the creation of an additional recirculating piping loop and room humidity sensing to maintain the cooling loop temperature above the dewpoint of the space. This requires a separate building wide piping system with central pumps or many individual zone pumps and control valves. Fancoils don’t require any of this complexity. In addition active chilled beams require primary air in order to provide cooling to the space. Fancoils can be cycled off when cooling is no longer required during occupied hours and can be shut down during unoccupied times.

Where heating is required by fan coil units, design for a 4-pipe cooling and heating system. Use of two-pipe changeover systems will not be considered for new projects. Projects with small footprints in existing buildings with changeover systems may be permitted. See the project Systems Engineering Group (SEG) engineer for guidance.
Fan coils concealed above ceilings must be provided with a water-level detection device conforming to UL 508. The fan coil controls must be configured to shut off the equipment served in the event that the primary drain is blocked. The water-level detection device shall also generate an alarm to the building automation system. The water-level detection device shall be installed by the manufacturer in the primary drain pan, located at a point higher than the primary drain line connection and below the overflow rim of the pan. The design engineer must be sure any auxiliary components (such as transformers and fan relays) are properly coordinated with the BMS subcontractor specification.

Fan coils of all sizes shall have a switch lock bracket and MIT padlock to allow the switch to be locked in the on or off position; equal to Garvin Industries Item TOGLOK.

Low profile horizontal or vertical fan coil unit sizes can range from 200 to 1200 CFM. Unit sizes should be limited to 800 CFM nominal if possible, as 1200 cfm units are difficult to service due to their size.

Condensate drains shall be piped to clear water drains, storm or grade, to meet MWRA requirements.

### 3.13 Design Strategies for Laboratories

In laboratories, excellent air circulation and ventilation is needed to create the correct environment for research and for safety. Location of supply air relative to hazardous exhaust should be reviewed. Recirculation of laboratory air between lab units is not acceptable. Recirculating fan-coil units and induction units serving labs individually are acceptable. Air from offices, conference rooms, classrooms and similar spaces can and should be recirculated, and may be used for make-up air for lab exhaust and fume hoods. For all the topics addressed below, please also refer to the EHS Thematic Folder regarding Lab Design.

**Cooling Laboratory Areas**

Generally, it is the philosophy of MIT to provide for energy-efficient design. In laboratories where hood density is high the make-up air required for the fume hoods result in air change rates as high as 30 to 45 per hour. With a variable volume fume hood exhaust and lab supply air system, the turn down can be significant, resulting in reduced operating cost and installed cost since central systems can be down sized by diversity. In some cases, the minimum air flow at maximum turndown may result in insufficient cooling. Thermal override of minimum airflow is required in this case.

If a thermal override sequence would be required due to internal equipment loads (as described above), consider locating heat producing equipment outside of the ventilated lab if possible. Once removed from the ventilated lab, this load can be served by recirculating fan coils.
**Chemical Laboratories**

The volume of exhaust ventilation should be sufficient to minimize hazards at all times. During non-use, volume of air exhausted may be reduced for energy conservation but a user override must be provided to accommodate after-hours work. Typically, occupancy sensors (used to sense vacancy) would be preferred over a clock/schedule approach.

The volume of ventilation and ventilation systems proposed must be reviewed with the MIT Systems Engineer and MIT Industrial Hygiene Office (EHS-IHO) early in the design phase. Minimum design rates may range from 6 to 12 air changes per hour as a minimum. Labs may be operated at lower minimum rates at times as permitted by EHS. Coordinate special exhaust requirements including equipment enclosures, local snorkel exhaust, (ovens, vacuum pumps), bench exhaust, chemical storage cabinets, flammable storage cabinets, glove box, etc.

**Animal Housing Areas**

Provide ventilation, temperature, relative humidity and filtration to comply with National Institute of Health laboratory design criteria and standards and to comply with MIT EHS requirements, energy conservation; use airside energy recovery heat exchangers. 100% outside air is used for these areas and typically is circulated at a rate of 10 to 16 air changes per hour to meet AALAC Standards.

**Heat Recovery**

For animal areas and other lab applications heat wheels are not acceptable due to cross-contamination risks. Use glycol based pumped heat recovery coils, or, if supply and exhaust are side-by-side, passive refrigerant circuits and coils may be used. Include appropriate filtration on the exhaust air side to protect the heat recovery coil. The heat recovery coil on the fresh air only requires a filter during pollen season. Tack pad blankets are used from March-June and replaced multiple times. From July-October, tack pad exchanges are usually not necessary. For additional guidance see “Heat Recovery” elsewhere in this document.

Enclosed work spaces such as laminar flow exhaust hoods or bio-safety cabinets may also have to satisfy containment criteria if hazardous substances are being used. Be sure to consult EHS on any type of hood application. Refer to the Lab Design thematic chapter in the Design Standards and strategies for airside heat recovery above.

**Operable Windows**

Operable windows shall not be used in laboratories or spaces where differential pressure and air flow is critical to the design and safety. In existing buildings, operable windows shall be permanently secured.
Positive Pressure or Clean Laboratories

The requirements and approval for a positive pressure laboratory containing chemicals shall be reviewed with MIT EHS. Often these rooms will require the need for a negative pressure ante-room. These requirements should be reviewed early in the design. Refer to the thematic folder “Lab Design” elsewhere.

Heat Rejecting Equipment

Verify heat rejecting equipment to be used and loads to be created early in the HVAC design phase.

Lab Exhaust Control

If pressure-independent spring balanced cone valves are used in lab exhaust systems, be aware that in the event that makeup air to the lab is down when the exhaust system is operating, the lab will be under a severe negative pressure. This is due to the fact that with tight building construction, leakage alone will not provide adequate makeup air. As the air flowing past the cone is reduced, the spring will open against the reduced airflow and slide the cone away from the venturi. This creates a suction in the lab even though there is inadequate air flow. The effect is so “transfer” the static pressure maintained by the exhaust fan VFD within the duct riser into the room. Remember that under normal operation the valve creates a pressure drop in the range of 0.6 to 3.0 inches of static. With no makeup air, the lab will approach the static pressure setpoint in the duct. Buildings with high fume hood density may become severely negative in the event supply air is lost while exhaust remains active. The negative can be so strong as to make it difficult to open doors and can cause an egress issue.

Fume Hoods

Use only fume hoods identified in the Lab Design thematic chapter in the Design Standards. Do not provide automatically controlled discharge dampers for single fume hoods or single fans. Do not use back draft dampers. Refer to the Lab Design thematic chapter in the Design Standards for information regarding face velocity and other fume hood design issues.

Constant-volume-exhaust fume hoods:

1. Shall be used where constant dilution is required (i.e., radioactive isotopes, perchloric acid and other acid digestion processes, etc.).
2. May be used when minimum room ventilation is satisfied by the hood airflow alone.
3. May be necessary when existing building systems do not allow for variable volume exhaust and variable volume make-up air.
4. May be of the combination sash type as opposed to vertical sash to reduce air flow and energy usage.

Variable-air-volume exhaust fume hoods and make-up air
1. Consider variable volume exhaust and supply make-up air with lab air controls where the type, use and dilution does not require constant volume exhaust.

2. Consider use of horizontal sash operation if hood is greater than six feet in length. If required by end user, consider the use of a combination vertical sash and horizontal sash type fume hood.

3. Refer to Lab Design Thematic Chapter for guidance regarding fume hood face velocities.

4. Variable volume fume hood minimum exhaust air flow rate shall be not less than 50 CFM per linear foot of fume hood unless a lower rate has been approved by EHS.

**Fume Hood Air Balancing**

Testing, adjusting and balancing of the fume hood exhaust air, general exhaust air and variable volume supply air with reheat coils shall be tested, recorded and reported at minimum, intermediate and maximum air flows. Eliminate adverse conditions such as air drafts caused by supply registers and transfer air grilles. Balancing reports shall be forwarded to MIT EHS for final review and approval of fume hood and laboratory exhaust air requirements. Refer to Lab Design Thematic Chapter for guidance regarding fume hood face velocities.

**Fume Hood Commissioning**

Commissioning of fume hoods shall be an independent qualified agency and shall not be performed by the manufacturer or installer. New or remodeled fume hoods must have ASHRAE 110 testing conducted at the design opening or installed openings as directed by MIT. The HVAC designer of record must write their specification division and coordinate with other divisions such that the responsibility for corrective actions necessary to pass the ASHRAE 110 test is clearly defined. The sash movement effect test must be conducted on variable air volume hoods as well as all other requirements of AHRAE 110. In general, once face velocity and smoke tests have been passed, the five-minute average test results for tracer gas testing must be less than or equal to 0.1 PPM for all operating conditions tested. Forward failed reports to MIT-EHS immediately if any fume hood fails any portion of any test. Submit successful results through the project commissioning process.

**Fume Hood Ductwork**

Preferred fume hood ductwork material is 316L stainless steel. If CPVC is used for ducts, it must comply with the requirements outlined in Section 4.10 below. Do not provide discharge dampers for single fume hoods or single fans. Do not use backdraft dampers on fume hood or specialized local exhaust systems. For systems with redundant fans, use blast gates for fan isolation. Butterfly dampers may be used as balancing dampers for fume hood and specialized exhaust systems. Evaluate fire-stopping issues and details on a project specific basis.

When conventional CPVC is exposed to UV radiation there may be a slight decrease in impact strength and a color change of the material. UV radiation will not penetrate even thin shields such as paint. CPVC duct exposed to the direct effects of UV radiation should be painted with a light colored paint.
acrylic or latex paint that is chemically compatible with the CPVC. Compatibility information should be confirmed with the paint and CPVC manufacturer. The use of oil-based paints is not recommended. When painted the effects of exposure to sunlight are significantly reduced, however, consideration should be given to the effects of expansion/contraction of the system caused by heat absorption in outdoor applications. The use of a light colored, reflective paint coating will reduce this affect, however, the system must also be designed and installed in such a manner to reduce the effects of movement due to thermal expansion. Consider cost savings to use stainless steel if applicable in these exposed applications.

Venturi style air valves shall be connected to adjacent ductwork with the manufacturer’s drawband kit of appropriate materials, paying particular attention to the sealant tape. The ductwork on either side of the valve must be well supported with hanger stock within 12 inches of the connection to the valve. Follow the manufacturer’s instructions explicitly. Self-tapping sheet metal screws and duct sealant are NOT acceptable.

**Exhaust Fans and Exhaust**

Fume hood exhaust fan motors and belts should not be in the air stream so they can be maintained without exposure to the hazardous exhaust airstream. Use backwardly inclined fan wheels with airfoil blades to assure stable operation. For safety, fans are typically “always on”. Variable volume air systems should be considered to reduce exhaust air volume as fume hood sash is lowered. The recapture of energy by use of a heat exchanger should be evaluated, but safe discharge must not be compromised. Achieve at least 3,000 fpm discharge velocity under all operating conditions. The top of the discharge stack must be at least 10 feet above general roof level and away from large rooftop structures such as penthouses. Additional code restrictions may apply to specific cases. Fume hood exhaust fans should be located on a roof or in a roof penthouse with the fewest positive pressure parts within the penthouse. If the fans are located in a penthouse, all positive pressure ductwork must be welded construction or the joints must be sealed with Hardcast mastic (or equivalent). If a penthouse is used, additional space may be needed for scrubbers, filters and other pollution control equipment which may be needed in the future. Exhaust ducts from humidified spaces may require external insulation to prevent condensation. Obtain MIT EHS design review and approval of fume hood exhaust system designs.

**Manifold Exhaust Air Systems**

1. Generally, fume hoods are not required to be individually exhausted by a dedicated exhaust air fan.
2. Fume hoods may be manifolded into a common exhaust air system combined with a general lab exhaust air system providing manifolding is performed per the BOCA 1993 Mechanical Code and NFPA 45. When manifolding fume hoods, careful considerations should be given to labs with same type use, defining a laboratory unit and fire zone, fire separation in shafts and horizontally. Typically manifolded systems provide for increased dilution of chemicals. Manifolded systems should be reviewed with MIT EHS.
3. Systems which are manifolded on the roof outdoors should be designed with careful consideration for pitch and drainage of condensation, expansion and contraction, insulated duct if it will be part of a heat recovery system.

4. Larger manifolded systems should be welded stainless steel duct as opposed to CPVC duct. CPVC duct is subject to cracking due to expansion and contraction extremes, is brittle in cold weather, is UV sensitive and heat sensitive.

5. Type II CPVC duct should be used outdoors.

6. Chemical Storage Cabinets (chemical storage/flammable storage): When exhaust is required, chemical storage cabinets shall be exhausted using materials which have the same fire rating as the wall of the cabinet. Cabinets shall be exhausted in accordance with MIT-EHS requirements. Follow NFPA 45.

7. Vacuum Pumps: A means shall be provided to exhaust pump discharge (indirect connection) at a minimum rate of 50 CFM. Confirm with end user pump discharge rates and increase air volume as required for multiple discharges into one snorkel exhaust. Review with MIT EHS.

8. Coordinate sprinkler head locations to be installed above CPVC duct and at top of the shafts. Do not install sprinkler heads inside CPVC duct.

9. Manifolded exhaust systems shall have redundant fan capacity.

10. If energy recovery is provided, a means of servicing coils and changing filters must also be provided either by use of multiple fans, filters and coils with diversity or redundancy. Shutting down one fan during off-peak periods or in systems which have redundant fans, filters and coils allow for routine maintenance to be performed without a system wide shut down if properly dampered. If this is not possible, a means must be provided for a dampered bypass duct around air filters and coils to allow for routine maintenance without system shutdown.

Perchloric Acid Fume Hood Exhaust Systems should be provided with a dedicated fan and duct and wash-down system that meets the following requirements:

1. Design to provide a complete system wash down.
2. Provide drain locations in the duct system as required to completely drain the duct.
3. At a minimum, fan casings and the hood work surface behind baffle shall have drain connections.
4. Wash down shall be activated by a manual valve located at the fume hood.
5. Prior to acceptance, testing of the wash down system must be witnessed and approved by appropriate MIT EHS Office representatives.

Heavy Acid / Heated Acid Hoods shall be designed to withstand reactions from strong acid and may be specially designed for performing acid digestion applications.

1. Depending upon the application, acid digestion fume hoods may feature wash-down systems similar to perchloric acid hoods. Some hoods may also require internal scrubbers.
2. The exhaust duct shall be welded 16 gauge 316L stainless steel or CPVC. A fluoropolymer
coated ductwork (trade named PSP) is also acceptable.

3. Note: This type of fume hood is not meant for perchloric acid applications. This hood is made of very high chemical resistant surfaces and the sash is designed to prevent fogging or etching. If a non-ferrous hood is selected for the application, all duct and fan materials should be non-ferrous.

Radiation Exhaust

In radiation lab exhausts, the welded ducts should be round and installed with the longitudinal seam within 45° of top center, to prevent radionuclides from accumulating at a weld bead. If carbon or HEPA filters are required for individual hood exhausts, space shall be provided in a mechanical room where maintenance (filter changes) can be performed while standing on the floor. If radiation hoods are connected to a building manifold and filtration is required, then the filter housing must be installed near the hood and access must be provided.

Duct Sizing and Manifolds

Exhaust ducts should be sized and designed to provide the necessary velocity to prevent material accumulation. See the latest version of the ACGIH Industrial Ventilation Manual for detailed guidance. The following hood exhausts should NOT be manifolded together:

1. Perchloric acid/hot acid hoods.
2. Any hoods with wash-down equipment.
3. Hoods that could deposit highly hazardous residues on the ductwork.
4. Exhaust requiring HEPA filtration or other special air cleaning.
5. Where the mixing of exhaust stream may create chemical reactions, causing fire or explosion, in the duct system.

For all applications the project team must determine laboratory air change rates. Review with MIT EHS. 6 air changes per hour minimum when the space is occupied. 10-12 air changes per hour is typical for many special conditions.

Environmental Controlled Temperature Rooms

Cold rooms, warm rooms and freezer rooms often have equipment such as condensing units which can significantly affect the HVAC design loads of nearby spaces. Verify equipment to be used and loads to be created early in the HVAC design phase. Environmental Controlled Temperature Rooms may also need exhaust. The preferred method of heat rejection is to use a local recirculated loop of chilled water at an elevated temperature (mimicking a condenser water loop) to carry the heat away with head pressure controls on the refrigerant circuit. Otherwise, utilize air cooled condensers. The preferred location for the condensers is within the building mechanical space. Environmentally controlled temperature rooms may also require exhaust and associated makeup air.
Lab Equipment Cooling

Many research labs have requirements for water cooling of equipment. The type of system (open versus closed system or local versus central system) and the advantages and disadvantages of each, should be evaluated and documented early in the design and reviewed with the design team and the end user. Some systems used for cooling lab equipment will require a relatively clean source of makeup water. These systems shall use the appropriate water both at start-up and to automatically make-up water. A backflow preventer must be provided when city water makeup is required. Typically, these systems may require:

1. Tight temperature tolerances.
2. Glycol due to low operating temperatures.
3. High or very low operating pressures.
4. Special water filtration.
5. Use of non-ferrous piping materials.
6. User control and adjustability.
7. Reliability (redundancy and city water backup).
8. Dew point control of space temperature to prevent condensation on research equipment (will dictate leaving cooling coil conditions).

For piping systems where the end user periodically connects and disconnects lab equipment, automatic air vents are required to remove air. Manual air vents will not provide a practical means of air removal when it is introduced frequently into the system. Typically, strainers shall be provided at water pumps. Do not provide strainers at terminal equipment.

Review requirements with MIT Systems Engineer.

3.14 Design Strategies for Special Filtration Requirements

High-efficiency filters typically have a minimum retention of 99.97% for a monodisperse test aerosol containing 0.3-µm particles (HEPA). Ultra-low penetration air (ULPA) filters used for 0.1-µm particles are known as to have efficiencies of 99.99–100%. Certain environments will require these types of filters to achieve the space performance requirements.

ISO 14644-1 classifies a space based on the size and number of airborne particles per cubic meter of air (see chart below).

Prior to the implementation of ISO 14644-1, US Federal Standard 209E set the industry guidelines for cleanroom classification, and denoted the number of particles 0.5µm or larger per cubic foot of air. For instance, under FED-STD-209E, a "class 1,000 cleanroom" would indicate 1,000 particles 0.5 µm or
smaller in each cubic foot of air. FED-STD-209E was officially cancelled on November 29th, 2001, though both standards are still widely used.

### Clean Room Standards

| ISO 14644-1 Cleanroom Standards |
| --- | --- | --- | --- | --- | --- | --- |
| Class | maximum particles / m$^3$ | FED STD 209E equivalent |
| --- | --- | --- | --- | --- | --- |
| ≥0.1 µm | ≥0.2 µm | ≥0.3 µm | ≥0.5 µm | ≥1 µm | ≥5 µm |
| ISO 1 | 10 | 2.37 | 1.02 | 0.35 | 0.083 | 0.0029 |
| ISO 2 | 100 | 23.7 | 10.2 | 3.5 | 0.83 | 0.029 |
| ISO 3 | 1,000 | 237 | 102 | 35 | 8.3 | 0.29 |
| ISO 4 | 10,000 | 2,370 | 1,020 | 352 | 83 | 2.9 |
| ISO 5 | 100,000 | 23,700 | 10,200 | 3,520 | 832 | 29 |
| ISO 6 | 1.0×10$^6$ | 237,000 | 102,000 | 35,200 | 8,320 | 293 |
| ISO 7 | 1.0×10$^7$ | 2.37×10$^6$ | 1,020,000 | 352,000 | 83,200 | 2,930 |
| ISO 8 | 1.0×10$^8$ | 2.37×10$^7$ | 1.02×10$^8$ | 3.520,000 | 832,000 | 29,300 |
| ISO 9 | 1.0×10$^9$ | 2.37×10$^8$ | 1.02×10$^9$ | 35,200,000 | 8,320,000 | 293,000 |

(µm denotes micron particle size)

The HVAC engineer shall review space cleanliness requirements for lab design with the user and with the MIT EHS office. It is important to decide early in the design process if a project requires high-efficiency air cleaning devices because these design requirements will be difficult and costly to implement late in the design process.

Biosafety cabinets are equipped with HEPA filters to protect the work surface from room contaminants and to protect the room from contaminants in the hood. These are commonly deployed as a containment device for biological work such as tissue culture.

Microorganisms, including virus particles, are of sizes that are captured effectively by HEPA filters. ULPA filters are especially useful for microelectronics laboratories where elimination of inert particles smaller than airborne microorganisms is of critical importance. For critical laboratory operations it is important to specify “certified filters” that conform to all of the size, construction, and sturdiness criteria contained in a code such as ASME AG-1, and have efficiency and pressure drop measurement results noted on the side of the filter case. HEPA and ULPA filter testing requirements must be included in project specifications.
Clean rooms may be required for some research applications and are designed and built to the cleanliness standards described in the table above. Special micro environments may be required within a clean space in order to create a higher level of cleanliness.

For duct mounted filtration system designs must allow easy access to ducts upstream and downstream of the filters. There should be straight duct runs of at least six duct diameters on each side of the filters. The design shall include testing ports. An entry port at least six duct diameters upstream of the filters is required to introduce the challenge aerosol for the leak test and a second port is needed close to the downstream face of the filters is recommended to measure the uniformity of the challenge aerosol.

The design team must include in the project specifications that a leak test is not another filter efficiency test; it is designed to detect the presence of a damaged filter as well as leaky mounting racks and poorly installed filter cartridges.

The design team should review any user requirement for exhaust adsorbent vapor phase filtration with MIT EHS office. Activated carbon is the usual adsorbent used in ventilation air systems to remove organic vapors, sulfur dioxide, nitrogen oxides, and ozone. It can also be used for filtering radio nuclides in Radiation Labs. Activated carbon, as well as other adsorbents, gives no discernible signal when it reaches the breakpoint or saturation. The air coming out of the carbon bed can be monitored for unacceptable gas penetration. For critical applications, the design team shall include sampling provisions in their design.

Electronic air cleaners are generally not recommended for MIT facilities.

### 3.15 Design Strategies for Transformer Rooms

Provide ventilation to comply with requirements of guideline Division 26 Section “Electrical Service and Distribution”. Evaluate cooling versus ventilation. Coordinate load with Electrical documents and MIT electrical department.

MIT’s experience has been that cooling transformer rooms with chilled water fan coil units is able to maintain superior cleanliness in compared to typical exhaust air fan/intake air damper and duct arrangements. Fan coils should be located outside of conditioned spaces, cooling air and return air should be ducted to fan coil units from rooms.

### 3.16 Design Strategies for IS&T Spaces

There are two types of spaces in buildings which house IS&T support equipment, Building Distribution Frames (BDF) and Intermediate Distribution Frames (IDF). Refer to MIT Design Standards Division 27 – Communications for more information.
The design team shall provide dedicated DX cooling equipment to remove heat from IS&T rooms. MIT’s preference is for DX cooling as we have found that when chilled water based cooling is utilized it is not practical to be able to obtain chilled water system shutdowns for the building. The loads are generally small, but constant cooling support is required as they are critical loads.

If the equipment in IS&T rooms will continue to operate and generate heat on a loss of normal power in the building, then the DX cooling shall be supported by the building’s optional standby electric system.

IS&T rooms should be provided with cooling that will control the room drybulb to a set-point of 75 deg. F and the dewpoint should not exceed 59 deg. F to conform with TIA -942 requirements.

### 3.17 Design Strategies for Kitchen Exhaust

#### Categories of Kitchen Exhaust Systems at MIT

1. **Type 1**: Residential applications where exhaust hoods are installed over stoves. The requirements are described in International Mechanical Code (IMC) section 505.
2. **Type 2**: Commercial applications where hoods are installed in large kitchens or food preparation and service areas. IMC section 507 defines commercial kitchen hoods to be two types requiring exhaust:
   
   a. **Type 1 Kitchen Exhaust Hoods**:
      
      1) Installed “where cooking appliances produce grease or smoke, such as griddles, fryers, boilers, ovens, ranges, smokers and wok ranges”, which may include conveyer and deck-style pizza ovens.
      2) Conform to NFPA 96 in design of all Type 1 hoods.
      3) The design team should ensure exhaust duct from Type 1 hoods to be a minimum of 16 gauge black iron, or 18 gauge stainless steel.
      4) To prevent liquid leakage all seams must be welded liquid-tight. No screws will be permitted.
      5) Clearances are 18 inch from combustible materials and 3 inch from gypsum board.

   b. **Type 2 Kitchen Exhaust Hoods**:
      
      1) Installed over cooking or dishwashing appliances that produce heat, steam or products of combustion and do not produce grease or smoke such as steamers, kettles, pasta cookers, and dishwashing machines.
      2) The design team should ensure exhaust duct from Type 2 to be welded aluminum or stainless steel not less than 18 gauge.
      3) Supports must be noncombustible and capable of supporting the hood, adjacent
ductwork, effluent load and weight of personnel working in or on the hood.  

4) Joints, seams, and penetrations shall be sealed on the interior of the hood and provide a smooth surface that is readily cleanable and water tight.

**Kitchen Exhaust System Layouts**

Design teams shall provide a separate duct system for each Type I hood, unless the following exceptions are noted:

1. Interconnected hoods are located within the same story.
2. Interconnected hoods are located within the same room or in adjoining rooms.
3. Interconnecting ducts do not penetrate assemblies required to be fire-resistance rated.
4. The exhaust duct system does not serve solid-fuel-fired appliances.

If multiple hoods are on a single duct, the design must naturally provide the relative flows required without dampers.

The design team will locate kitchen exhaust fan termination to be a minimum 10 feet above grade and a minimum 40 inch above the roof. One side of the fan will be hinged with a flexible electrical connector for inspection and cleaning of the interior. The location must not be a public nuisance or create problems in general due to the location, direction, or nature of the wind.

Exhaust velocity shall comply with NFPA and IMC.

**Kitchen Exhaust System Clean Outs**

The design team must provide duct cleanouts and openings to remove accumulated grease. The cleanout design must be complete and reviewed by MIT’s duct cleaning vendor before the design development is considered complete.

1. Cleanouts openings shall be equipped with tight-fitting bolted doors constructed of steel with same or more thickness as the duct. Doors shall bolt tight to the stand-off flange which is provided to clear the insulation thickness.
2. Cleanout doors shall be installed liquid tight.
3. Door assemblies including any frames and gaskets shall be approved for the application and shall not have fasteners that penetrate the duct.
4. Gasket and sealing materials shall be rated for not less than 1500°F (816°C).

**Duct Wrapping**

The design team will specify a kitchen duct wrap system that extends from 18 inches below any combustible truss or wood joist to a point 18 inch above the surface of roof coverings or; provide 18 inch clearance to combustible material for the same distance or; provide noncombustible 1-hour fire-
rated shaft with a gypsum board and 3 inch minimum clearance. Comply with NFPA and IMC requirements.

Testing

The design team will specify a system to check leak test kitchen exhaust ducts. A “light test” for duct leak testing in accordance with the IMC prior to enclosing or concealing will be a minimum requirement.

Fire Extinguishing Systems

The design team will consult with MIT SEG on the type of Fire extinguishing system to be provided in kitchen hoods and exhaust ducts. Every Type 1 kitchen exhaust hood and duct system shall be protected with an approved automatic fire-extinguishing system installed per latest codes, including UL 300, developed by Underwriters Laboratories, Inc. (UL) entitled 'Fire Extinguishing Systems for Protection of Restaurant Cooking Areas'.

Although other types of extinguishing may be approved by UL, MIT’s experience is that wet-chemical extinguishing systems per NFPA 17A are preferred. Foam-water sprinkler system or foam-water spray systems per NFPA 16 may be considered as an alternative.

Fans must be provided and installed in accordance with the IMC.

Controls

The design team will provide heat sensor or other device to ensure automatic operation of both kitchen hoods and make-up air systems upon activation of cooking operations. Airflow shall be modulated to meet the demand of each hood. Be aware that optical sensing devices require close coordination with the installation of the fire protection package. It has been MIT’s experience that including a manual “on” switch which enables the automatic controls and allows for complete shutdown in the “off” position can yield the best combined result for energy conservation and operational integrity. Adequate regular training for the cooking staff and instructional signs must be provided.

Residential Kitchen Exhaust

For domestic range hoods and domestic appliances equipped with downdraft exhaust located within dwelling units, such hoods and appliances A/E design team will provide an exhaust system discharging to the outdoors through code compliant sheet metal ducts. Such ducts shall have smooth inner walls and shall be air tight and equipped with a backdraft damper.

4. PRODUCTS
The following is a list of equipment products which should be reviewed and discussed with the MIT Project Engineer. The manufacturers listed here represent the current acceptable products for use on the MIT campus.

4.1 Lab Exhaust and Airflow Control Systems

When airflow control is a critical design parameter, use Phoenix or Price venture style laboratory airflow control components. Variable flow fume hood exhaust applications always require critical airflow control.

The manufacturer’s controller shall regulate the supply and exhaust valves to obtain rapid rate of response and maintain appropriate airflow offsets. In some applications speed of response on the air supply may not be critical, and typical VAV boxes may be used in conjunction with venturi valves on the exhaust.

Hood exhaust shall be modulated to meet face velocity criteria.

Pressure independent valves shall be provided for each fume hood on manifolded exhaust systems.

Control range 20-100 percent air flow.

Response time shall be one second or less after reaching 90 percent of sash height or change in system static pressure.

Room pressure shall be maintained using a volumetric offset. This is typically 10% of the minimum room exhaust flow or 100 cfm per door leaf.

Provide a fume hood monitor.

Air flow supply and exhaust valves shall include the following features:

1. Venturi control type.
2. Pressure independent.
3. Turn down 8 to 1 with +/-5 percent accuracy.
4. Air supply valves: 16-gauge aluminum assembly with type 316 stainless steel hardware.
5. Fume hood and general exhaust valves shall coatings and materials appropriate for the application. See section 3.12 for installation and application guidance. Shaft and hardware shall be type 316 L and shall have phenolic coating when appropriate.
6. Exhaust valves generally shall fail open, supply valves generally shall fail to minimum air flow.
7. Valves shall be individually factory calibrated and supplied with a permanently attached calibration chart.
Provide one lab controller per lab. Control supply, exhaust and reheat coils for air flow and room temperature control.

Coordinate interface to building automation systems for remote monitoring and alarm including:

1. Exhaust air flow quantity.
2. Emergency override and flow alarm.
3. Room supply air quantity.

Sound Attenuators: Review noise requirements with acoustical consultant to determine if an attenuator is required to be provided with the exhaust valve.

4.2 Building Automation Systems

Provide Schneider or Automated Logic building automation systems. See the BAS section of the Design Standards for detailed information regarding automatic temperature controls.

4.3 Electric Motors and Variable Frequency Drives

Refer to the electrical section of the Design Standards for information on motors and variable frequency drives.

4.4 Automated Dampers

Outdoor air applications are best served by the installation of TAMCO dampers with the SW (saltwater) construction features. These features are also important where a damper is located downstream of the cooling coil and sees nearly 100% RH conditions during the cooling season.

For applications requiring unit smoke/fire isolation, Ruskin isolation dampers FSD-60 or FSD-60LP have been used successfully. For floor level smoke/fire dampers we use only Greenheck’s product, as we have had issues with Ruskin in this application.

4.5 Central Station Air Conditioning Units

General: Double wall construction with solid inner liner.

Fans: Higher efficiency and generally quieter wheels shall be used where possible.

Bearings selected for fatigue life rating L10 of 200,000 hour operation.

Specify statically and dynamically balanced fan wheels to 0.10 inch/second at peak velocity.

All steam coils shall be ARI certified.

Chilled Water Cooling Coils:
1. Each coil row or each coil shall have its own aluminum or stainless drain pan and that condensate shall be piped within the unit to a location near the drain base’s outlet.

2. The floor of the section downstream of the cooling coils shall have a recessed, integral stainless or aluminum drain pan pitched in 2 directions with adequate drain points to provide positive flow to the outlet.

3. The dimension in the direction of airflow shall be adequate to capture all coil carryover at maximum design velocities.

4. All coils shall be ARI certified.

5. Cooling coil construction shall be 304L stainless steel casings with copper tubes, aluminum fins and steel headers.

Starters, Variable Frequency Drives and Motors: Motors shall be premium efficiency conforming to NEMA Standard 31, MG1.31. Motors shall be suitable for use with variable frequency drives where applicable. Coordinate all requirements with design electrical engineer. Also see Electrical Section of the Design Standards for additional guidance.

Starters and variable frequency drives shall be specified to be furnished and installed under the electrical section.

4.6 **Horizontal Propeller Unit Heaters**

Steam coils shall be rated at 150 psig.

OSHA compliant fan guard shall be provided.

The fan/motor assembly shall be provided with vibration isolation.

Provide an ECM motor with fan speed modulation to meet room set-point. No steam control valve is required.

4.7 **Fancoils**

Manufacturer: Airtherm, Price or MIT approved equal.

Four-way adjustable discharge grilles shall be provided for units located below ceilings.

Provide an EC motor to permit fan speed modulation.

Provide internal vibration isolation.

Drain pan shall be of sufficient size to cover end pocket piping and control valve.

Provide a drain pain configuration to comply with the IMC requirements.
High capacity cooling coil shall be provided to meet MIT delta T chilled water performance requirements.

The manufacturer shall provide a local disconnect switch, with a permanent lockable means (switch lock bracket), mounted to the unit.

### 4.8 Hot Water Reheat Coils

Provide ARI certified coils.

All coils shall be pressure tested at the factory.

Hot water reheat coils shall be selected to operate successfully in the future when fed from the future campus hot water loop. See section 3.6 for more information.

### 4.9 VAV Terminal Units

Units shall be internally insulated. The insulation material shall have a non-porous surface.

Damper air leakage shall not exceed 2 percent of rated air quantity at 1 inch static pressure. Casing leakage shall not exceed 2 percent of rated air quantity at 1 inch static pressure.

Units shall be provided with multi-port averaging flow sensors.

Boxes shall be shipped with the actuator from the factory. Controls shall be provided by the controls subcontractor, not the box manufacturer.

Sound performance shall be per ARI Standard 880, radiated and discharge NC less than 30 at 1 inch water gauge.

### 4.10 Laboratory Ductwork

Laboratory exhaust ducts should be preferably round, non-combustible, inert to agents to be used, nonabsorbent, and free of any organic impregnation.

Duct Material: Galvanized duct is not acceptable for laboratory exhaust systems. Ducts in shaft are recommended to be stainless steel. In new installations round 18 gauge minimum thickness Type 316L stainless steel is recommended. For most lab exhaust applications, 316L stainless or CPVC are suitable materials.

CPVC fume hood ductwork must be low flame spread CPVC with a flame spread rating of 5 or less, a smoke developed index of less than 25, (both in accordance with ULC S102.2) and meet FM 4910 Clean Room Materials Flammability Test. The material shall be Type IV, Grade I with a Cell Classification of 23437 as defined in ASTM D1784.
Duct Connections: ANSI Z9.5-2012 Section 5.4.2.1 states: “Longitudinal sections of a duct shall be a continuous seamless tube or of a continuously welded formed sheet. Longitudinal seams that are formed mechanically shall be utilized only for light duty systems with no condensation or accretion inside the duct.” and “Traverse joints shall be continuously welded or flanged with welded or Van Stone flanges.”

1. Clarification: The process of manufacturing a pipe spool with both flanges rotating without the use of conventionally welded or screw threaded collars is known as the “Conrac” or more properly the “Van Stone” system. The process essentially forms a lap collar by spinning over the parent tube at right angles to the original tube axis.

2. NFPA 45-2015 Chapter 7 contains: “7.4.5 Positive pressure portions of the lab hood exhaust systems (e.g., fans, coils, flexible connections, and ductwork) located within the laboratory building shall be sealed airtight or located in a continuously mechanically ventilated room.”

3. These codes require duct connections to be tight. As the exhaust is under negative pressure, air leakage will be into the ductwork, not out of it. If the pressure differential is not too great it is possible that condensing liquids could possibly drip out of an open seam at the bottom of the duct.

4. Connections at the fan intake can be made with coated glass fiber cloth. Be sure that the cloth coating (neoprene, vinyl, silicone, Teflon, etc.) is compatible with chemicals used in the hoods connected to the upstream ductwork. In general, the MIT EHS office recommends that the transition joint from duct to fan shall be made of inert, corrosion and UV-resistant materials. The duct alignment offset shall not exceed 1.2 inch at the fan.

5. For welded duct work a continuous "butt" weld (use appropriate filler rod of same material as duct) for joint construction is required for both stainless and CPVC duct. CPVC duct welding shall be by the hot gas method only. Solvent welding shall not be used.

6. A flanged removable spool piece at each fume hood connection shall be provided. This spool sections can be used for leak tests, inspection, and to facilitate removal of equipment. Acceptable gaskets at flanged joint connections should be installed.

4.11 Flexible Duct Connections

Flexible connections generally be installed between fans and the connected duct system.

Hard duct all fume hood exhaust fans. No flexible connections should be used in this case.

Variable Volume Terminals: Generally, hard ducted where exposed to view.

4.12 Manual Dampers and Splitters

Ruskin and Greenheck are also acceptable products.

Provide manual opposed blade volume damper in each supply, return and exhaust branch duct from associated main duct and in each run-out to supply or return diffuser or register.
For scavenger or snorkel exhaust use blast gate damper.

### 4.13 Fire Dampers

Fire dampers shall be UL labeled in accordance with UL-555.

Fire dampers shall be installed per SMACNA standards.

For accordion-style fire dampers, the blades should be completely out of air stream when in the open position.

Provide access panel in duct and in ceiling or wall.

Use static type for systems that shut down on fire and dynamic type on systems that continue to operate.

Do not install on hazardous exhaust systems.

Ruskin combination fire/smoke dampers are not an acceptable product in this application due to significant issues with performance. Greenheck dampers are preferred for fire/smoke applications.

### 4.14 Belt Guards

Provide for all belt driven equipment, OSHA approved guards designed for easy removal and hinged arrangement.

### 4.15 Diffusers, Registers and Grilles

Provide vaned diffusers, registers and grilles to reduce drafts and slow outlet velocities.

For high volume areas, provide round or flat oval perforated duct diffusion equal to United type SP. Constructed and engineered in accordance with United Corporation’s Engineering Report No. 153 “Designing SP Duct Diffuser Systems”. Maximum pressure drop .1 inch static pressure. For user comfort avoid downward flow of air. In certain conditions the bottom portion of the perforated duct may require a sheet metal (shroud) blank-off piece.

Location and types of diffusers must be carefully determined to avoid drafts, fogging windows, disruption of air flow at fume hoods, etc. In rooms without ceilings, consider use of lay-in panel type diffusers to avoid “dumping”.

### 4.16 Exhaust Fans

AMCA certified for sound and air performance.

Exhaust fans shall be statically and dynamically balanced to no greater than 0 .1 inch per second. Vibration shall be tested and documented at factory.
Provide centrifugal, general purpose, Class II, fans for supply, exhaust and transfer with backward inclined or air foil type fan wheel. All fans should be Class II construction as a minimum level of quality.

Centrifugal used for fume hood exhaust installed indoors shall be up blast with weather hood and drain. Fan shall be tested per AMCA 210-85. Fan sound tests shall be per AMCA 300. UL listed per UL 705. Fans shall meet NFPA-45. Spark resistant construction per AMCA “C” shall be specified when appropriate.

4.17 Gravity Roof Ventilators

Spun aluminum with bird screen and insulated roof curb.

4.18 Motors, Drives and Starters

Premium efficiency motors, conform to utility company standards for rebate if available. Starters and VFD’s provided by electrical unless part of packaged equipment. Motors for VFD shall be VFD rated.

4.19 Variable Speed Controllers

VFD’s shall be provided under electrical section. Coordinate with electric design.

4.20 Access Panels and Doors in Ductwork

Access doors and panels must be appropriate size for intended purpose. Show location and sizes of access doors and panels on Contract Documents and do not assume Contractor will provide the correct size or the correct locations. Provide access doors and panels for all valves, dampers, fire dampers, at both sides of booster coils, at VAV boxes, at all control devices, and elsewhere needed.

4.21 Humidifiers

Specify Nortec, Armstrong, and Dri-Steem for small wall mount canister units. Dri-Steem or Armstrong wands in duct shall be provided for large systems.
4.22 Acoustical Duct Lining

If at all possible, do not use duct lining anywhere on the air supply system. Use silencers or double wall ductwork constructed with a perforated steel liner to achieve sound attenuation.

If silencers will not achieve the desired result and the extent of double wall duct required is cost prohibitive, use flexible closed cell engineered polymer foam insulation duct lining. Emphasize compliance with the manufacturer’s installation standards in the specification.

4.23 Insulation

Insulate ducts on the exterior for condensation control. Duct-board is more durable and neater in appearance than duct-wrap. Do not use internal insulation on fans. If ductwork insulation is to be exposed, review the requirements, durability and appearance of externally mounted insulation with MIT Project Manager and Architect.

4.24 Sound Attenuators

The designer shall schedule acoustic performance requirements for all relevant equipment. Coordinate these requirements with the client’s goals and the acoustical consultant’s advice.

Verify self-generated noise does not exceed noise criteria.

Test silencer per ASTM E477.

Attenuation material must be protected from erosion. Perforated covers should be used, but may not be adequate to prevent fibers from entering the air stream. Erosion coatings may not be long lasting and durable. Use mylar film for critical areas. Review special coatings which may be required for fume hood exhaust systems.

4.25 Fan Drives

Adjustable speed sheaves are not permitted. Provide fixed sheaves once balancing is complete.

4.26 Heat Wheels

We have had good results with the Thermotech heat wheel which has a number of robust design features, including the rim construction and design, the spoke arrangement, and the seal mechanism. The Thermotech wheel is our preferred product, but we have had success with products from SG America. We exclude the Trane OEM wheels as sold by AirExchange and wheels from SEMCO for reasons of durability and performance.
4.26 Static Plate Total Energy Recovery Devices

Static plate ERD’s shall be by RenewAire or SEG approved equal. Static plate ERD’s must insure no contaminants pass from the exhaust airstream into the supply airstream. They must transfer latent heat as well as sensible heat energy.

4.26 Outdoor Condensing Units

Outdoor condensing units shall be specified with hail guards to reduce weather related damage.

5. GREEN DESIGN

5.1 Opportunities

Sustainable, green building design opportunities include, but are not limited to the following:

1. Fume hood design, including facilitation of hood hibernation program.
2. Ventilation design.
3. Cleaning water treatment systems.
4. CFC Reduction in HVAC and R Equipment Renewable Energy: Solar or Wind Power Elimination of HCFC’s and Halons.
5. Green Power: Purchased from “Green” Utilities.
6. Thermal Comfort: Comply with ASHRAE 55-2013 and provide permanent monitoring system.
8. Economizers on water or air side.
10. VAV Systems.
11. IAQ Monitoring, including CO2.
12. Commissioning.
15. Review the impact of green design on indoor air quality.
16. Receive design input and comments from the “Green Building Task Force” or similar.

5.2 Energy Conservation

Since the conditioning and movement of air is a major component of energy conservation management systems, MIT has generally used off-hour “temperature drift” and shut-down techniques. HVAC energy conservation is generally implemented through the building automation system. HVAC systems must be designed to permit transition from off-hour to peak-hour conditions within a reasonable period of
time. It is expected that systems with adequate capacity be able to transition from off-hour to peak-hour conditions within 90 minutes or less.

1. Zoning: Zoning of building HVAC system into subsystems serving areas with common environmental and occupancy requirements is typically required. Give consideration to zoning techniques which accommodate individual after hour occupants with minimum operation of areas not in use. Buildings with fan coil units shall have those units controlled (on/off) in blocks by a time clock or building automation control point occupancy schedule. After hours occupant override shall be provided through occupied/unoccupied button on thermostat.

2. Ventilation: Ventilation rates should be minimized, but always maintained within the acceptable parameters established by the IMC, ASHRAE, MIT EHS, and the project requirements.

Refer to the Design Guidelines thematic folder “Sustainability” for additional requirements.

6. OPERATIONS

6.1 Operations Requirements

Provide adequate space around equipment for maintenance.

Provide proper clearance for panels, tube pull, etc.

For critical applications, lube oil lines for fans may be extended to outside the unit to permit lubrication without requiring a shutdown.

For contaminated exhaust place the motors outside of the air stream.

Provide adequate valves, dampers, etc., to isolate equipment and major system branches during maintenance.

6.2 Integrated Pest Management

Depending on the design of the cooling and heating system, these systems can at times serve as dark, quiet, and sheltered walkways for pests.

Prior to starting work a pest inspection of the space should be conducted, by the Pest Management Vendor and Design team, to control or eliminate any pest and to seal any pest access points in to the space.
After the work is concluded a follow up a pest inspection of the space should be conducted, by the Pest management Vendor and Design team to ensure all pest access points have been blocked with suitable materials.

Focus for both inspections should be the perimeter of the room, closets, electrical systems, drop ceilings, sewer systems, heating and cooling systems.

### 7. TESTING, ADJUSTING, BALANCING AND COMMISSIONING

#### 7.1 Preliminary Installation Tests

The Construction Contractor and its subcontractors shall make the following preliminary mechanical system tests and obtain approval and acceptance of MIT and the Project Engineer and Architect, as applicable.

**Certifications**

Require the Contractor to provide test certifications showing the test has been made and is approved by local authorities and the MIT Project Manager.

**Steam, Condensate and Water Piping Testing**

Make hydrostatic pressure tests for 2 hours at not less than 150% of operating pressure, but never less than 50 psi. For large projects, test system in sections. X-ray of welds where required by piping spec.

**Medium and High Pressure Ductwork Testing**

Test duct risers and branches individually with a blower, orifice section and U-tube gauge board. Isolate each riser and branch under test with seals, plugs and caps. Maintain 8” pressure with maximum loss of 1” pressure difference across the orifice plate. Repair leaks with loss of more than 1” and all noisy or whistling leaks and retest until accepted.

**Horizontal Mains**

Test horizontal mains in the mechanical room after all risers have been accepted, after horizontal mains have been connected to the risers and before branches have been connected to the risers. Make tests as indicated above for duct risers and branches.

**Final Connections**
Only after work has been tested and accepted, connect branches to the risers and begin insulation work.

7.2 Custom AHU Factory Tests

Makeup Air Handling Units (MAHUs) and Exhaust Air Handling Units (EAHUs) Factory Testing

Scope of testing:

1. Airflow delivery at static (with duct traverse), 100 to 110% of design is acceptable. Also manufacturer to test at 50% of design flow.
2. Leakage and deflection with dial micrometers (positive & negative). 1/2% at 12” w.c. for leakage, L/250 for deflection.
3. Vibration test on fans to BV-5 (0.08 in/s).
4. Sound pressure readings by octave band at inlet, outlet, and adjacent to fan section.
5. Filter rack deflection test. L/250 at 3 inch water column.
7. All test plates for leakage testing to be in place for field re-testing by others.

Witnessing and video recording of testing:

1. Customer will be witnessing testing of AHU
2. Manufacturer to video record and distribute as directed all tests that the customer does not witness – all the tests on other units in under the same order
3. Manufacturer’s Submittal Engineer/Project Engineer will act as surrogate witness for the testing for any units customer will not be here to witness.

Following is a narrative and explanation of each of the tests listed in the summary above.

Airflow Delivery at Static

1. Related standards: AMCA 203 Field Performance Measurement of Fan Systems
2. Basic Methodology:
   a. Unit to be connected to a test duct that follows the intent of AMCA 210, the standard for generating published fan ratings.
   b. Round ducts will be used, approximately 10 duct diameters long with a straightener section in the middle.
   c. Readings are taken toward the air leaving end of the duct, where the flow is best developed and there is the best opportunity to obtain a useable set of readings from a duct traverse.
   d. Static pressure is simulated using an adjustable cone at the end of the test duct, partial
blocking off of coils and filter racks, or a combination thereof.

3. Readings taken are:
   a. Duct traverse for airflow.
   b. Static pressure across the fan(s).
   c. Fan power consumed is taken as the output power of the VFD used in the test stand, read directly from the VFD display.

4. Acceptance Criterion:
   a. Per job specification, 110 to 100% on flow. This is more stringent than the AMCA ratings program or the reference standard on field testing, AMCA 203.

5. Details:
   b. Under the current AMCA ratings program, a fan manufacturer is entitled to apply the AMCA sticker to a fan if it can achieve a given operating point with a 3% speed variation or less from that published. In the testing at hand, we expect to adjust the VFD Hz and hence the fan speed until we reach 100% flow or more at the design static pressure. AMCA 203 states the uncertainty of the method as 2 to 10%, so it would not be unusual to see a fan speed higher than predicted under the ratings program as the speed needed to reach the acceptance criterion per the job specifications.
   c. For the MAHU’s, the discharge opening on the 45 degree angle face of the discharge plenum will be blocked and sealed. A removable plug panel will be built in to the end wall, to allow the test duct to connect in a direct fashion, on a common horizontal line with the unit, without transition ductwork out of the 45 degree discharge opening.
   d. For the EAHUs, units will be tested without the attenuating round stacks installed, owing to height constraints within the factory. The fan inlet pressure will be measured and the other side of the manometer will be left open to atmosphere, just as the discharge of the fan is open to atmosphere in the test set up. The test duct will be connected to the inlet openings of the units via suitable transitions.
   e. For the 50% airflow test, all fans will be running and turned down 50%.

Leakage and Deflection Tests

1. Related standards: ASHRAE 111, AHRI 1350
2. Basic Methodology:
   a. Unit openings are sealed. Test pressure is generated using an external test fan. Positive
pressure sections are tested at positive pressure; negative pressure sections are tested at negative pressure. Fan isolation dampers are removed so that fan wall openings can be properly sealed to separate positive from negative sections. Leakage is determined using a calibrated orifice. Deflection is read from digital plunger-type micrometers during the leakage test.

3. Acceptance Criterion:
   
   a. Leakage: 1/2% of design unit cfm at +/-12” w.c test pressure.
   
   b. Deflection: L/250 at +/-12” w.c test pressure.

4. Details:
   
   a. Instruments:
      
      1) Shortridge AirData Multimeter ADM – 870C (manometer functionality)
         Internal tube #5202-5 which has a 3.25” calibrated orifice mounted in a tube of suitable length.
      
      2) B&K Vibrotest 60 kit with included accelerometers.
      
      3) Fowler Digital Indicator 0-1”, manufacturers part # 54-520-250 (micrometer, plunger type).
      
   b. Tube is mounted between the test blower and the unit being tested.
   
   c. Measured pressure drop across calibrated orifice is used with calibration curve or equation for orifice to infer cfm of leakage.
   
   d. Measured pressure within unit is recorded as test pressure.

Vibration Tests on Fans

   1. Related standards: AMCA 204
   
   2. Basic Methodology:
      
      a. Motors are powered to design speed and sensor is placed at appropriate points for analyzer to take readings. Isolators are locked down. Readings are filter-in. Per job specification, all three axes are to be checked.

   3. Acceptance Criterion: BV-5 (0.08 in/s vibration velocity)

Sound Pressure Readings

   1. Related standards: None
   
   2. Basic Methodology:
      
      a. A hand-held B&K 2238 sound analyzer/filter will be used to take 8 octave band
readings at these locations during the airflow test (i.e., fan running at design conditions): 5 feet from end of test duct, 5 feet outside fan section casing, 5 feet from unit inlet for MAHUs, as near fan discharge as we can physically get with the personnel lifts we have for the EAHUs

3. Acceptance Criterion: None. Information only.

Filter Rack Deflection Tests

1. Related standards: None
2. Basic Methodology:
   a. Rack will be covered with shrink wrap so that shrink wrap will be sucked against rack when pressure is applied. Deflection will be measured with a micrometer at mid-point of rack.
3. Acceptance Criterion: L/250, where L is the greater of rack height or rack width
4. Details: Deflection will be read using same digital micrometers as used in casing deflection test.

Motor Hi Pot Test (High Potential)

2. Instrument: 02925 – 5kV 12mA AC Tester.
3. Basic Methodology: Each motor wire is subject to 2.1kVA voltage, to verify integrity of winding insulation at voltage substantially higher than operating.
5. Details: This test is a standard part of procedures we are obligated to follow under our ETL listing.

7.3 Operating Tests and Balancing

MIT may employ a separate balancing contractor, independent of contractors employed for other mechanical work on a project, to test and balance mechanical system piping and air handling systems. Discuss particular project requirements with the MIT Systems Engineer before developing operating test and balancing specifications.

Balancing Contractor’s Responsibilities During Original Installation: The Balancing Contractor shall make regular visits to the job site during installation of mechanical systems to ensure that work is being installed in a manner and with accessories which will permit satisfactory balancing of the systems.
Balancing Contractor’s Responsibilities During Pressure Testing: The Balancing Contractor shall observe pressure testing of medium and high pressure ductwork to the extent that the Balancing Contractor can ensure that the completed system will be sufficiently air tight to permit proper air balancing.

Notification Required: The Balancing Contractor shall immediately notify the MIT Project Manager and the Architect in writing with specific information if the Balancing Contractor believes that additional accessories such as dampers and valves are necessary for proper balancing, and if the Balancing Contractor believes that any work is being installed in a manner, which adversely affects proper balancing.

Test Policies and Procedures: The Balancing Contractor employed by MIT will make operation and balancing tests only after pressure tests and system cleaning is completed by the Project Contractor and its Mechanical Subcontractor. Make tests in the presence of MIT Project Manager and Project Engineers and Architect. Make CFM and static pressure tests.

1. Test Equipment: The Balancing Contractor shall provide all test equipment, gauges, instruments and personnel needed to properly complete the tests performed by the Balancing Contractor.

2. Construction Contractor’s Responsibilities: The Construction Contractor and its subcontractors shall cooperate with the Balancing Contractor and shall make all necessary adjustments as recommended by the Balancing Contractor. At no additional cost to MIT, the Construction Contractor and its subcontractors shall adjust or replace all impellers, pulleys, sheaves, belts, dampers and other work, and shall add dampers as needed for correct system operation and balance. After balancing is complete, the Construction Contractor and its subcontractors shall replace adjustable sheaves with fixed sheaves and check total system airflow to be sure it remains within specification.

3. Test Evaluation and Acceptance: The Balancing Contractor shall provide a detailed Balancing Report. The Balancing Report shall not be a copy of the design documents. The Balancing Report shall be a new report with tables having columns for Room Name and Number, Design Requirement, Measured Value and Deviation. The Balancing Contractor shall also provide typewritten opinions and evaluation as to whether the installed systems meet design requirements. Acceptance and approval of the installed work, however, shall remain with the Project Engineer, Project Architect and MIT Project Manager, and not the Balancing Contractor.

Acceptance Criteria: To be acceptable, design requirements must be met within +/-10%. In addition to meeting design requirements, the installed work shall operate with the least possible and no objectionable noise or vibration. Quiet and vibration free operation is a Contract requirement. Work, which does not meet this requirement, shall be repaired or replaced at no additional cost to MIT.
Acceptance by Authorities: A Contract requirement shall be to provide systems, which are acceptable to authorities having jurisdiction. Work, which does not meet this requirement, shall be repaired or replaced at no additional cost to MIT.
## APPENDIX A: PIPE CLASS INDEX TABLE

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<tr>
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<th>SERVICE</th>
<th>MATERIALS</th>
</tr>
</thead>
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<tr>
<td>125 CHW-C</td>
<td>Chilled Water in Buildings</td>
<td>Copper and Bronze</td>
</tr>
<tr>
<td>125 HHW-C</td>
<td>Heating Hot Water in Buildings</td>
<td>Copper and Bronze</td>
</tr>
<tr>
<td>125 CHW-S</td>
<td>Chilled Water in Buildings</td>
<td>Carbon Steel</td>
</tr>
<tr>
<td>125 HHW-S</td>
<td>Heating Hot Water in Buildings</td>
<td>Carbon Steel</td>
</tr>
<tr>
<td>300</td>
<td>High Pressure Steam in Buildings</td>
<td>Carbon Steel</td>
</tr>
<tr>
<td>300C</td>
<td>High Pressure Condensate in Buildings</td>
<td>Carbon Steel</td>
</tr>
<tr>
<td>150</td>
<td>Medium Pressure Steam in Buildings</td>
<td>Carbon Steel</td>
</tr>
<tr>
<td>150C</td>
<td>Medium Pressure Condensate in Buildings</td>
<td>Carbon Steel</td>
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<tr>
<td>150L</td>
<td>Low Pressure Steam in Buildings</td>
<td>Steel, Cast Iron, and Bronze</td>
</tr>
<tr>
<td>125C</td>
<td>Low Pressure Condensate in Buildings</td>
<td>Steel, Cast Iron, and Bronze</td>
</tr>
<tr>
<td>150F</td>
<td>Generator Fuel Oil in Buildings</td>
<td>Steel, Malleable Iron, and Bronze</td>
</tr>
</tbody>
</table>
### APPENDIX B: HEATING AND COOLING PIPE CLASSES

<table>
<thead>
<tr>
<th>Pipe Class:</th>
<th>125CHW-C</th>
<th>125HHW-C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary ANSI Class:</strong></td>
<td>125</td>
<td>125</td>
</tr>
<tr>
<td><strong>Primary Material Use:</strong></td>
<td>Chilled Water/Heating Hot Water within buildings</td>
<td></td>
</tr>
<tr>
<td><strong>Date:</strong></td>
<td>September, 2016</td>
<td></td>
</tr>
<tr>
<td><strong>Corrosion Allowance:</strong></td>
<td>0.05 inch</td>
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</tr>
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#### Service Limits

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<thead>
<tr>
<th>Temperature, °F</th>
<th>150</th>
<th>200</th>
<th>250</th>
<th>300</th>
<th>350</th>
<th>406</th>
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<tbody>
<tr>
<td>Pressure, psig</td>
<td>200</td>
<td>185</td>
<td>170</td>
<td>155</td>
<td>140</td>
<td>125</td>
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#### PIPE AND FITTINGS

<table>
<thead>
<tr>
<th>ITEM</th>
<th>SIZE</th>
<th>THICKNESS</th>
<th>STANDARD</th>
<th>MATERIAL SPECIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tubing</td>
<td>4” – Under</td>
<td>Type L</td>
<td>ANSI B16.22</td>
<td>Seamless Hard Copper Tubing ASTM B-88</td>
</tr>
<tr>
<td>Unions</td>
<td>1/2” – 2”</td>
<td></td>
<td>ANSI B16.5</td>
<td>Cast Bronze, 125#, ASTM B62, solder joint</td>
</tr>
<tr>
<td></td>
<td>2 1/2” – 4”</td>
<td>ANSI B16.6</td>
<td>Bronze, Use flanges or Victaulic couplings where possible instead of unions</td>
<td></td>
</tr>
<tr>
<td>Flanges</td>
<td>4” and Under</td>
<td>ANSI B16.5</td>
<td>Ductile iron housing, ASTM A536, cast with off-setting, angle-pattern bolt pads (no torque requirement). Installation Ready similar to Victaulic Style 607.</td>
<td></td>
</tr>
<tr>
<td>Couplings</td>
<td>2” – 4”</td>
<td>ASTM A536</td>
<td>Soldered type, wrought copper brass or cast bronze, ASTM AB75 or B62</td>
<td></td>
</tr>
<tr>
<td>Soldered Fittings</td>
<td>1/2” - 4”</td>
<td>ANSI B16.18</td>
<td>Cast iron, wrought copper brass or cast bronze, ASTM AB75 or B62</td>
<td></td>
</tr>
<tr>
<td>Grooved Fittings</td>
<td>2” – 4”</td>
<td>ANSI B16.18</td>
<td>Cast iron, wrought copper brass or cast bronze, ASTM AB75 or B62</td>
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</tr>
<tr>
<td>Pressed fittings</td>
<td>1/2” - 4”</td>
<td>ASME B16.18</td>
<td>Copper and copper alloy, ProPress by Viega</td>
<td></td>
</tr>
<tr>
<td>Soldered Joints</td>
<td>1/2” – 4”</td>
<td>ANSI B16.18</td>
<td>Cast iron, wrought copper brass or cast bronze, ASTM AB75 or B62</td>
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</tr>
</tbody>
</table>

#### VALVES

<table>
<thead>
<tr>
<th>TYPE</th>
<th>USE</th>
<th>SIZE</th>
<th>STANDARD</th>
<th>SPECIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ball</td>
<td>Block/Isolation</td>
<td>1/2” – 4”</td>
<td>ANSI B2.1</td>
<td>Bronze ASTM B-62, 125# WSP rating, Solder joint, (Hammond 8311, Apollo 7-200 or equal) or Forged brass, 300 psig CWP, pressure-sealed ends (Similar to Victaulic Series 589)</td>
</tr>
<tr>
<td>Butterfly</td>
<td>Block/Isolation</td>
<td>2 1/4” – 4”</td>
<td>MSS-SP67</td>
<td>Brass (conforming to UNS C87500), copper tube dimensioned grooved ends, offset aluminum-bronze disc, integrally cast steel stem, pressure responsive elastomer seat. Similar to Victaulic Series 608N.</td>
</tr>
<tr>
<td>Check / Swing Type</td>
<td>Prevent Reverse Flow</td>
<td>1/2” – 2”</td>
<td>MSS-SP80-2 ANSI 16.18</td>
<td>Bronze ASTM B-62, 125# WSP rating, Solder joint</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 1/2” and Larger</td>
<td>MSS-SP70-1 ANSI B16.10</td>
<td>Cast Iron A-126, 125#, flanged ends, swing or piston check</td>
</tr>
<tr>
<td>Check/ Silent Type</td>
<td>Pump Discharge</td>
<td>1/2” – 2”</td>
<td></td>
<td>Spring loaded, Center guided, Manufactured by Williams-Hager, Miller, Mueller, or Combination Pump Valve</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 1/2” and Larger</td>
<td></td>
<td>Spring loaded, Center guided, Manufactured by Williams-Hager, Miller, Mueller, or Combination Pump Valve</td>
</tr>
</tbody>
</table>
### BOLTING AND GASKETS

<table>
<thead>
<tr>
<th>Bolting:</th>
<th>Studs: Square or hex head, ASTM A307, Grade B, 2A threads</th>
<th>Nuts: Heavy Hex, ANSI B18, 2B threads, ASTM A194 or A307</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Track-head heat-treated carbon steel per ASTM A449 and A183</td>
<td>Track-head heat-treated carbon steel per ASTM A449 and A183</td>
</tr>
<tr>
<td>Gaskets</td>
<td>1/16&quot; Red rubber, Full face</td>
<td></td>
</tr>
<tr>
<td>Coupling Gaskets</td>
<td>Grade “EHP” EPDM with red and copper color code, suitable for water temperature range from -30 deg F to +250 deg F</td>
<td></td>
</tr>
</tbody>
</table>

### NOTES:

1. Viega ProPress and Victaulic valves may be considered as alternates.
2. Other equivalent pressed or grooved systems may be considered.
3. Grooved couplings and fittings shall only be used in locations that are accessible for maintenance.
4. Grooved joint piping systems shall be installed in accordance with the manufacturer's (Victaulic) guidelines and recommendations. All grooved couplings, fittings, valves, and specialties shall be the products of a single manufacturer. Grooving tools shall be of the same manufacturer as the grooved components. The gasket style and elastomeric material (grade) shall be verified as suitable for the intended service as specified. Gaskets shall be molded and produced by Victaulic. Grooved end shall be clean and free from indentations, projections, and roll marks in the area from pipe end to groove for proper gasket sealing.
5. A Victaulic factory-trained field representative shall provide on-site training for contractor's field personnel in the proper use of grooving tools, verification of groove and installation of grooved piping products. Prior to the installation of Victaulic systems, a formal project-specific contractor kick-off meeting shall be performed by Victaulic with the appropriate subcontractor personnel who will be assigned to each project. A sign-in sheet and confirmation signatures shall be obtained by all attendees as documentation support that any personnel who will be grooving pipe and/or installing Victaulic products has obtained and understands the requirements as put forth by Victaulic installation instructions. Factory-trained representative shall periodically review the product installation. Contractor shall remove and replace any improperly installed products.
6. Where possible, carbon steel grooved pipe 4” and larger shall be produced using the Victaulic RG5200i fully automated grooving tool that provides groove traceability documentation, corresponding identification marks on the pipe, and confirms all critical dimensions fall into the required tolerance range as listed by the tool manufacturer.
Pipe Class: 125CHW-S  
Material: Steel

**Primary ANSI Class:** 125  
**Primary Material Use:** Chilled Water within buildings

**Date:** Dec, 2016

<table>
<thead>
<tr>
<th>Service Limits</th>
<th>Temperature, °F</th>
<th>150</th>
<th>200</th>
<th>250</th>
<th>300</th>
<th>350</th>
<th>406</th>
<th>Corrosion Allowance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure, psig</td>
<td></td>
<td>200</td>
<td>185</td>
<td>170</td>
<td>155</td>
<td>140</td>
<td>125</td>
<td>0.05 inch</td>
</tr>
</tbody>
</table>

### PIPE AND FITTINGS

<table>
<thead>
<tr>
<th>ITEM</th>
<th>SIZE</th>
<th>THICKNESS</th>
<th>STANDARD</th>
<th>MATERIAL SPECIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe</td>
<td>½”-2”</td>
<td>Schedule 80</td>
<td>ANSI B36.10</td>
<td>Black steel pipe, ASTM A-53 Gr. B, ERW</td>
</tr>
<tr>
<td></td>
<td>2 1/2” and Larger</td>
<td>Standard Wall</td>
<td></td>
<td>Black steel pipe, ASTM A-53 Gr. B, CW or ERW</td>
</tr>
<tr>
<td>Equipment Mating Flanges</td>
<td>1/2” – 2”</td>
<td>See Note 2</td>
<td>ANSI B16.5</td>
<td>Steel, 150 lb., socket weld or screwed, ASTM A-181, Gr 1, RF</td>
</tr>
<tr>
<td></td>
<td>2 1/2” and larger</td>
<td></td>
<td></td>
<td>Steel, 150 lb., weld neck or slip-on, ASTM A181, Gr I, RF</td>
</tr>
<tr>
<td>Fittings (option)</td>
<td>2 1/2” and Larger</td>
<td></td>
<td></td>
<td>Grooved ductile iron, ASTM A-536 or A-395, or forged or fabricated from carbon steel pipe, ASTM A-53 or carbon steel ASTM 105, 106 or 235.</td>
</tr>
<tr>
<td>Couplings (option)</td>
<td>2 1/2” and Larger</td>
<td></td>
<td></td>
<td>Victaulic style 177, 107, W77, W07 as applicable; a minimum of three (3) Victaulic series 177 or W77; flexible couplings must be used on pump suction and discharge, and other connections to rotating or vibrating equipment such as cooling towers, chillers. Proper joint assembly for non-tongue &amp; recess couplings shall be verified by visual means (no coupling torque requirements as a primary means of obtaining joint rigidity).</td>
</tr>
<tr>
<td>Unions</td>
<td>1/2” – 2”</td>
<td></td>
<td></td>
<td>Malleable Iron, 250#, ASTM A197, Screwed, for ground joint use flanges</td>
</tr>
<tr>
<td></td>
<td>2 1/2” and larger</td>
<td></td>
<td></td>
<td>Use flanges or Victaulic couplings.</td>
</tr>
<tr>
<td>Fittings</td>
<td>1/2” – 2”</td>
<td></td>
<td>ANSI B16.3</td>
<td>Malleable Iron, 250#, ASTM A126, Screwed</td>
</tr>
<tr>
<td></td>
<td>2 1/2” and Larger</td>
<td>Wall thickness to match pipe</td>
<td>ANSI B16.9 or ASTM A536/395</td>
<td>Steel, Extra Strong, Butt Welded, ASTM A234, WPA or Victaulic grooved ended full-flow, as-cast ductile iron.</td>
</tr>
</tbody>
</table>

### VALVES

<table>
<thead>
<tr>
<th>TYPE</th>
<th>USE</th>
<th>SIZE</th>
<th>STANDARD</th>
<th>SPECIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ball</td>
<td>Block/Isolation</td>
<td>1/2” – 2”</td>
<td>ASTM B62</td>
<td>Bronze, 125# WSP, Screwed (Hammond 8311, Apollo 70-200 or equal)</td>
</tr>
<tr>
<td>Check / Swing Type</td>
<td>Prevent Reverse Flow</td>
<td>1/2” – 2”</td>
<td>ANSI B62</td>
<td>Bronze, 125#, WSP, Screwed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 1/2” and larger</td>
<td>ANSI B16.1</td>
<td>Cast iron, 125#, Flanged, ASTM A-126 Class B, Renewable seat, Swing or piston type</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2” – 3”</td>
<td>AWWA C606</td>
<td>Ductile iron, ASTM A536, horizontal swing, grooved ends, 300 psi CWP, Victaulic Series 716H</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4”–12”</td>
<td></td>
<td>Ductile iron, ASTM A536, horizontal swing, grooved ends, 300 psi CWP, Victaulic Series 716</td>
</tr>
</tbody>
</table>
Silent Type
See note 5

Grooved
Butterfly
Check /

Y
Globe

NOTE
Gaskets

Gaskets

BOLTING AND GASKETS

| Bolting: | Studs: Square or Hex head, ASTM A307, Grade B, 2A threads | Nuts: Heavy Hex, ASTM A194- or A-307, ANSI B18, 2B threads |

| Gaskets | 1/16" Red Rubber or EPDM for grooved fittings; Ring for raised face joints, full face or flat flanges |

| Grooved Coupling Gaskets | Grade “EHP” EPDM with red and green color code suitable for water and oil-free compressed air with operating temperatures from -30 deg F to +250 deg F, available with installation-Ready couplings 2” through 12”.

| Grade “E Flushseal” EPDM with green color code suitable for water and oil-free compressed air with operating temperatures from -30 deg F to +230 deg F, available with standard and AGS couplings 14” and Larger |

NOTES:

1. All welds shall comply with requirements of B31.1
2. Flange bore to match pipe.
3. Grooved couplings and fittings shall only be used in locations that are accessible for maintenance.
4. Triple duty valves shall not be used.
5. Wafer style butterfly valves shall not be used.
6. Other equivalent grooved systems may be considered.
7. Grooved couplings and fittings shall only be used in locations that are accessible for maintenance.
8. Grooved joint piping systems shall be installed in accordance with the manufacturer's (Victaulic) guidelines and recommendations. All grooved couplings, fittings, valves, and specialties shall be the products of a single manufacturer. Grooving tools shall be of the same manufacturer as the grooved components. The gasket style and elastomeric material (grade) shall be verified as suitable for the intended service as specified. Gaskets shall be molded and produced by Victaulic. Grooved end shall be clean and free from indents, projections, and roll marks in the area from pipe end to groove for proper gasket sealing.
9. A Victaulic factory-trained field representative shall provide on-site training for contractor's field personnel in the proper use of grooving tools, verification of groove and installation of grooved piping products. Prior to the installation of Victaulic systems, a formal project-specific contractor kick-off meeting shall be performed by Victaulic with the appropriate subcontractor personnel who will be assigned to each project. A sign-in sheet and confirmation signatures shall be obtained by all attendees as documentation support that any personnel who will be grooving pipe and/or installing Victaulic products has obtained and understands the requirements in the Victaulic installation instructions. Factory-trained representative shall periodically review the product installation. Contractor shall remove and replace any improperly installed products.
10. Where possible, carbon steel grooved pipe 4” and larger shall be produced using the Victaulic RGS200i fully automated grooving tool that provides groove traceability docs, corresponding identification marks on the pipe, and confirms all critical dimensions fall into the required tolerance range as listed by the tool manuf.
**Pipe Class:** 125HHW-S

**Primary ANSI Class:** 125

**Primary Material Use:** Heating Water within buildings

**Date:** Dec, 2016

<table>
<thead>
<tr>
<th>Service Limits</th>
<th>Temperature, °F</th>
<th>150</th>
<th>200</th>
<th>250</th>
<th>300</th>
<th>350</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Pressure, psig</td>
<td>200</td>
<td>185</td>
<td>170</td>
<td>155</td>
<td>140</td>
<td>125</td>
<td>0.05 inch</td>
</tr>
</tbody>
</table>

### PIPE AND FITTINGS

<table>
<thead>
<tr>
<th>ITEM (option)</th>
<th>SIZE</th>
<th>THICKNESS</th>
<th>STANDARD</th>
<th>MATERIAL SPECIFICATION</th>
</tr>
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<tbody>
<tr>
<td>Pipe</td>
<td>½&quot;-2&quot;</td>
<td>Schedule 80</td>
<td>ANSI B36.10</td>
<td>Black steel pipe, ASTM A-53 Gr. B, ERW</td>
</tr>
<tr>
<td></td>
<td>2 1/2&quot; and Larger</td>
<td>Standard Wall</td>
<td>ANSI B36.10</td>
<td>Black steel pipe, ASTM A-53 Gr. B, CW or ERW</td>
</tr>
<tr>
<td>Equipment Mating Flanges</td>
<td>1/2&quot; – 2&quot;</td>
<td>See Note 2</td>
<td>ANSI B16.5</td>
<td>Steel, 150 lb., socket weld or screwed, ASTM A-181, Gr 1, RF</td>
</tr>
<tr>
<td></td>
<td>2 1/2&quot; and larger</td>
<td>See Note 2</td>
<td>ANSI B16.3</td>
<td>Steel, 150 lb., weld neck or slip-on, ASTM A181, Gr I, RF</td>
</tr>
<tr>
<td>Fittings (option) See note 3</td>
<td>2 1/2&quot; and Larger</td>
<td>Grooved ductile iron, ASTM A-536 or A-395, or forged or fabricated from carbon steel pipe, ASTM A-53 or carbon steel ASTM 105, 106 or 235.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Couplings (option) See note 3</td>
<td>2 1/2&quot; and Larger</td>
<td>Victaulic style 177, 107, W77, W07 as applicable; a minimum of three (3) Victaulic series 177 or W77, flexible couplings must be used on pump suction and discharge, and other connections to rotating or vibrating equipment such as cooling towers, chillers. Proper joint assembly for non-tongue &amp; recess couplings shall be verified by visual means (no coupling torque requirements as a primary means of obtaining joint rigidity).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unions</td>
<td>1/2&quot; – 2&quot;</td>
<td>Malleable Iron, 250#, ASTM A197, Screwed, for ground joint use flanges</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 1/2&quot; and larger</td>
<td>Use flanges or Victaulic couplings.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fittings</td>
<td>1/2&quot; – 2&quot;</td>
<td>ANSI B16.3</td>
<td>Malleable Iron, 250#, ASTM A126, Screwed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 1/2&quot; and Larger</td>
<td>ANSI B16.9 or ASTM A536/395</td>
<td>Steel, Extra Strong, Butt Welded, ASTM A234, WPA or Victaulic grooved ended full-flow, as-cast ductile iron.</td>
<td></td>
</tr>
</tbody>
</table>

### VALVES

<table>
<thead>
<tr>
<th>TYPE</th>
<th>USE</th>
<th>SIZE</th>
<th>STANDARD</th>
<th>SPECIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ball</td>
<td>Block/Isolation</td>
<td>1/2&quot; – 2&quot;</td>
<td>ASTM B62</td>
<td>Bronze, 125# WSP, Screwed (Hammond 8311, Apollo 70-200 or equal)</td>
</tr>
<tr>
<td>Check / Swing Type</td>
<td>Prevent Reverse Flow</td>
<td>1/2&quot; – 2&quot;</td>
<td>ASTM B62</td>
<td>Bronze, 125#, WSP, Screwed</td>
</tr>
<tr>
<td></td>
<td>2 1/2&quot; and larger</td>
<td>ANSI B16.1</td>
<td>Cast iron, 125#, Flanged, ASTM A-126 Class B, Renewable seat, Swing or piston type</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2&quot; – 3&quot;</td>
<td>AWWA C606</td>
<td>Ductile iron, ASTM A536, horizontal swing, grooved ends, 300 psi CWP, Victaulic Series 716H</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4&quot; – 12&quot;</td>
<td>AWWA C606</td>
<td>Ductile iron, ASTM A536, horizontal swing, grooved ends, 300 psi CWP, Victaulic Series 716</td>
<td></td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Check / Silent Type</th>
<th>Prevent Reverse Flow at Pump Discharge</th>
<th>$1/2'' - 2''$</th>
<th>ASTM B62</th>
<th>Spring loaded, Center guided, Manufactured by Williams-Hager, Miller, Mueller, Bronze, 125# screwed ends</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 1/2'' and Larger</td>
<td>$2 1/2'' - 2''$</td>
<td>ASTM A126 CL B</td>
<td>Spring loaded, Center guided, Manufactured by Williams-Hager, Miller, Mueller, with Cast iron, flanged ends, or Victaulic Tri-Service valve assembly.</td>
<td></td>
</tr>
<tr>
<td>Y-Pattern Globe</td>
<td>Manual Balancing</td>
<td>$1/2''$ and Larger</td>
<td>Multi-tube, ductile-iron or bronze body, with screwed, soldered, flanged or grooved ends. Digital handwheel with concealed/tamperproof locking device to permit full valve closure and re-opening to set position.</td>
<td></td>
</tr>
<tr>
<td>Butterfly See note 5</td>
<td>Block Isolation</td>
<td>$2 1/2'' - 2''$ and Larger</td>
<td>For main line isolation valves which separate the building from the campus system and other critical locations, provide high performance valves designed for bubble tight shut-off at a minimum of 200 psig differential pressure with water at 150°F. For installations between flanges, provide lug type or flanged valves. Provide steel body, worm gear operated, SS shaft, bronze or Ni-Resist disc, and Buna-N seat. Victaulic 300 MasterSeal (2''-12'') or Vic-300 AGS (14'' - 24'') are acceptable.</td>
<td></td>
</tr>
</tbody>
</table>

**BOLTING AND GASKETS**

<table>
<thead>
<tr>
<th>Bolting:</th>
<th>Studs: Square or Hex head, ASTM A307, Grade B, 2A threads</th>
<th>Nuts: Heavy Hex, ASTM A194- or A-307, ANSI B18, 2B threads</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gaskets</td>
<td>1/16'' Red Rubber or EPDM for grooved fittings; Ring for raised face joints, full face or flat flanges</td>
<td></td>
</tr>
<tr>
<td>Grooved Coupling Gaskets</td>
<td>Grade &quot;EHF&quot; EPDM with red color code suitable for water and oil-free compressed air with operating temperatures from -30 deg F to +250 deg F, available with Installation-Ready couplings 2'' through 12''..</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grade &quot;E Flushseal&quot; EPDM with green color code suitable for water and oil-free compressed air with operating temperatures from -30 deg F to +230 deg F, available with standard and AGS couplings 14'' and Larger</td>
<td></td>
</tr>
</tbody>
</table>

**NOTES:**

1. All welds shall comply with requirements of B31.1
2. Flange bore to match pipe.
3. Grooved couplings and fittings shall only be used in locations that are accessible for maintenance.
4. Triple duty valves shall not be used.
5. Wafer style butterfly valves shall not be used.
6. Other equivalent grooved systems may be considered.
7. Grooved couplings and fittings shall only be used in locations that are accessible for maintenance.
8. Grooved joint piping systems shall be installed in accordance with the manufacturer's (Victaulic) guidelines and recommendations. All grooved couplings, fittings, valves, and specialties shall be the products of a single manufacturer. Grooving tools shall be of the same manufacturer as the grooved components. The gasket style and elastomeric material (grade) shall be verified as suitable for the intended service as specified. Gaskets shall be molded and produced by Victaulic. Grooved end shall be clean and free from indentations, projections, and roll marks in the area from pipe end to groove for proper gasket sealing.
9. A Victaulic factory-trained field representative shall provide on-site training for contractor's field personnel in the proper use of grooving tools, verification of groove and installation of grooved piping products. Prior to the installation of Victaulic systems, a formal project-specific contractor kick-off meeting shall be performed by...
Victaulic with the appropriate subcontractor personnel who will be assigned to each project. A sign-in sheet and confirmation signatures shall be obtained by all attendees as documentation support that any personnel who will be grooving pipe and/or installing Victaulic products has obtained and understands the requirements as put forth by Victaulic installation instructions. Factory-trained representative shall periodically review the product installation. Contractor shall remove and replace any improperly installed products.

10. Where possible, carbon steel grooved pipe 4” and larger shall be produced using the Victaulic RG5200i fully automated grooving tool that provides groove traceability documentation, corresponding identification marks on the pipe, and confirms all critical dimensions fall into the required tolerance range as listed by the tool manufacturer.
APPENDIX C: PIPE CLASS 150L AND 125C (LOW PRESSURE STEAM AND CONDENSATE)
Pipe Class: 150L  
Material: Carbon Steel

Primary ANSI Class: 150 and 125  
Primary Material Use: Low Pressure Steam  
Date: Dec, 2016

<table>
<thead>
<tr>
<th>Temperature, °F</th>
<th>150</th>
<th>200</th>
<th>250</th>
<th>300</th>
<th>350</th>
<th>406</th>
<th>Limits established by ASTM B-62, pressure Class 125</th>
<th>Corrosion Allowance 0.05 inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure, psig</td>
<td>200</td>
<td>185</td>
<td>170</td>
<td>155</td>
<td>155</td>
<td>125</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**PIPE AND FITTINGS**

<table>
<thead>
<tr>
<th>ITEM</th>
<th>SIZE</th>
<th>THICKNESS</th>
<th>STANDARD</th>
<th>MATERIAL SPECIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 ½” and larger</td>
<td>Schedule 40 or std. wall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flanges</td>
<td>¼” – 2”</td>
<td>Bore to match pipe diam.</td>
<td>ANSI B16.5</td>
<td>Socket weld 150 lb. raised face flange, ASTM A-181, Gr. I</td>
</tr>
<tr>
<td></td>
<td>2 ½” and larger</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Threaded Fittings</td>
<td>¼” – 2”</td>
<td>250 lb.</td>
<td>ANSI B16.4</td>
<td>Screwed, Cast Iron, ASTM A-126 Class B</td>
</tr>
<tr>
<td>Weld Fittings</td>
<td>2 ½” and larger</td>
<td>Wall thickness to match pipe</td>
<td>ANSI B16.9</td>
<td>Butt weld, steel, ASTM A-234WPB</td>
</tr>
<tr>
<td>Unions</td>
<td>½“-2”</td>
<td>300 lb.</td>
<td>ANSI B16.3</td>
<td>Screwed, malleable iron ASTM A-197</td>
</tr>
</tbody>
</table>

**VALVES**

<table>
<thead>
<tr>
<th>TYPE</th>
<th>USE</th>
<th>SIZE</th>
<th>STANDARD</th>
<th>SPECIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gate</td>
<td>Block/Isolation</td>
<td>½” – 2”</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 ½” - 24”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Globe</td>
<td>Throttling</td>
<td>½” – 2”</td>
<td>ANSI B16.34</td>
<td>Cast iron ASTM A-126 Class B, 125 lb, bolted bonnet, OS&amp;Y, bronze trim, flanged ends, Crane Fig. 465 or MIT approved equal</td>
</tr>
<tr>
<td></td>
<td>2 ½” and larger</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Check/ Swing Type</td>
<td>Prevent Reverse Flow</td>
<td>½” – 2”</td>
<td>ANSI B16.34</td>
<td>Screwed end with bronze ASTM B-62 body, and bronze or brass disc holder, PTFE composite similar to Stockham Fig B-320TY or MIT approved equal</td>
</tr>
<tr>
<td></td>
<td>2 ½” and larger</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traps</td>
<td>All</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**BOLTING AND GASKETS**

<table>
<thead>
<tr>
<th>Bolting:</th>
<th>Studs: ASTM A-193, Square or hex head, 2A threads</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gaskets</td>
<td>1/16” Anchor Packing 443A, Flexitallic, Remantite, or Garlock Blueguard, 150 lb. ring for steel to steel, full face for flat flange</td>
</tr>
</tbody>
</table>

**NOTES:**

1. Use flanges for equipment connections 2 ½” and larger
2. All welds shall comply with the requirements of B31.1
### Pipe Class:

- **125C**

### Material:

- **Carbon Steel**

#### Primary ANSI Class:

- 150 and 125

#### Primary Material Use:

- Low Pressure Condensate

#### Date:

- Dec, 2016

<table>
<thead>
<tr>
<th>Service Limits</th>
<th>Temperature, °F</th>
<th>150</th>
<th>200</th>
<th>250</th>
<th>300</th>
<th>350</th>
<th>406</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure, psig</td>
<td></td>
<td>200</td>
<td>185</td>
<td>170</td>
<td>155</td>
<td>155</td>
<td>125</td>
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</tbody>
</table>

Corrosion Allowance: 0.05 inch

<table>
<thead>
<tr>
<th>ITEM</th>
<th>SIZE (if applicable)</th>
<th>STANDARD</th>
<th>MATERIAL SPECIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flanges</td>
<td>¼&quot; – 2&quot;</td>
<td>Bore to match pipe diam.</td>
<td>ANSI B16.5</td>
</tr>
<tr>
<td>Flanges</td>
<td>2 ¼&quot; and larger</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Threaded fittings</td>
<td>¼&quot; – 2&quot;</td>
<td>250 lb.</td>
<td>ANSI B16.4</td>
</tr>
<tr>
<td>Threaded fittings</td>
<td>2 ¼&quot; and larger</td>
<td>Wall thickness to match pipe</td>
<td>ANSI B16.9</td>
</tr>
<tr>
<td>Weld fittings</td>
<td>¼&quot;-2&quot;</td>
<td>300 lb.</td>
<td>ANSI B16.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ITEM</th>
<th>USE</th>
<th>SIZE</th>
<th>STANDARD</th>
<th>SPECIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gate</td>
<td>Block/Isolation</td>
<td>½&quot; – 2&quot;</td>
<td>Screwed end with bronze ASTM B-62 body, bonnet, and disc holder. PTFE composite disc and copper silicon steel stem Stockham Fig B-13T or MIT approved equal</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 ½&quot; – 24&quot;</td>
<td>ANSI B16.34</td>
<td>Cast iron ASTM A-126 Class B, 125 lb, bolted bonnet, OS&amp;Y, bronze trim, flanged ends, Crane Fig. 465 ½ or MIT approved equal</td>
</tr>
<tr>
<td>Globe</td>
<td>Throttling</td>
<td>½&quot; – 2&quot;</td>
<td>Screwed end with bronze ASTM B-62 body, bonnet, and disc holder. PTFE composite disc and copper silicon steel stem similar to Stockham Fig B-16 or MIT approved equal</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 ½&quot; and larger</td>
<td>ANSI B16.34</td>
<td>Cast iron ASTM A-126 Class B, 125 lb, bolted bonnet, OS&amp;Y, bronze trim, flanged ends, Crane Fig. 351 or MIT approved equal</td>
</tr>
<tr>
<td>Check/Swing Type</td>
<td>Prevent Reverse Flow</td>
<td>½&quot; – 2&quot;</td>
<td>Screwed end with bronze ASTM B-62 body, and bronze or brass disc holder. PTFE composite similar to Stockham Fig B-320TY or MIT approved equal</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 ½&quot; and larger</td>
<td>ANSI B16.34</td>
<td>Cast iron ASTM A-126 Class B, 125 lb, bolted cap, bronze trim. flanged ends, Crane Fig. 373 or MIT approved equal</td>
</tr>
<tr>
<td>Traps</td>
<td>All</td>
<td></td>
<td></td>
<td>Cast steel or forged steel, 150 lb. bucket type</td>
</tr>
</tbody>
</table>

**Bolting and Gaskets**

- **Bolting:**
  - Studs: ASTM A-193, Square or hex head, 2A threads
  - Hex Nuts: Heavy hex, ASTM A-194, ANSI B18, 2B threads

- **Gaskets:**
  - 1/16" Anchor Packing 443A, Flexitallic, Remantite, or Garlock Blueguard, 150 lb. ring for steel to steel, full face for flat flange

**NOTES:**

1. Use flanges for equipment connections 2 ½" and larger
2. All welds shall comply with the requirements of B31.1
APPENDIX D: PIPE CLASS 150 AND 150C (MEDIUM PRESSURE STEAM AND CONDENSATE)
<table>
<thead>
<tr>
<th>Pipe Class: 150</th>
<th>Material: Carbon Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary ANSI Class: 150</td>
<td>Primary Material Use: Medium Pressure Steam</td>
</tr>
<tr>
<td>Date: Dec, 2016</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Service Limits</th>
<th>Temperature, °F</th>
<th>100</th>
<th>200</th>
<th>300</th>
<th>400</th>
<th>500</th>
<th>600</th>
<th>Corrosion Allowance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure, psig</td>
<td>285</td>
<td>260</td>
<td>230</td>
<td>200</td>
<td>170</td>
<td>140</td>
<td></td>
<td>0.05 inch</td>
</tr>
</tbody>
</table>

### PIPE AND FITTINGS

<table>
<thead>
<tr>
<th>ITEM</th>
<th>SIZE</th>
<th>THICKNESS</th>
<th>STANDARD</th>
<th>MATERIAL SPECIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 ½” and larger</td>
<td>Schedule 40 or std. wall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flanges</td>
<td>½” – 2”</td>
<td>Bore to match pipe diam.</td>
<td>ANSI B16.5</td>
<td>Socket weld 150 lb. raised face flange, ASTM A-181, Gr. I</td>
</tr>
<tr>
<td></td>
<td>2 ½” and larger</td>
<td></td>
<td></td>
<td>Weld neck 150 lb. raised face flange, ASTM A-181, Gr. I</td>
</tr>
<tr>
<td>Fittings</td>
<td>½” – 2”</td>
<td>3,000 lb.</td>
<td>ANSI B16.11</td>
<td>Socket welded forged carbon steel, ASTM A-105, Gr. II</td>
</tr>
<tr>
<td></td>
<td>2 ½” and larger</td>
<td>Standard</td>
<td>ANSI B16.9</td>
<td>Carbon steel, standard butt weld ASTM A-234 WPB</td>
</tr>
<tr>
<td>Unions</td>
<td>½”-2”</td>
<td>3,000 lb.</td>
<td>ANSI B16.11</td>
<td>Socket welded forged carbon steel, ASTM A-105, Gr. II, ground joint</td>
</tr>
<tr>
<td></td>
<td>2 ½” and larger</td>
<td>See Note 1</td>
<td>ANSI B16.5</td>
<td></td>
</tr>
</tbody>
</table>

### VALVES

<table>
<thead>
<tr>
<th>TYPE</th>
<th>USE</th>
<th>SIZE</th>
<th>STANDARD</th>
<th>SPECIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gate</td>
<td>Block/Isolation</td>
<td>¼” – 2”</td>
<td>ANSI B16.34</td>
<td>Cast carbon steel ASTM A-216 Gr. WCB, bolted bonnet, OS&amp;Y, stainless steel trim, butt welded ends, ANSI Class 150. Velan API 600, Crane Fig. 47 ½, or MIT approved equal.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 ½” and larger</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Globe</td>
<td>Throttling</td>
<td>¼” – 2”</td>
<td>ANSI B16.34</td>
<td>Cast carbon steel ASTM A-216 Gr. WCB, bolted bonnet, OS&amp;Y, stainless steel trim, butt welded ends, ANSI Class 150. Velan API 600, Crane Fig. 143 ½, or MIT approved equal.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 ½” and larger</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Check/Swing Type</td>
<td>Prevent Reverse Flow</td>
<td>¼” – 2”</td>
<td>ANSI B16.34</td>
<td>Cast carbon steel ASTM A-216 Gr. WCB, bolted bonnet, OS&amp;Y, stainless steel trim, butt welded ends, ANSI Class 150. Velan API 600, Crane Fig. 147 ½, or MIT approved equal.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 ½” and larger</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traps</td>
<td>All</td>
<td></td>
<td></td>
<td>Cast steel or forged steel, 300 lb. bucket type</td>
</tr>
</tbody>
</table>
## BOLTING AND GASKETS

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Gaskets</td>
<td>1/16” Anchor Packing 443A, Flexitallic, Remantite, or Garlock Blueguard, 300 lb. for steel on steel, full face for flat flange</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### NOTES:
1. Use flanges for equipment connections 2 1/8” and larger
2. All welds shall comply with the requirements of B31.1
3. Valve packing for 150 class and 800 class steam service valves shall be non-hardening PTFE impregnated packing yarn similar to Chesterton style 1724.
Pipe Class: 150C
Material: Carbon Steel

<table>
<thead>
<tr>
<th>Primary ANSI Class:</th>
<th>150</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Material Use:</td>
<td>Medium Pressure Condensate</td>
</tr>
<tr>
<td>Date:</td>
<td>Dec, 2016</td>
</tr>
</tbody>
</table>

### Service Limits

<table>
<thead>
<tr>
<th>Temperature, °F</th>
<th>100</th>
<th>200</th>
<th>300</th>
<th>400</th>
<th>500</th>
<th>600</th>
<th>Corrosion Allowance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure, psig</td>
<td>285</td>
<td>260</td>
<td>230</td>
<td>200</td>
<td>170</td>
<td>140</td>
<td>0.05 inch</td>
</tr>
</tbody>
</table>

### Pipe and Fittings

<table>
<thead>
<tr>
<th>ITEM</th>
<th>SIZE</th>
<th>THICKNESS</th>
<th>STANDARD</th>
<th>MATERIAL SPECIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flanges</td>
<td>1/2&quot; and larger</td>
<td>Schedule 160</td>
<td>ANSI B36.10</td>
<td>ASTM A-106 Gr. B or ASTM A-53 Gr. B</td>
</tr>
<tr>
<td></td>
<td>1/2&quot; – 2&quot;</td>
<td>Bore to match pipe diam.</td>
<td>ANSI B16.5</td>
<td>Socket weld 150 lb. raised face flange, ASTM A-181, Gr. I</td>
</tr>
<tr>
<td></td>
<td>2 ½” and larger</td>
<td></td>
<td></td>
<td>Weld neck 150 lb. raised face flange, ASTM A-181, Gr. I</td>
</tr>
<tr>
<td>Fittings</td>
<td>¾” – 2&quot;</td>
<td>3,000 lb.</td>
<td>ANSI B16.11</td>
<td>Socket welded forged CS steel, ASTM A-105, Gr. II</td>
</tr>
<tr>
<td></td>
<td>2 ½” and larger</td>
<td>Wall thickness to match pipe</td>
<td>ANSI B16.9</td>
<td>Carbon steel, standard butt weld ASTM A-234 WPB</td>
</tr>
<tr>
<td>Unions</td>
<td>½&quot; - 2&quot;</td>
<td>3,000 lb.</td>
<td>ANSI B16.11</td>
<td>Socket welded forged carbon steel, ASTM A-105, Gr. II, ground joint</td>
</tr>
<tr>
<td></td>
<td>2 ½” and larger</td>
<td>See Note 1</td>
<td>ANSI B16.5</td>
<td></td>
</tr>
</tbody>
</table>

### Valves

<table>
<thead>
<tr>
<th>TYPE</th>
<th>USE</th>
<th>SIZE</th>
<th>STANDARD</th>
<th>SPECIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gate</td>
<td>Block/Isolation</td>
<td>½&quot; – 2&quot;</td>
<td>ANSI B16.34</td>
<td>Forged carbon steel ASTM A-105, bolted bonnet, OS&amp;Y, stainless steel trim, socket welded ends ANSI Class 800. Velan 2054B or MIT approved equal.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 ½” and larger</td>
<td></td>
<td>Cast carbon steel ASTM A-216 Gr. WCB, bolted bonnet, OS&amp;Y, stainless steel trim, butt welded ends, ANSI Class 150. Velan API 600, Crane Fig. 47 ½ , or MIT approved equal.</td>
</tr>
<tr>
<td>Globe</td>
<td>Throttling</td>
<td>½&quot; – 2&quot;</td>
<td>ANSI B16.34</td>
<td>Forged carbon steel ASTM A-105, bolted bonnet, OS&amp;Y, stainless steel trim, socket welded ends, ANSI Class 800. Velan 2074B or MIT approved equal.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 ½” and larger</td>
<td></td>
<td>Cast carbon steel ASTM A-216 Gr. WCB, bolted bonnet, OS&amp;Y, stainless steel trim, butt welded ends, ANSI Class 150. Velan API 600, Crane Fig. 143 ½ , or MIT approved equal.</td>
</tr>
<tr>
<td>Check/Swing Type</td>
<td>Prevent Reverse Flow</td>
<td>½&quot; – 2&quot;</td>
<td>ANSI B16.34</td>
<td>Forged carbon steel ASTM A-105, bolted bonnet, OS&amp;Y, stainless steel trim, socket welded ends, ANSI Class 800. Velan 114B or MIT approved equal.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 ½” and larger</td>
<td></td>
<td>Cast carbon steel ASTM A-216 Gr. WCB, bolted bonnet, OS&amp;Y, stainless steel trim, butt welded ends, ANSI Class 150. Velan API 600, Crane Fig. 147 ½ , or MIT approved equal.</td>
</tr>
<tr>
<td>Traps</td>
<td>All</td>
<td></td>
<td></td>
<td>Cast steel or forged steel, 300 lb. bucket type</td>
</tr>
<tr>
<td>BOLTING AND GASKETS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Bolting:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Studs: ASTM A-193, Grade B7, heavy hex</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hex Nuts: ASTM A-194, Class 2H, heavy hex</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cap Screws: ASTM A-325</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Gaskets:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/16” Anchor Packing 443A, Flexitallic, Remantite, or Garlock Blueguard, 300 lb. for steel on steel, full face for flat flange</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**NOTES:**
1. Use flanges for equipment connections 2 ½” and larger
2. All welds shall comply with the requirements of B31.1
3. Valve packing for 150 class and 800 class steam condensate service valves shall be non-hardening PTFE impregnated packing yarn similar to Chesterton style 1724.
APPENDIX E: PIPE CLASS 300 AND 300C (HIGH PRESSURE STEAM AND CONDENSATE)
Pipe Class: 300  
Material: Carbon Steel

<table>
<thead>
<tr>
<th>Service Limits</th>
<th>Temperature, °F</th>
<th>100</th>
<th>200</th>
<th>300</th>
<th>400</th>
<th>500</th>
<th>600</th>
<th>Corrosion Allowance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure, psig</td>
<td></td>
<td>740</td>
<td>675</td>
<td>655</td>
<td>635</td>
<td>600</td>
<td>550</td>
<td>0.05 inch</td>
</tr>
</tbody>
</table>

### PIPE AND FITTINGS

<table>
<thead>
<tr>
<th>ITEM</th>
<th>SIZE</th>
<th>THICKNESS</th>
<th>STANDARD</th>
<th>MATERIAL SPECIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 ½” and larger</td>
<td>Schedule 40</td>
<td>ANSI B36.10</td>
<td>ASTM A-106 Gr. B or ASTM A-53 Gr. B</td>
</tr>
<tr>
<td>Flanges</td>
<td>½” – 2”</td>
<td>Bore to match pipe diam.</td>
<td>ANSI B16.5</td>
<td>Socket weld 300 lb. raised face flange, ASTM A-105, Gr. II</td>
</tr>
<tr>
<td></td>
<td>2 ½” and larger</td>
<td>Bore to match pipe diam.</td>
<td>ANSI B16.5</td>
<td>Weld neck 300 lb. raised face flange, ASTM A-105, Gr. II</td>
</tr>
<tr>
<td>Fittings</td>
<td>½” – 2”</td>
<td>3,000 lb.</td>
<td>ANSI B16.11</td>
<td>Socket welded forged carbon steel, ASTM A-105, Gr. II</td>
</tr>
<tr>
<td></td>
<td>2 ½” and larger</td>
<td>Wall thickness to match pipe</td>
<td>ANSI B16.9</td>
<td>Butt weld seamless ASTM A-234 WPB</td>
</tr>
</tbody>
</table>

### VALVES

<table>
<thead>
<tr>
<th>TYPE</th>
<th>USE</th>
<th>SIZE</th>
<th>STANDARD</th>
<th>SPECIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gate</td>
<td>Block/isolation</td>
<td>½” – 2”</td>
<td>ANSI B16.34</td>
<td>Forged carbon steel ASTM A-105, bolted bonnet, OS&amp;Y, stainless steel trim, socket welded ends, ANSI Class 800. Velan 2054B, or MIT approved equal.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 ½” and larger</td>
<td>ANSI B16.34</td>
<td>Cast carbon steel ASTM A-216 Gr. WCB, bolted bonnet, OS&amp;Y, stainless steel trim, butt welded ends. ANSI Class 300. Velan API 600, Crane Fig. 33 ½, or MIT approved equal.</td>
</tr>
<tr>
<td>Globe</td>
<td>Throttling</td>
<td>½” – 2”</td>
<td>ANSI B16.34</td>
<td>For valves located at the service branch to the building, division valves on the campus steam loop, or the individual feed valve to any pressure reducing station, use Adams Class 300 rotary tight shut-off valve, MAK type, with manual gear operator or MIT approved equal.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 ½” and larger</td>
<td>ANSI B16.34</td>
<td>Cast carbon steel ASTM A-216 Gr. WCB, bolted bonnet, OS&amp;Y, stainless steel trim, butt welded ends, ANSI Class 300. Velan API 600, Crane Fig. 151 ½, or MIT approved equal.</td>
</tr>
<tr>
<td>Check/Swing Type</td>
<td>Prevent Reverse Flow</td>
<td>½” – 2”</td>
<td>ANSI B16.34</td>
<td>Forged carbon steel ASTM A-105, bolted bonnet, OS&amp;Y, stainless steel trim, socket welded ends, ANSI Class 800. Velan 114B or MIT approved equal.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 ½” and larger</td>
<td>ANSI B16.34</td>
<td>Cast carbon steel ASTM A-216 Gr. WCB, bolted bonnet, OS&amp;Y, stainless steel trim, butt welded ends, ANSI Class 300. Velan API 600, Crane Fig. 159 ½ or MIT approved equal.</td>
</tr>
</tbody>
</table>

Traps: All Cast steel or forged steel, 300 lb. bucket type
## BOLTING AND GASKETS

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Gaskets</td>
<td>1/16&quot; Anchor Packing 443A, Flexitallic, Remantite, or Garlock Blueguard, 300 lb. for steel on steel, full face for flat flange</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**NOTES:**

7. All welds shall comply with the requirements of B31.1
8. Valve packing for 300 class and 800 class steam service valves shall be non-hardening PTFE impregnated packing yarn similar to Chesterton style 1724.
### Pipe Class:

<table>
<thead>
<tr>
<th>Material: Carbon Steel</th>
</tr>
</thead>
</table>

#### Primary ANSI Class:

<table>
<thead>
<tr>
<th>Primary Material Use:</th>
</tr>
</thead>
</table>

#### Date:

<table>
<thead>
<tr>
<th>Corrosion Allowance:</th>
</tr>
</thead>
</table>

#### Temperature, °F

<table>
<thead>
<tr>
<th>Service Limits</th>
<th>100</th>
<th>200</th>
<th>300</th>
<th>400</th>
<th>500</th>
<th>600</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure, psig</td>
<td>740</td>
<td>675</td>
<td>655</td>
<td>635</td>
<td>600</td>
<td>550</td>
</tr>
</tbody>
</table>

### PIPE AND FITTINGS

<table>
<thead>
<tr>
<th>ITEM</th>
<th>SIZE</th>
<th>THICKNESS</th>
<th>STANDARD</th>
<th>MATERIAL SPECIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe</td>
<td>¾” and larger</td>
<td>Schedule XSS</td>
<td>ANSI B36.10</td>
<td>ASTM A-106 Gr. B or ASTM A-53 Gr. B</td>
</tr>
<tr>
<td>Flanges</td>
<td>¼” – 2”</td>
<td>Bore to match pipe diam.</td>
<td>ANSI B16.5</td>
<td>Socket weld 300 lb. raised face flange, ASTM A-105, Gr. II</td>
</tr>
<tr>
<td></td>
<td>2 ½” and larger</td>
<td></td>
<td></td>
<td>Weld neck 300 lb. raised face flange, ASTM A-105, Gr. II</td>
</tr>
<tr>
<td>Fittings</td>
<td>½” – 2”</td>
<td>3,000 lb.</td>
<td>ANSI B16.11</td>
<td>Socket welded forged carbon steel, ASTM A-105, Gr. II</td>
</tr>
<tr>
<td></td>
<td>2 ½” and larger</td>
<td>Wall thickness to match pipe</td>
<td>ANSI B16.9</td>
<td>Butt weld seamless ASTM A-234 WPB</td>
</tr>
</tbody>
</table>

### VALVES

<table>
<thead>
<tr>
<th>TYPE</th>
<th>USE</th>
<th>SIZE</th>
<th>STANDARD</th>
<th>SPECIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gate</td>
<td>Block/Isolation</td>
<td>¾” – 2”</td>
<td>ANSI B16.34</td>
<td>Cast carbon steel ASTM A-216 Gr. WCB, bolted bonnet, OS&amp;Y, stainless steel trim, butt welded ends, ANSI Class 300. Velan API 600, Crane Fig. 33 ½, or MIT approved equal.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 ½” and larger</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Globe</td>
<td>Throttling</td>
<td>½” – 2”</td>
<td>ANSI B16.34</td>
<td>Cast carbon steel ASTM A-216 Gr. WCB, bolted bonnet, OS&amp;Y, stainless steel trim, butt welded ends, ANSI Class 300. Velan API 600, Crane Fig. 151 ½, or MIT approved equal.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 ½” and larger</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Check/Swing Type</td>
<td>Prevent Reverse Flow</td>
<td>¾” – 2”</td>
<td>ANSI B16.34</td>
<td>Cast carbon steel ASTM A-216 Gr. WCB, bolted bonnet, OS&amp;Y, stainless steel trim, butt welded ends, ANSI Class 300. Velan API 600, Crane Fig. 159 ½ or MIT approved equal.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 ½” and larger</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Traps

| All | Cast steel or forged steel, 300 lb. bucket type |

### BOLTING AND GASKETS

<table>
<thead>
<tr>
<th>Bolting:</th>
<th>Studs: ASTM A-193, Grade B7, heavy hex</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hex Nuts: ASTM A-194, Class 2H, heavy hex</td>
</tr>
<tr>
<td></td>
<td>Cap Screws: ASTM A-325</td>
</tr>
<tr>
<td>Gaskets</td>
<td>1/16” Anchor Packing 443A, Flexitaitic, Remantite, or Garlock Blueguard, 300 lb. for steel on steel, full face for flat flange</td>
</tr>
</tbody>
</table>

### NOTES:

1. All welds shall comply with the requirements of B31.1
2. Valve packing for 300 class and 800 class steam condensate service valves shall be non-hardening PTFE impregnated packing yarn similar to Chesterton style 1724.
Pipe Class: 150F  
Material: Carbon Steel

<table>
<thead>
<tr>
<th>Primary ANSI Class: 150</th>
<th>Primary Material Use: Fuel Oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date: Sept, 2016</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Service Limits</th>
<th>Temperature, °F</th>
<th>150</th>
<th>200</th>
<th>250</th>
<th>300</th>
<th>350</th>
<th>406</th>
<th>Corrosion Allowance 0.05 inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure, psig</td>
<td>225</td>
<td>210</td>
<td>195</td>
<td>180</td>
<td>165</td>
<td>150</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### PIPE AND FITTINGS

<table>
<thead>
<tr>
<th>ITEM</th>
<th>SIZE</th>
<th>THICKNESS</th>
<th>STANDARD</th>
<th>MATERIAL SPECIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 ½&quot; and larger</td>
<td>Schedule 40 or std. wall</td>
<td></td>
<td>ASTM A-106 Gr. B or ASTM A-53 Gr. B</td>
</tr>
<tr>
<td>Flanges</td>
<td>½&quot; – 2&quot;</td>
<td>Bore to match pipe diam.</td>
<td>ANSI B16.5</td>
<td>Socket weld 150 lb. raised face flange, ASTM A-181, Gr. I</td>
</tr>
<tr>
<td></td>
<td>2 ½&quot; and larger</td>
<td>Wall thickness to match pipe</td>
<td></td>
<td>Weld neck 150 lb. raised face flange, ASTM A-181, Gr. I or A-105 Gr I</td>
</tr>
<tr>
<td>Fittings</td>
<td>½&quot; – 2&quot;</td>
<td>150 lb.</td>
<td>ANSI B16.3</td>
<td>Malleable iron, screwed ASTM A-197</td>
</tr>
<tr>
<td></td>
<td>2 ½&quot; and larger</td>
<td>Wall thickness to match pipe</td>
<td>ANSI B16.9</td>
<td>Carbon steel, standard butt weld ASTM A-234 WPA</td>
</tr>
<tr>
<td>Unions</td>
<td>½&quot;-2&quot;</td>
<td>300 lb.</td>
<td>ANSI B16.3</td>
<td>Malleable iron, screwed ASTM A-197</td>
</tr>
</tbody>
</table>

### VALVES

<table>
<thead>
<tr>
<th>TYPE</th>
<th>USE</th>
<th>SIZE</th>
<th>STANDARD</th>
<th>SPECIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gate</td>
<td>Block/Isolation</td>
<td>½&quot; – 2&quot;</td>
<td>ANSI B16.34</td>
<td>Screwed end, rising stem with bronze ASTM B-62 body, bonnet, and disc. Crane 431 UB or MIT approved equal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 ½&quot; and larger</td>
<td></td>
<td>Cast carbon steel ASTM A-216 Gr. WCB, 150 lb. ANSI rating, bolted bonnet, OS&amp;Y, stainless steel trim, butt welded ends. Crane Fig. 47 ½, or MIT approved equal.</td>
</tr>
<tr>
<td>Globe</td>
<td>Throttling</td>
<td>½&quot; – 2&quot;</td>
<td>ANSI B16.34</td>
<td>Screwed end, rising stem with bronze ASTM B-62 body, bonnet, and disc. Crane 7TF or MIT approved equal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 ½&quot; and larger</td>
<td></td>
<td>Cast carbon steel ASTM A-216 Gr. WCB, 150 lb. ANSI rating, bolted bonnet, OS&amp;Y, stainless steel trim, butt welded ends. Crane Fig. 143 ½, or MIT approved equal.</td>
</tr>
<tr>
<td>Check/Swing Type</td>
<td>Prevent Reverse Flow</td>
<td>½&quot; – 2&quot;</td>
<td>ANSI B16.34</td>
<td>Screwed end, with bronze ASTM B-62 body, and disc. Crane 137 or MIT approved equal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 ½&quot; and larger</td>
<td></td>
<td>Cast carbon steel ASTM A-216 Gr. WCB, 150 lb. ANSI rating, bolted bonnet, OS&amp;Y, stainless steel trim, butt welded ends. Crane Fig. 147 ½, or MIT approved equal.</td>
</tr>
</tbody>
</table>

### BOLTING AND GASKETS

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Gaskets:</td>
<td>1/16&quot; Anchor Packing 445, Flexitallic, Remantite, or Garlock Blueguard</td>
<td></td>
</tr>
</tbody>
</table>

**NOTES:**
1. All welds shall comply with the requirements of B31.1
# APPENDIX G: STRAINER TABLE

<table>
<thead>
<tr>
<th>CLASS</th>
<th>SIZE</th>
<th>SPECIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>125 CHW-C, 125 HHW-C</td>
<td>½&quot;-2&quot;</td>
<td>Cast bronze body 125# rating, threaded ends, Y-type with 20 mesh (maximum) stainless steel screen openings, Mueller Steam Specialty #351M</td>
</tr>
<tr>
<td>125 CHW-C, 125 HHW-C</td>
<td>2 ½&quot; to 4&quot;</td>
<td>Cast bronze body 125# rating, threaded ends, Y-type with 1/16 inch (maximum) stainless steel screen openings, Mueller Steam Specialty #351M</td>
</tr>
<tr>
<td>125 CHW-C, 125 HHW-C</td>
<td>3&quot; and 4&quot;</td>
<td>Cast bronze body 125# rating, flanged ends, Y-type with 1/32 inch (maximum) stainless steel screen openings, Mueller Steam Specialty #851M</td>
</tr>
<tr>
<td>125 CHW-S, 125 HHW-S</td>
<td>4&quot;</td>
<td>Cast iron body 125# rating, flanged ends, Y-type with 1/16 inch (maximum) stainless steel screen openings, Mueller Steam Specialty #758</td>
</tr>
<tr>
<td>125 CHW-S, 125 HHW-S</td>
<td>5&quot; and up</td>
<td>Cast iron body 125# rating, flanged ends, Y-type with 1/8 inch (maximum) stainless steel screen openings, Mueller Steam Specialty #758</td>
</tr>
<tr>
<td>300 and 300C</td>
<td>½&quot;-2&quot;</td>
<td>Cast steel body 600# rating, socket weld ends, Y-type with 1/32 inch (maximum) stainless steel screen openings, Mueller Steam Specialty #582</td>
</tr>
<tr>
<td>300</td>
<td>2 1/2&quot;-4&quot;</td>
<td>Cast steel body 300# rating, butt weld ends, Y-type with 1/32 inch (maximum) stainless steel screen openings, Mueller Steam Specialty #782-WE</td>
</tr>
<tr>
<td>300C</td>
<td>2 1/2&quot;-4&quot;</td>
<td>Cast steel body 300# rating, flanged ends, Y-type with 1/32 inch (maximum) stainless steel screen openings, Mueller Steam Specialty #782</td>
</tr>
<tr>
<td>300C</td>
<td>5&quot;-12&quot;</td>
<td>Cast steel body 300# rating, flanged ends, Y-type with 3/64 inch (maximum) stainless steel screen openings, Mueller Steam Specialty #782</td>
</tr>
<tr>
<td>150 and 150C</td>
<td>½&quot;-2&quot;</td>
<td>Cast steel body 600# rating, socket weld ends, Y-type with 1/32 inch (maximum) stainless steel screen openings, Mueller Steam Specialty #582</td>
</tr>
<tr>
<td>150</td>
<td>2 1/2&quot;-4&quot;</td>
<td>Cast steel body 150# rating, butt weld ends, Y-type with 1/32 inch (maximum) stainless steel screen openings, Mueller Steam Specialty #781-WE</td>
</tr>
<tr>
<td>150C</td>
<td>2 1/2&quot;-4&quot;</td>
<td>Cast steel body 150# rating, flanged ends, Y-type with 1/32 inch (maximum) stainless steel screen openings, Mueller Steam Specialty #781</td>
</tr>
<tr>
<td>150C</td>
<td>5&quot;-12&quot;</td>
<td>Cast steel body 150# rating, flanged ends, Y-type with 3/64 inch (maximum) stainless steel screen openings, Mueller Steam Specialty #781</td>
</tr>
<tr>
<td>150L and 125C</td>
<td>½&quot;-2&quot;</td>
<td>Cast bronze body 125# rating, threaded ends, Y-type with 1/32 inch (maximum) stainless steel screen openings, Mueller Steam Specialty #351</td>
</tr>
<tr>
<td>150F</td>
<td>2 ½&quot;-10&quot;</td>
<td>Cast iron body 125# rating, flanged ends, Y-type with 3/64 inch (maximum) stainless steel screen openings, Mueller Steam Specialty #758</td>
</tr>
<tr>
<td>150F</td>
<td>½&quot;-2&quot;</td>
<td>Cast bronze body 125# rating, threaded ends, Y-type with 1/32 inch (maximum) stainless steel screen openings, Mueller Steam Specialty #351</td>
</tr>
<tr>
<td>150F</td>
<td>2 ½&quot;-10&quot;</td>
<td>Cast iron body 125# rating, flanged ends, Y-type with 3/64 inch (maximum) stainless steel screen openings, Mueller Steam Specialty #758</td>
</tr>
</tbody>
</table>

Note: Strainers may need to exceed line size for acceptable pressure drop
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1. INTRODUCTION TO INTEGRATED AUTOMATION AT MIT

1.1 Goal of this Document

To provide guidance and insight into MIT’s minimum standards and recommended best practices for Integrated Automation of Building Management Systems (BMS) design and implementation.

1. This document shall be used by MEP design consultants to supplement their traditional BMS specification. It is imperative that certain aspects of this document are incorporated into a traditional specification produced by MEP design consultants.

2. This document shall be used by BMS contractors to tailor their work to meet the expectations of MIT. During the design phase and RFP process, enough detail is given to price MIT specific alarm strategies, reports, and graphics development, but often certain nuances inherent in a BMS are not defined well enough to execute these tasks. This document will define those nuances and ultimately provide MIT with a finished product that meets our expectations.

1.2 Current Challenges or Questions this Document Will Address

1. Which BMS shall be used for new construction, retrofit, or buildings with mixed BMS platforms.

2. Expectations for A/E design firms when designing a BMS at MIT:
   a. Drawing requirements.
   b. Points list.
   c. Sequences of Operation.
   d. Scope matrix for use by Construction Manager.
   e. Coordination completeness.

3. Expectations for BMS contractors when implementing a BMS at MIT:
   a. Hardware design.
   b. Network design.
   c. Software design.
   d. Installation.
   e. Commissioning including:
      1) Installation verification.
      2) Start-up testing.
      3) Operational verification including:
         a) System tests.
         b) Integrated system tests.
4. Expectations for Commissioning Authority (CxA) when testing a BMS at MIT:
   a. Pre-requisites from BMS contractors.

1.3 Brief History of Building Management Systems at MIT

1. In the 1980s as the MIT campus transitioned from pneumatic receiver/controllers to DDC, the primary BMS product was Carrier Comfort Network (CCN). This product was installed as an overlay of the local pneumatic controls in approximately 50+ buildings. CCN still exists in over 40+ buildings on campus. CCN is accessed through hard client workstations spread among the campus. The CCN system is currently on the MIT open network.

2. In the early 1990s, Andover Controls was introduced to the MIT campus as a competitor of CCN. The legacy Andover Controls BMS product now known as Schneider Electric Continuum exists in over 75+ buildings. Schneider Electric Continuum is accessed through hard client workstations spread among the campus as well as WebClient interface. The Continuum system is currently on the MIT open network with a firewall; however, a project is underway to convert the system to the MIT protected VLAN and virtualize the workstations so that they can be accessed via a remote desktop application.

3. In 2013, Schneider Electric’s latest BMS product known as StruxureWare was introduced to the MIT campus. StruxureWare currently exists in over 20+ buildings. In the future it is likely that Continuum will be merged into the StruxureWare platform. StruxureWare can be accessed by a web browser interface.

4. In 2013, Carrier’s BMS product known as iVu was introduced to the MIT campus. iVu has been migrated into a newer ALC platform called WebCTRL and currently exists in 10+ buildings. WebCTRL can be accessed by a web browser interface.

5. In 2012, Siemens’ BMS product known as APOGEE was introduced to the MIT campus. APOGEE currently exists in four buildings. APOGEE is accessed through hard client workstations spread among the campus as well as a remote desktop application.

1.4 Current State of Building Management Systems at MIT

1. The following BMS platforms are in place (see Appendix A for Building List):
   a. Automated Logic WebCTRL.
   b. CCN.
   c. Schneider Electric Continuum.
   d. Schneider Electric StruxureWare.

1.5 Future State of Building Management Systems at MIT

1. CCN hardware and software will eventually be replaced by either ALC or Schneider Electric.
2. Schneider Electric Continuum will eventually be merged into Schneider Electric StruxureWare.
3. As of 2017, the implementation plan per building will be as follows:
   a. For complete building new construction acceptable BMS platforms shall be:
1) Schneider Electric StruxureWare.
2) Automated Logic WebCTRL.

4. For buildings with a single BMS platform requiring additional controls or partial retrofits, the incumbent platform shall dictate the future. Refer to the matrix in Appendix A to determine if a building has a single platform. The following platforms will be allowed to expand within a building that they already have a presence in:

   a. Schneider Electric Continuum.
   b. Schneider Electric StruxureWare.
   c. Automated Logic WebCTRL.
   d. Siemens APOGEE.

5. For buildings with a mix of BMS platforms, requiring additional controls or partial retrofits, the incumbent platforms shall dictate the future. Refer to the matrix in Appendix A to determine if a building has multiple platforms. The mixed buildings include the following combinations:

   a. Automated Logic WebCTRL / CCN:
      1) The following platforms will be allowed to expand within these buildings:
         a) Automated Logic WebCTRL.
      
   b. Automated Logic WebCTRL / Schneider Electric Continuum:
      1) The following platforms will be allowed to expand within these buildings:
         a) Automated Logic WebCTRL.
         b) Schneider Electric Continuum.
      
   c. Automated Logic WebCTRL / Schneider Electric Continuum / CCN:
      1) The following platforms will be allowed to expand within these buildings:
         a) Automated Logic WebCTRL.
         b) Schneider Electric Continuum.
      
   d. Automated Logic WebCTRL / Schneider Electric Continuum / Schneider Electric StruxureWare / CCN:
      1) The following platforms will be allowed to expand within these buildings:
         a) Automated Logic WebCTRL.
         b) Schneider Electric Continuum.
         c) Schneider Electric StruxureWare.
      
   e. Automated Logic WebCTRL / Schneider Electric Continuum / Schneider Electric StruxureWare / Siemens / CCN:
1) The following platforms will be allowed to expand within these buildings:
   a) Automated Logic WebCTRL.
   b) Schneider Electric Continuum.
   c) Schneider Electric StruxureWare.

f. Schneider Electric Continuum / CCN:
   1) The following platforms will be allowed to expand within these buildings:
      a) Schneider Electric Continuum.

g. Schneider Electric Continuum / Schneider Electric StruxureWare:
   1) The following platforms will be allowed to expand within these buildings:
      a) Schneider Electric StruxureWare.
      b) Schneider Electric Continuum.

h. Schneider Electric Continuum / SE StruxureWare / CCN:
   1) The following platforms will be allowed to expand within these buildings:
      a) Schneider Electric Continuum.
      b) Schneider Electric StruxureWare.

i. SE StruxureWare / CCN:
   1) The following platforms will be allowed to expand within these buildings:
      a) Schneider Electric StruxureWare.

2. MIT’S EXPECTATIONS OF MEP DESIGN CONSULTANTS

2.1 BMS Design Requirements

MIT expects MEP design consultants to include the following in BMS designs:

1. BMS specification.
2. Network riser diagram clearly distinguishing MIT Information Systems and Technology (IS&T) scope from BMS.
3. P&ID type instrumentation drawings for each typical system requiring control
4. Points list for each typical system
5. Points list for miscellaneous systems (plumbing, electrical, lab monitoring)
6. I/O list to be mapped to the BMS from software interfaces
7. Sequence of operations for each typical system requiring control incorporating alarms and long-term trending requirements either in separate specification form or on the control diagrams listed.
8. Metering one-line diagram outlining scope delineation.
9. Incorporation of MIT standards into BMS design. The above items listed must reflect an understanding of the MIT BMS standards.
10. Items involving requiring multiple trades are recommended to be addressed in a detailed scope matrix that clearly delineates each piece of work that could be handled by a different contractor. (Examples include: installation, and implementation of fire/smoke dampers, power wiring).

A sample of the expectation is shown below:

<table>
<thead>
<tr>
<th>Description</th>
<th>Furnish</th>
<th>Install</th>
<th>Control</th>
<th>Control Wiring</th>
<th>Power Wiring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Flow Stations &amp; Transmitters</td>
<td>BMS</td>
<td>Mechanical</td>
<td>BMS</td>
<td>BMS</td>
<td>BMS</td>
</tr>
<tr>
<td>Combination Fire/Smoke Damper &amp; Actuators</td>
<td>Mechanical</td>
<td>Mechanical</td>
<td>Fire Alarm</td>
<td>Electrical</td>
<td>Electrical</td>
</tr>
<tr>
<td>Control Dampers</td>
<td>BMS</td>
<td>Mechanical</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Control Damper Actuators</td>
<td>BMS</td>
<td>BMS</td>
<td>BMS</td>
<td>BMS</td>
<td>BMS</td>
</tr>
</tbody>
</table>

11. Where a building is “locked in” by a certain BMS contractor it is expected that the MEP design consultant work closely with the BMS contractor in the design stages to ensure that design meets MIT expectations.

2.2 Design Review Milestones

MIT expects to have at least two reviews prior to release of the bid documents from an MEP design consultant. Based on the size of the project and the scope of the controls, review will likely occur at the following.

1. 100% Design Development.
2. 50% Construction Documents.
3. 100% Construction Documents (pre-release).
4. As-built Documentation (if applicable).

2.3 MEP Equipment Naming Standards

Design drawings should include equipment designations in their schedules and plan views which are unique and do not duplicate existing equipment. Contact the MIT Systems Engineering Group to determine which equipment names are available.

Equipment names should conform to the following standard:
XXX_XXXXXXXX
Examples:
Building 76, Air Handling Unit 12A would be:  
M76_AHU12A

Buildings which have no letter prefix assigned in the MIT naming convention (Buildings 1, 2, 3, etc.) will be preceded with an “M”.

Building E17, Chilled Water Pump 2 would be:  
E17_CHWPMP02

Note that system, equipment, and number are combined as one text string.  
The following is the standardized list of system, equipment, and other abbreviations:

<table>
<thead>
<tr>
<th>System, Equipment, and Other Abbreviations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Handling Unit</td>
</tr>
<tr>
<td>Exhaust Air Handling Unit</td>
</tr>
<tr>
<td>Exhaust Fan</td>
</tr>
<tr>
<td>Return Fan</td>
</tr>
<tr>
<td>Pump</td>
</tr>
<tr>
<td>Air Cooled Condensing Unit</td>
</tr>
<tr>
<td>Heat Exchanger</td>
</tr>
<tr>
<td>Heating Converter (shell and tube)</td>
</tr>
<tr>
<td>Chilled Water</td>
</tr>
<tr>
<td>Process Chilled Cooling Water</td>
</tr>
<tr>
<td>Hot Water</td>
</tr>
<tr>
<td>Condenser Water</td>
</tr>
<tr>
<td>Domestic Hot Water</td>
</tr>
<tr>
<td>Domestic Cold Water</td>
</tr>
<tr>
<td>Supply</td>
</tr>
<tr>
<td>Return</td>
</tr>
<tr>
<td>Temperature</td>
</tr>
<tr>
<td>Pressure</td>
</tr>
<tr>
<td>Flow</td>
</tr>
</tbody>
</table>

For example, Domestic Hot Water Return Temperature in Building 2 would be:  
M02_DHWRETEMP

3. **BUILDING MANAGEMENT SYSTEM DESIGN GUIDELINES**

3.1 **Building Management Systems Design Guidelines - General**

BMS designs and installations for MIT under this specification shall include the following:
1. The BMS shall be based on an open implementation of BACnet using ASHRAE 135 exclusively as the communications protocol for communication between BMS hardware devices.

2. The BMS hardware and software shall perform the control sequences as specified and shown in the MEP design consultant’s control drawings and sequence of operation.

3. The engineering workstations must run the standard workstation software developed and tested by the manufacturer of the BMS controllers. No third party front-end workstation software shall be acceptable. Engineering workstations must conform to the B-OWS BACnet device profile.

4. Web-based users shall have access to all system points and graphic display screens, shall be able to receive and acknowledge alarms, and shall be able to control setpoints and other parameters, based on their access credentials. All engineering work, such as trends, reports, that are accomplished from the engineering workstation shall be available for viewing through the web browser interface. The web-based interface must conform to the B-OWS BACnet device profile. There shall be no need for additional computer based hardware to support the web-user interface.

5. All BMS controllers shall be connected to an ASHRAE 135 BACnet/IP or MSTP control network.

6. Control sequence logic for a particular system shall reside in that system’s dedicated BMS controller. The hardware in conjunction with the software residing on the controller shall, where possible, execute the sequence of operation without relying on the building network.

7. The BMS shall be designed and installed such that MIT is able to perform repair, replacement, upgrades, and expansions of the system without further dependence on the original BMS contractor. BMS implementation documentation, configuration information, configuration tools, application programs (with comments explaining program logic), and other software used by the BMS shall be licensed to and remain property of MIT.

8. Exceptions to BACnet compliant requirements will be allowed only when expanding a legacy proprietary Continuum BMS within a building.

9. The BMS shall interface with MIT’s web-based Building Analytics System called KGS Clockworks. The work associated with this interface is not part of the BMS contractor’s scope.

The following are additional guidelines of how MIT expects certain equipment to work on campus.

### 3.2 Network Level

1. The BMS shall reside on the protected MIT Ethernet Network also known as the MIT BMS VLAN.

2. The BMS shall be an extension of the campus approved BMS platforms listed above.

3. The BMS shall be web-based.

4. The BMS shall be native BACnet except where proprietary Continuum expansion is required.

5. The BMS shall be capable of being polled by KGS Clockworks.

6. The BMS shall be capable of communication with the PI data historian.

7. The BMS shall be capable of Modbus IP communication.

8. Workstations and printers for buildings are not generally required.

### 3.3 Uninterruptable Power Supply

1. All network controllers and critical system controllers shall be on UPS power. A critical system
controller is defined as one that controls:


b. Air Handlers (Supply AHUs, Make-up Air AHUs, Exhaust AHUs, Energy Recovery Units).

c. Rooftop Units.

d. Air Distribution for Critical Rooms: Labs, Vivariums, Executive Offices, IS&T Data Rooms.

2. The UPS strategy can be designed and implemented as a small UPS per controller or one standalone UPS dedicated for the critical controls for an entire building. Additionally, a building UPS used for other systems may be used for the BMS as well.

3. The UPS shall be monitored by the BMS for “low battery” and “battery on” status.

4. Individual UPSs used for controllers shall be similar to APC Model #SUA500PDR-S and mounted underneath the controller in an enclosure of similar specifications to the controller enclosure.

### 3.4 Field Controllers

1. Field controllers shall be BACnet compliant (except where proprietary Continuum expansion is required).

2. All field controllers must contain all of the I/O and sequence logic for the particular system that they serve. For example, it is not acceptable to split an air handling unit between two field controllers.

3. Airflow tracking control for a laboratory or vivarium shall reside on one controller and not rely on the network to function.

4. The hardware in conjunction with the software residing on the controller must execute the sequence of operation as specified. Controllers that contain “canned” uneditable programs that do not meet the sequence of operations will not be acceptable.

5. The hardware in conjunction with the software residing on the controller shall, where possible, execute the sequence of operation without relying on the building network.

6. IP based field controllers that control major HVAC equipment (Air Handlers, Heating and Cooling Equipment) shall be acceptable.

### 3.5 BMS Controller Enclosures

1. Control enclosures shall be as follows:

   a. Single keyed locking twistable knob(s).

   b. Ratings:

      1) Enclosures located outside: NEMA Type 4X.
      2) Mechanical and Electrical Rooms: NEMA Type 1.
      3) Other Locations: NEMA Type 1.
3.6 Field Devices

1. Control Valves:

   a. Chilled water and hot water control valves for air handling unit applications and terminal unit applications shall be pressure-independent:

      1) Valves 2 inch and smaller: Pressure independent characterized ball valve, 400# WOG, bronze body, stainless ball and stem, pressure and temperature ports, reinforced PTFE seats & seals, screwed ends, 250°F rating, 200 psig close-off pressure, and a maximum differential pressure rating of not less than 50 psig.

         a) Acceptable Manufacturers: Belimo or MIT Approved Equal (prior to bid).

      2) Valves 2-1/2 inch and larger: Pressure independent ball valves. The valve body shall be of cast iron and rated for 150 PSI working pressure. Internal parts shall be of stainless steel.

         a) Acceptable Manufacturers: Belimo or MIT Approved Equal (prior to bid).

   b. Steam control valves shall be characterized control valves including:

      1) Valves 2 inch and smaller: Characterized ball valve, 400# WOG, bronze body, stainless ball and stem, pressure and temperature ports, reinforced PTFE seats and seals, screwed ends, 250°F rating, close-off pressure rating of 150% of total system head pressure, and a maximum differential pressure rating of not less than 50 psig.

         a) Acceptable Manufacturers: Schneider Electric, Belimo.

      2) Valves 2-1/2 inch and larger: Characterized ball valve, the valve body shall be of cast iron and rated for 150 PSI working pressure. Internal parts shall be of stainless steel.

         a) Acceptable Manufacturers: Belimo or MIT Approved Equal (prior to bid).

   c. Two-way modulating valves used for liquids and steam shall have an equal percentage flow characteristic that yields a linear heat output.

   d. Automated two-position isolation valves for CHW and HW (above 6” line size) shall be butterfly type as follows:

      1) Threaded lug type suitable for dead-end service to the fully-closed position, with carbon-steel bodies and non-corrosive discs, stainless steel shafts supported by
bearings, and EPDM seats suitable for temperatures from -20°F to plus 250°F.
2) Valve assembly including actuator and limit switches, if required, shall be assembled by the valve manufacturer.
3) Acceptable Manufactures: Bray, Belimo, or MIT Approved Equal (prior to bid).

e. Valve Actuators:
   1) Valve actuators shall be electric and integrated with the valve body.
   2) Valve actuators shall provide shutoff pressures and torques as required.
   3) Valve actuators for major equipment and laboratory and vivarium applications shall be spring return.
   4) Valve actuators for terminal unit control (with the exception of laboratory and vivarium applications) shall be non-spring return.
   5) Valve actuators shall be fail open (FO) or fail closed (FC) as shown.
   6) Valve actuators shall have an electronic cut off or other means to provide burnout protection if stalled.
   7) Valve actuators shall have a visible position indicator.
   8) Valve actuators for major equipment shall provide position feedback to the BMS controller.
   9) Valve actuators shall smoothly open or close the devices to which they are applied.
   10) Valve actuators shall have a full stroke response time in both directions of 90 seconds or less at rated load.
   11) Valve actuators located outside shall be provided with internal heaters.
   12) Tri-state actuation is not acceptable.

2. Control Dampers:
   a. Opposed or parallel blade type that at a minimum match the materials of construction of the associated ductwork.
   b. See Division 23 for additional damper requirements.
   c. Damper actuators:
      1) Damper actuators shall be electric and integrated with the valve body.
      2) Damper actuators shall provide shall provide the torque necessary per damper manufacturer's instructions to modulate the dampers smoothly over their full range of operation.
      3) Damper actuators shall be spring return.
      4) Damper actuators shall be fail open (FO) or fail closed (FC) as shown.
      5) Damper actuators shall have an electronic cut off or other means to provide burnout protection if stalled.
      6) Damper actuators shall have a visible position indicator.
      7) Damper actuators shall be capable of providing position feedback to the BMS controller.
      8) Damper actuators shall smoothly open or close the devices to which they are
applied.

9) Damper actuators shall have a full stroke response time in both directions of 90 seconds or less at rated load.

10) Damper actuators located outside shall be provided with a weather shield.

11) Tri-state actuation is not acceptable.

12) Fail last position is not acceptable.

13) Acceptable Manufacturers: Schneider Electric, Belimo, or MIT Approved Equal (prior to bid).

3. Temperature Sensors:
   a. All temperature sensors shall be thermistors.
   b. Sensors shall be accurate to +/- 0.5°F for space applications and +/- 1.0°F for duct and pipe applications.
   c. Where local room level manual overrides are required, the sensor housing shall feature both a setpoint adjustment and a push button for selecting after hours operation.
   d. Where local displays are required, the sensor shall incorporate an LED or LCD display for viewing the temperature, setpoint, and other operator selectable parameters. If the setpoint adjustment is integral to the LED or LCD display, the BMS contractor should align the high and low limits from the front end workstation so that they are in synchronization with the BMS software.
   e. Averaging Sensors shall be sized to ensure sensing element has a minimum length equal to 1 foot / 2 square feet of duct cross-sectional area at the installed location.
   f. Outside air temperature shall be measured by the MIT weather station(s).

4. Relative Humidity Sensors:
   a. Relative humidity sensors shall use thin film capacitive type. The transmitters shall have replaceable sensing elements.
   b. Duct mounted relative humidity sensing element shall be encapsulated in potting material within a stainless steel probe.
   c. Relative humidity sensors shall be +/- 3% accurate.
   d. Outside air relative humidity temperature shall be measured by the MIT weather station(s).
   e. Veris or equal.

5. Pressure Sensors:
   a. Pressure sensor range shall be as shown or as required for the application. Pressure sensor ranges shall not exceed the high end range shown by more than 50 percent.
   b. Provide remote sensing element(s) whenever operating temperature exceeds the transmitter’s maximum allowable temperature.
   c. Air pressure measurements in the range of 0 to 10” w.c. shall be +/- 1% of full scale accurate.
   d. Pressure measurements of liquids or gas shall be +/- 1.5% of full scale accurate.
e. Transmitter shall have provision for zeroing by pushbutton or digital input.

f. Wet differential pressure sensors/transmitters for water and steam applications shall be provided with 3-valve manifold for servicing. If an electronic differential pressure sensor is used, there must be isolation valves installed and a take-off for bleeding of the system.

g. Space differential pressure elements/pick-ups required to measure pressure shall be constructed of appropriate material for the space and application and shall be ceiling mounting or wall mounted.

6. **Air Flow Stations:**
   
a. Ebtron Gold Series thermal dispersion type.

7. **Flow Meters:**
   
a. Liquid and gas flow meters shall adhere to the MIT metering specification.

8. **Current Sensors:**
   
a. Split-core current sensors shall be used to monitor fan and pump motors.
   
b. Measurement of electric feeds shall adhere to the MIT metering specification.

9. **Current Switches:**
   
a. Split-core current switches shall be used to monitor fan coil units with EC motors.

10. **Floor or Pan Mounted Leak Detectors:**
    
a. Corrosion and abrasion resistant.
   
b. Adjustable height.
   
c. Configured for normally open or normally closed as required by the application.
   
d. Form C output relay.
   
e. Operating temperature range of (-20°F to 120°F).

11. **Low Limit Temperature Switches (Freezestats):**
    
a. Automatic reset type.
    
b. Minimum element length of 1 foot/square-foot of coverage which shall respond to the coldest 12 inch segment.
    
c. Field-adjustable setpoint with a range of at least 15°F to 55°F.
    
d. Two sets of contacts, with each contact having a rating greater than its connected load. Contacts shall open or close upon drop of temperature below setpoint as shown and shall remain in this state until reset automatically.
    
e. Johnson/Penn, Schneider Electric or MIT approved equal (prior to bid).

12. **Damper Limit Switches:**
    
a. Limit switch shall be integral to the damper actuator.
13. Level Switches:

a. Solid state electronic level sensing probes and SPDT contacts for indication of switch point actuation
b. Measurement probe shall detect rising water in cooling coil condensate drain pan (where required).

14. Capacitance Level Transmitters:

a. Radio Frequency (RF) type continuous level probe shall have a 4-20 mA transmitter. Output shall be linear to measured level. Probe shall have probe shielding to reject a build-up of conductive, sticky or viscous material. Probe length shall match vessel dimensions to measure within 6” of bottom.

b. Include probe brace every 4 feet if probe length exceeds 6 feet and is not installed in stilling well.

c. Supply Voltage: 120 VAC/60 Hz
d. Output: 2 wire, 4-20 mA DC
e. Fail Safe: Low Level output on instrument failure
f. Ambient Temperature Limits: -40°F to 160°F
g. Minimum Enclosure Rating: NEMA 4
h. Local Indicator: LCD meter
i. Transmitter Mounting: Remote
j. Performance:

1) Accuracy: ± 2% nominal.
2) Linearity: ± 1% nominal.
3) Repeatability: ± 1% nominal.
4) Response Time: 20 milliseconds.
5) Ambient Temperature Effect: 2% per 100°F maximum.
6) Voltage Variation Effect: ± 0.2% maximum per 10 V change.

15. CO2 Space Sensors:

a. Sensor type shall be Non-dispersive infrared (NDIR).

b. Accuracy: ±30 ppm ±2% of measured value with annual drift of ±10 ppm.

c. Repeatability: ±20 ppm ±1% of measured value.

d. Response Time: <60 seconds for 90% step change.

e. Outputs: Field selectable 4-20mA or 0-5/0-10VDC with SPDT Relay 1A@30VDC.

f. Power: 12-30 VDC or 24 VAC supply power.

g. Output range: programmable to 0-2000 or 0-5000 ppm.

h. Transmitter shall be available in an enclosure for mounting on a standard electrical box.

i. Transmitter shall have integrated temperature sensor and humidity sensor where
applicable.

j. Veris or equal.

16. CO2 Duct Sensors:

a. Sensor type shall be Non-dispersive infrared (NDIR).
b. Accuracy: ±30 ppm ±2% of measured value with annual drift of ±10 ppm.
c. Repeatability: ±20 ppm ±1% of measured value.
d. Response Time: <60 seconds for 90% step change.
e. Outputs: Field selectable 4-20mA or 0-5/0-10VDC with SPDT Relay 1A@30VDC.
f. Power: 12-30 VDC or 24 VAC supply power.
g. Output range: programmable to 0-2000 or 0-5000 ppm.
h. Enclosure shall not require remote pickup tubes and make use of integrated H-beam probe to channel air flow to the sensor.
i. Enclosure lid shall require no screws and make use of snap on features for attachment.
j. Enclosure shall be made of high impact ABS plastic.
k. Transmitter shall have integrated temperature sensor and humidity sensor where applicable.
l. Veris or equal.

17. Gas Monitoring Systems:

a. The system shall be a complete package with local or remote sensor(s), monitor, alarm contacts, local audible/visual alarm, local indication of current measured value for sensor, and status indicator lights for power and status of sensor. All status indicators shall be mounted on panel faceplate. Where multiple sensors are located in single space, provide single monitoring panel which incorporates display for multiple sensors. Units shall have adjustable setpoints and self-test diagnostics. Multiple gases can be measured by the same master panel.

1) Gas to be Detected: Carbon Monoxide (CO):

a) Power Requirements: 120 VAC, 50/60 Hz, 50 VA.
b) Signal Input: Integral Sensor.
c) Signal Output: 4-20 mA DC.
d) Alarm Relays: 3 Amps, 120 VAC (1 Warning relay and 1 Alarm relay).
e) Alarm Setpoint: Two field adjustable setpoints for Warning (25 ppm) and Alarm (200 ppm).
f) Range: 0-250 ppm CO.
g) Sensor: Electrochemical CO Sensor.
h) Sensor Life: 1 year minimum.

2) Gas to be Detected: Oxygen (O2):

a) Power Requirements: 120 VAC, 50/60 Hz, 50 VA.
b) Signal Input: Integral Sensor.
c) Signal Output: 4-20 mA DC.

d) Alarm Relays: 3 Amps, 120 VAC (1 Warning relay and 1 Alarm relay).

e) Alarm Setpoint: Two field adjustable setpoints for Warning (20%) and Alarm (19.5%).

f) Range: 0-25% O2.

g) Sensor: Electrochemical O2 Sensor.

h) Sensor Life: 1 year minimum.

b. Panel mounted audible alarm horn with silence switch and display for indication of full scale range, sensor, zone, warning, alarm, and fault status.

c. Remote mounted audible/visual alarm (red) as indicated on plans.

d. The system shall have to be ability to send alarms to the BMS for warning, alarm, and system fault.

e. Honeywell Vulcain or MIT approved equal (prior to bid).

18. Refrigerant Detection Systems:

a. Infrared type refrigerant detection and alarm systems detecting refrigerant in listings at adjustable detection points to provide both visual and audible alarms.

b. System shall conform to ANSI/BSR ASHRAE Standard 15 Safety Code for Mechanical Refrigeration including alarm light and horn outside room at each door to room and inside space as indicated on drawings.

c. Sensor shall be compound specific and calibrated for refrigerant used in chillers.

d. System shall be automatically zero at set intervals by sensing air from and uncontaminated air source. Auto zero cycle may be manually or remotely initiated.

e. Latched alarms shall be capable of being reset locally by remote contact closure.

f. System malfunction alarm shall be non-latching contact annunciated locally and remotely.

g. System shall require no more than annual recalibration and monthly confirmation of clean air source for auto-zero.

h. Provide local alarm and control panel to accept these inputs and provide outputs for system fault alarm, warning alarm and critical alarm, which shall energize emergency ventilation system. Each alarm shall have DPDT relays. Warning and critical level alarms shall energize local horn-strobe alarm. Provide contact for each alarm for monitoring by the BMS.

i. Refrigerant leak detection system to have the following minimum performance:


2) Power: 120 VAC/60 Hz.

3) Operating Temperature: 60°F to 105°F.

4) Operating Humidity: 10% to 90% RH.

5) Contact Ratings: 5 amp 120 VAC.

6) Contact(s): 2 sets DPDT independently configured for different concentrations.

7) Performance:
a) Minimum measurable: 1 ppm as tested per UL2075.
b) Response time: 20 seconds at 99%.
c) Accuracy: Error < ± 2% full scale.

8) Operating Temperature: 0°F to 120°F.
9) Display: 3 digit LED or LCD displaying refrigerant gas concentration.

j. Quantity of Required Monitor Points: Two monitoring points per chiller.
k. Output: 4-20 mA/24VDC

19. Photocells:

a. Non-corroding and weatherproof housing with sensor shield suitable for exterior installations.
b. 4-20 mA or 0-10 VDC output proportional to the ambient light level.
c. Accuracy at room temperature: 1%, 100°F temperature: 2.5%.
d. Solid-state photo diode circuitry and transducer as required.
e. Sensor reading from 0 to 750 foot candles.
f. Temperature and humidity independent.
g. Temperature range of 10°F to 120°F.

20. Push Buttons:

a. Illuminated red mushroom heads shall be used for emergency stop switches. The push buttons shall be illuminated with the switch is engaged.
b. Contact Type: Two contact blocks for 2 N.O. and 2 N.C. contacts each.
c. Unit shall be provided complete with enclosure, contact unit, and legend plate.

21. Control Relays:

a. Coil ratings of 120 VAC, 50 mA or 10-30 VAC/VDC, 40 mA as suitable for the application.
b. Complete isolation between the control circuit and the digital output.
c. Pickup rating, time and hold rating as required for individual applications.
d. Rated for a minimum of ten (10) million mechanical operations and a minimum of 500,000 electrical operations.
e. Internal status LED.

22. Electronic Thermostats:

a. Multifunction devices incorporating a temperature sensor and a temperature indicating device.
b. Electronic or other types of Thermostats shall not contain mercury. In addition, the thermostat shall have the following as applicable:

1) External setpoint adjustment.
2) Push button override.

3.7 Wire and Cable

1. The BMS contractor shall provide complete electrical wiring for the BMS, including 120 VAC power wiring from circuit breaker provided by Division 26 to BMS panel or device.
2. The BMS contractor shall provide control wiring, including conduit, to control devices from appropriate BMS controller enclosures.
3. The BMS contractor shall provide communications wiring, including conduit, for the BACnet MSTP network.
4. The BMS contractor shall provide final power connections, including conduit, wire, and/or disconnect switches, to control devices and control panels from the appropriate electrical distribution panels.
5. Final connection points at devices and panels shall be made either at terminal blocks integral to the device or at separate terminal blocks mounted inside of BMS controller enclosures. Crimped connections are not allowed for termination of control wiring.
6. All wire and cable shall meet the requirements of NFPA 70 and NFPA 90A in addition to the requirements of this specification.
7. Terminal blocks which are not integral to other equipment shall be insulated, modular, feed-through, clamp style with recessed captive screw-type clamping mechanism, shall be suitable for rail mounting, and shall have end plates and partition plates for separation or shall have enclosed sides.
8. Control Wiring for Analog Signals:
   a. Control wiring for analog signals shall be 18 AWG, copper, single or multiple-twisted, minimum 2 inch lay of twist, 100 percent shielded pairs, and shall have 300-volt insulation. Each pair shall have a 20 AWG tinned-copper drain wire and individual overall pair insulation. Cables shall have an overall aluminum-polyester or tinned-copper cable-shield tape, overall 20 AWG tinned-copper cable drain wire, and overall cable insulation.
   b. Stranded twisted/shielded control conductors are required with shields to be terminated within variable frequency drive enclosures to reduce effects of noise from the VFD. The BMS contractor shall follow the VFD manufacturer's installation instructions for wiring control conductors to the VFD.
9. Control Wiring for Digital Signals:
   a. Control wiring for digital signals shall be 18 AWG copper and shall be rated for 300-volt service.
10. Control Wiring and Power Wiring for 120-Volt Circuits:
   a. Wiring for 120-volt circuits shall be 12 AWG stranded copper and shall be rated for 600-volt service.
11. Transformers:
a. Transformers shall be UL 1585-3 approved. Transformers shall be sized so that the connected load is no greater than 80 percent of the transformer rated capacity.

12. BMS Ethernet Network Cable shall be provided by the telecom contractor to a jack located in the network panel.

   a. BMS Ethernet network cable shall meet or exceed all requirements of Category 6 cable as specified in TIA/EIA-568-B.2. Terminations, patch panels, and other hardware shall meet or exceed Category 6 specifications and shall be as specified in Telecommunications specification.
   b. Cabling products shall be tested and certified for use at data speeds up to at least 100 Mbps.

3.8 Sensing Tubing

1. The BMS contractor shall provide MIT sensing tubing required for a complete and functional BMS, including sensing tubing required for:

   b. Air Flow Sensing for VAV Boxes (if not provided with the VAV box).
   c. Static Pressure Sensors and Switches (for air applications).
   d. Differential Pressure Sensors and Switches (for air applications).
   e. Differential Pressure Sensors and Switches (for water applications).
   f. Refrigerant Detection Monitoring.
   g. Gas Detection Monitoring.
   h. Differential Pressure Sensors and Switches (for water applications).

2. Copper:

   a. Copper tubing shall conform to ASTM B 88 and ASTM B 88M.

3. Stainless Steel:

   a. Stainless steel tubing shall conform to ASTM A 269.

4. Plastic:

   a. Plastic tubing shall have the burning characteristics of linear low-density polyethylene tubing, shall be self-extinguishing when tested in accordance with ASTM D 635, shall have UL 94 V-2 flammability classification or better, and shall withstand stress cracking when tested in accordance with ASTM D 1693.
   b. Plastic-tubing bundles shall be provided with Mylar barrier and flame-retardant polyethylene jacket.
3.9 Sequences of Operation and I/O Lists

1. Air Handling Units.
2. Exhaust/Supply Fan.
3. Room Control:
   b. Room Combinations.
   c. VAV Boxes:
      1) VAV Box Sample I/O.
      2) VAV Box w/o Reheat Coil.
      3) VAV Box w/o Reheat Coil and Radiation.
      4) VAV Box with Reheat Coil.
      5) VAV Box with Reheat Coil and Radiation.
      6) VAV Box (Return Air).
   d. Fan Coil Units:
      1) Fan Coil Unit Sample I/O.
      2) Fan Coil Unit (2-pipe Cooling Only).
      3) Fan Coil Unit (2-pipe) and Radiation.
      4) Fan Coil Unit (4-pipe).
      5) Fan Coil Unit (4-pipe) and Radiation.
   e. Finned Tube Radiation:
      1) Chilled Beam Sample I/O.
      2) Chilled Beam with Zone Pump (2-pipe Cooling Only).
      3) Chilled Beam with Zone Pump (4-pipe).
      4) Chilled Beam (2-pipe Cooling Only).
      5) Chilled Beam (4-pipe).

4. Hydronic or Electric Unit Heaters.
5. Split DX Units.
8. Life Safety Equipment.
10. Equipment Restart Following a Power Failure.
11. Miscellaneous Monitoring.
### 3.10 Air Handling Units (AHU)

1. **Key Concepts:**

   a. Air Handling Units (AHU) including Variable Frequency Drives (VFD) on graphic shall have a separate tab for software values.
   
   b. VFD shall have four hardwired points (start/stop, status, speed modulation signal, and fault).
   
   c. BMS shall have full direct control of the heat recovery wheel. Hardwired I/O to the BMS is preferable to a packaged heat wheel and BMS integration.
   
   d. Damper end switches, static pressure switches, and smoke detectors shall be hardwired to the respective fan safety circuit.
   
   e. Freezestat shall be auto-reset type and shall be hardwired to the respective fan safety circuit.
      
      1) When freezestat is tripped, unit must still be capable of running in firemen’s override mode.
      
      2) When freezestat is tripped heating valve will control to maintain a case temperature in the unit.
   
   f. As a second level of protection, devices that are hardwired to a safety circuit should, when active, also be part of a software shutdown sequence.
   
   g. Firemen’s override “fan on” switch (if required) shall be tied into the safety circuit such that the unit will run in all safety conditions except for high (or low) static pressure.
   
   h. Firemen’s override “fan off” switch (if required) shall be tied into the safety circuit for fan shutdown.
   
   i. Firemen’s override “fan on” position switch shall be monitored by the BMS for switch “on” and switch “off” position.
   
   j. Firemen’s override “fan off” position switch shall be monitored by the BMS for switch “on” and switch “off” position.
   
   k. Filter differential pressure is not required to be monitored by the BMS.
   
   l. Where applicable, the system shall employ the following energy savings strategies:
      
      1) Economizer Control.
      
      2) Energy Recovery.
      
      3) Demand Control Ventilation.
      
      4) Supply Air Static Pressure Setpoint Reset.
      
      5) Supply Air Temperature Setpoint Reset (based on outside air).

2. **Sequence of Operation (generic sequence that includes all components):**

   a. The unit shall have the following occupancy related modes:
      
      1) Occupied.
2) Unoccupied.
3) Start-up.
4) Morning warm up.
5) Shut down.

b. The unit shall have the following control modes in addition to occupied and unoccupied:

1) Heating.
2) Cooling.
3) Dehumidification.
4) Economizer.

c. If a sensible heat wheel exists, it shall be capable of the following modes in addition to those above:

1) Reheat.
2) Purge.

d. If an enthalpy heat wheel exists, it shall be capable of the following modes in addition to those above:

1) Anti-Frost.
2) Purge.

e. Occupied System Start Up/Shut Down:

1) Occupied mode will be determined via BMS schedule supplied by MIT.
2) Start Up:

a) Supply fans and return fans shall be enabled by automatic or manual command at the BMS.
b) The supply smoke isolation, return smoke isolation, exhaust and outside air dampers shall be commanded open via hardwire interlock to their system start circuits.
c) The supply and return fan VFDs shall be enabled via their respective smoke isolation damper end switches.
d) The individual fan isolation dampers shall be opened via hardwired interlock to their respective VFDs.
e) When the individual fan isolation dampers are proven open via hard wired end switches, the BMS will start the supply and return fans and ramp them to their minimum speed.
f) When fan status is proven on for the supply and return fans via current transducers, the BMS shall enable the discharge air temperature control loop.
g) When the heating coil discharge temperature has achieved setpoint, the BMS shall enable the supply fan and return fan speed control loops.
h) If either supply or return fans have been called to start but the status shows that the fans are not running 120 seconds (adjustable) after their respective smoke isolation damper proves open, the BMS shall lock out the unit. An alarm shall be sent to the operator workstation and the unit will only be enabled to run after the alarm is manually reset at the BMS.

i) When an application requires multiple AHUs feeding a common plenum (for system redundancy), the fans and dampers shall be staged appropriately to prevent the fan(s) from spinning backwards.

j) When an application requires a negative pressure for a space (i.e., laboratory, vivarium) the AHU return/exhaust fan shall be proven on prior to starting the supply fan.

3) Single Fan Failure (when there are two or more fans):
   a) If a supply or return fan fails or is shut off locally during regular operation, as determined through the BMS by the fan status sensors, the BMS shall close the failed fan’s isolation damper.
   b) If fans are sized for N+1 configuration, the BMS shall modulate the other operable fans’ VFD(s) to match the total unit CFM (or in some cases a static pressure setpoint for the supply fan with the return fan continuing to track CFM) of the unit in normal operation mode.
   c) Once the failed fan is ready to start again and enabled by the user, upon receiving fan status via current transducer, the BMS shall release all fans back into the speed control loop.

4) Shut Down:
   a) The BMS shall modulate each fan down to minimum speed and de-energize the fans. The BMS shall close the individual fan isolation dampers.
   b) Once the individual fan isolation dampers are proven closed, the supply smoke isolation, return smoke isolation, exhaust and outside air dampers shall close.
   c) The BMS shall turn off the heat wheel(s).
   d) The BMS shall close the cooling coil valve.
   e) The BMS shall modulate the heating coil valve to maintain plenum temperature setpoint as sensed by the cooling coil averaging temperature sensor.

f. Occupied Mode Control:

1) Supply Static Pressure Control:
   a) Once started, the BMS shall modulate the AHU supply fan VFDs speed signals from the same control loop to maintain supply static pressure...
setpoint in the supply duct as measured by the remote mounted supply air static pressure sensors. When there are multiple static pressure sensors, the sensor whose value is furthest from the setpoint should be used as the control sensor.

2) Return Static Pressure Control:
   a) Once started, the BMS shall modulate the AHU return fan VFDs speed signals from the same control loop to maintain return static pressure setpoint in the return duct as measured by the remote mounted supply air static pressure sensors. When there are multiple static pressure sensors, the sensor whose value is furthest from the setpoint should be used as the control sensor.
   b) In some cases the BMS shall modulate the return fans to track the supply fans to maintain a CFM offset.

3) Priority for Temperature Control:
   a) The matrix below simply summarizes the text that follows for each piece of equipment. The matrix is explained as follows:

<table>
<thead>
<tr>
<th>Equipment and Action</th>
<th>Cooling</th>
<th>Heating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economizer</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Heat Recovery</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Hot Water Coil</td>
<td>N/A</td>
<td>3</td>
</tr>
<tr>
<td>Chilled Water Coil</td>
<td>3</td>
<td>N/A</td>
</tr>
</tbody>
</table>

  g. Unoccupied System Start Up/Shut Down:

   1) Unoccupied mode shall be enabled based on a date/time schedule. The AHUs shall be off (reference shutdown sequence above) when in unoccupied mode with the following exceptions:

   a) Unoccupied Occupant Override: The pushbutton on any three (adjustable) building space temperature sensors shall cause the BMS to restore the AHU to occupied mode (reference startup sequence above) for a period of two hours (adjustable).
   b) Zone Temperature: If outside air temperature is below 55°F (adjustable) and multiple zone temperatures (exact strategy to be determined by MEP design consultant) drop below the unoccupied setpoint, the BMS shall
start the AHUs and restore occupied mode until the zone temperature rises to 3°F above the unoccupied setpoint, at which point the AHUs shall shut down and restore unoccupied mode.

c) High Dew Point: If outside air dew point is above 53°F (adjustable), the BMS will control the AHUs in dehumidification mode with the fans at minimum speed. When outside air dew point reduces below 53°F (adjustable), the unoccupied high dew point mode will be disabled and the BMS shall shut down the AHUs.

h. Morning Warm Up/Cool Down: The AHU shall have optimized morning warm-up and cool-down control.

1) Once morning warm-up or cool-down is complete, the BMS shall operate the AHU under normal occupied control.

i. Freeze Protection Pump Operation:

1) MIT requires a freeze protection pump and an associated check valve in the bypass between coil supply and return for all AHUs with hot water heating coils.

a) The BMS shall only energize the freeze protection pump when the outside air temperature is 40°F or less.

b) Once the hot water coil control valve is proven to be more than 60% open (adjustable), the BMS shall de-energize the freeze protection pump.

c) If the hot water coil control valve is proven to be less than 50% open (adjustable), the BMS shall energize the freeze protection pump.

d) The BMS shall de-energize the freeze protection pump when the outside air temperature is 40°F or more.

e) If the pump is commanded to run and is not proven by current switch, the BMS shall de-energize the AHU and follow the same steps as in a freezestat alarm condition listed below.

j. Safeties:

1) **Freezestat (Auto Reset):**

a) The auto reset freezestat shall be set at 38°F.

b) In the event of a freezestat trip the following will occur:

1) The supply and return fans will stop via hardwired interlock.

2) The supply smoke isolation, return smoke isolation, exhaust and outside air dampers shall close via hardwired interlock.

3) The BMS shall fully open the cooling coil valve.

4) The BMS will modulate the heating coil valve to maintain plenum temperature setpoint as sensed by the cooling coil averaging temperature sensor.
c) When the freezestat auto resets the unit will restart as described in the Start/Stop section of this sequence. In some cases, if the unit trips and tries to restart three times in a half hour, subsequent software code will be implemented, such that a manual software reset via the BMS will be required for the unit to restart again.

2) Supply or Return Static Pressure Switches (Manual Reset):

   a) In the event of a static switch trip on any fan the following will occur:

   1) The supply fan(s) or return fan(s) will stop via hardwired safety.
   2) The return fans will be commanded off.
   3) The supply smoke isolation, return smoke isolation, exhaust and outside air dampers shall close.
   4) The cooling valve shall close.
   5) The BMS will modulate the heating coil valve to maintain plenum temperature setpoint as sensed by the cooling coil averaging temperature sensor.
   6) When the static pressure switch is manually reset and the alarm is reset at the BMS, the unit will restart as described above.

3) Fire Alarm System:

   a) The BMS will adjust the control mode of the AHU based on signals received from the fireman’s HOA (FHOA) contacts. An alarm will be generated to the BMS anytime a FHOA override is activated. The following contacts will be monitored per AHU:

   1) General Fire Alarm (Complete AHU Shut Down).
   2) Supply Fans “Hand”:

      a) Supply Fans On.
      b) Supply fans run to preset speed or static pressure control.
      c) Supply smoke isolation and outside air damper open.
      d) Safeties bypassed except high and/or low static.
      e) BMS maintains supply air temperature.

   3) Supply Fans “Off”:

      a) Supply Fans “Off”.
      b) Supply smoke isolation and outside air damper closed.
      c) All temperature control devices in normal positions.

   4) Return Fans “Hand”:

      a) Return Fans On.
b) Return fans run to preset speed or static pressure control.
c) Return smoke isolation and exhaust air damper open.
d) Safeties bypassed except high and/or low static.

5) Return Fans “Off”:
   a) Return Fans “Off”.
   b) Return smoke isolation and outside air damper closed.
   c) All temperature control devices in normal positions.

### Air Handling Units Typical Hardwired and Software Points

<table>
<thead>
<tr>
<th>Point</th>
<th>Type</th>
<th>Alarm</th>
<th>Short Term Trend</th>
<th>Long Term Trend</th>
<th>On Graphic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fan Status</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Fan Runtime</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Fan Amps</td>
<td>AI</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
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<tr>
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<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Fireman’s Override On</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Fireman’s Override Off</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<td>Yes</td>
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<td>Yes</td>
</tr>
<tr>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Return Air Temperature</td>
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<td>Yes</td>
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<tr>
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<tr>
<td>Cooling Coil Temperature</td>
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<td>Yes</td>
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<td>Yes</td>
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<tr>
<td>Heating Coil Temperature</td>
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<td>Yes</td>
<td>Yes</td>
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<td>Heat Recovery Temperature</td>
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<tr>
<td>Cooling Coil Water Return Temperature</td>
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<td>Preheat Coil Valve Position</td>
<td>AI</td>
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<td>Yes</td>
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<td>Heating Coil Valve Position</td>
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<td>Yes</td>
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<td>Cooling Coil Valve Position</td>
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<td>HR Wheel Status</td>
<td>AI</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>HR Wheel Runtime</td>
<td>SW</td>
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<td>No</td>
<td>Yes</td>
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<tr>
<td>Dewpoint Sensor</td>
<td>AI</td>
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<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Static Pressure</td>
<td>AI</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Damper End Switch</td>
<td>DI</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Pressure Switch</td>
<td>DI</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Smoke Detector</td>
<td>DI</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<td>VFD Fault</td>
<td>DI</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<td>VFD Bypass</td>
<td>DI</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
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<td>Fan Flow</td>
<td>AI</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Freeze Protection Pump Status</td>
<td>DI</td>
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<td>Yes</td>
<td>Yes</td>
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<tr>
<td>VFD Modulation</td>
<td>AO</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Preheat Coil Valve</td>
<td>AO</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
3.11 Exhaust/Supply Fans

1. Key Concepts:
   a. VFD on graphic shall have a separate tab for software values.
   b. VFD shall have four hardwired points (start/start, status, speed modulation signal, and fault).
   c. Damper end switch and static pressure switch be hardwired to the fan safety circuit.
   d. As a second level of protection, devices that are hardwired to a safety circuit should, when active, also be part of a software shutdown sequence.
   e. Firemen’s override “fan on” switch if required shall be tied into the safety circuit such that the unit will run in all safety conditions except for high (or low) static pressure.
   f. Firemen’s override “fan off” switch if required shall be tied into the safety circuit for fan shutdown
   g. Firemen’s override “fan on” position switch shall be monitored by the BMS for switch “on” and switch “off” position.
   h. Firemen’s override “fan off” position switch shall be monitored by the BMS for switch “on” and switch “off” position.
   i. Sequence of Operation
   j. Temperature Control (if applicable)
   k. On a high temperature, the BMS shall energize the fan.
   l. Static Pressure (if applicable)
   m. The BMS shall modulate the fan VFD to maintain static pressure setpoint.

Exhaust/Supply Fans Typical Hardwired and Software Points

<table>
<thead>
<tr>
<th>Point</th>
<th>Type</th>
<th>Alarm</th>
<th>Short Term Trend</th>
<th>Long Term Trend</th>
<th>On Graphic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fan Status</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Fan Amps</td>
<td>AI</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
3.12 Room Control

1. Key Concepts:

   a. All heating and cooling units serving one space shall be connected and controlled to prevent simultaneous heating and cooling.

   b. When there a terminal unit serves multiple rooms each with a space temperature sensor, one sensor shall act as a master. The BMS shall not use an average of the temperature sensors to maintain a certain space temperature setpoint.

   c. Spaces shall have dual setpoints for occupied heating and cooling of 70°F and 74°F respectively with a deadband between the setpoints.

   d. Spaces shall have dual setpoints for daytime unoccupied heating and cooling of 68°F and 76°F respectively with a deadband between the setpoints.

   e. Spaces shall have dual setpoints for unoccupied heating and cooling of 65°F and 80°F respectively.

      1) When the space temperature reaches 80°F, the BMS shall go to unoccupied cooling mode until room temperature reaches 77°F.

      2) Conversely, when the space temperature reaches 65°F, the BMS shall go to unoccupied heating mode until room temperature reaches 68°F.

   f. For applicable spaces (usually offices and residences), room temperature sensors shall have a physical setpoint adjustment of +/- 1.5°F (software adjustable) integral to the room temperature sensor.

   g. For applicable spaces (usually offices), room temperature sensors shall have an occupancy override pushbutton (software adjustable) integral to the room temperature sensor.
sensor which shall but the system into temporary occupancy mode for two hours (adjustable).

h. For applicable spaces (usually offices and residences), room temperature sensors shall have local display showing actual temperature, mode (heating or cooling), occupancy status, and setpoint.

i. Operator shall have the ability to modify room base setpoint without changing a program or disabling a setpoint.

j. Applicable spaces (usually high occupant density areas like classrooms, conference rooms, and auditoriums) shall have CO2 sensors. The CO2 can be integrated into the room temperature sensor.

k. Fan coil units shall have electronically commutated motors (ECMs) and shall not have packaged control. Due to accuracy at low current draws, fan coil unit manufacturer dry contact for fan status shall be preferable to current switch.

l. Local fan control speed switches are not required for fan coil units with ECMs.

3.13 Sequence Matrix Summaries

1. The matrix below simply summarizes the text that follows for each piece of equipment. The matrix is explained as follows:

   a. In the Cool Priority or Heat Priority, the lower number dictates the first action by the BMS (i.e., in heat mode with a VAV (with Reheat Coil), the BMS will first use the damper (1), then use the HW Valve (2) in an attempt to maintain setpoint.

<table>
<thead>
<tr>
<th>Equipment and Action</th>
<th>Occupied/Daytime Unoccupied Cool Mode Priority</th>
<th>Occupied/Daytime Unoccupied Heat Mode Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>CV (without Reheat Coil) Supply or Return</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>CV (without Reheat Coil) and Radiation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiation Valve Modulates Toward Open</td>
<td>N/A</td>
<td>1</td>
</tr>
<tr>
<td>CV (with Reheat Coil)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HW Valve Modulates Toward Open</td>
<td>N/A</td>
<td>1</td>
</tr>
<tr>
<td>CV (with Reheat Coil) and Radiation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiation Valve Modulates Toward Open</td>
<td>N/A</td>
<td>1</td>
</tr>
<tr>
<td>HW Valve Modulates Toward Open</td>
<td>N/A</td>
<td>2</td>
</tr>
<tr>
<td>VAV (without Reheat Coil)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Damper Modulates Toward Minimum</td>
<td>N/A</td>
<td>1</td>
</tr>
<tr>
<td>Damper Modulates Toward Maximum</td>
<td>1</td>
<td>N/A</td>
</tr>
<tr>
<td>VAV (without Reheat Coil) and Radiation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiation Valve Modulates Toward Open</td>
<td>N/A</td>
<td>2</td>
</tr>
<tr>
<td>Damper Modulates Toward Minimum</td>
<td>N/A</td>
<td>1</td>
</tr>
<tr>
<td>Damper Modulates Toward Maximum</td>
<td>1</td>
<td>N/A</td>
</tr>
<tr>
<td>VAV (with Reheat Coil)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HW Valve Modulates Toward Open</td>
<td>N/A</td>
<td>2</td>
</tr>
<tr>
<td>Damper Modulates Toward Minimum</td>
<td>N/A</td>
<td>1</td>
</tr>
<tr>
<td>Damper Modulates Toward Maximum</td>
<td>1</td>
<td>N/A</td>
</tr>
<tr>
<td>VAV (with Reheat Coil) and Radiation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiation Valve Modulates Toward Open</td>
<td>N/A</td>
<td>2</td>
</tr>
</tbody>
</table>
2. In many cases the above items will work together to control the temperature in a space. Special care must be given to stage the pieces of control properly. Some common occurrences are detailed in the matrix below. MIT has tried to address a couple common cases with the most parts so that if for example finned tube radiation is not present, the line time can be removed and the other parts can be renumbered accordingly.

<table>
<thead>
<tr>
<th>HW Valve Modulates Toward Open</th>
<th>N/A</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Damper Modulates Toward Minimum</td>
<td>N/A</td>
<td>1</td>
</tr>
<tr>
<td>Damper Modulates Toward Maximum</td>
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<td>N/A</td>
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</tbody>
</table>

**VAV (Return Air)**

<table>
<thead>
<tr>
<th>Damper Modulates Toward Minimum</th>
<th>N/A</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Damper Modulates Toward Maximum</td>
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<td>N/A</td>
</tr>
</tbody>
</table>

**Fan Coil Unit (2-pipe Cooling Only)**

<table>
<thead>
<tr>
<th>Fan On Turns with ECM @Minimum Speed</th>
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<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHW Valve Modulates Toward Open</td>
<td>2</td>
<td>N/A</td>
</tr>
<tr>
<td>ECM Modulates Toward Minimum</td>
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<tr>
<td>ECM Modulates Toward Maximum</td>
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**Fan Coil Unit (2-pipe Cooling Only) w/ Radiation**

<table>
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<tr>
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<tbody>
<tr>
<td>Radiation Valve Modulates Toward Open</td>
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<tr>
<td>CHW Valve Modulates Toward Open</td>
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</tr>
<tr>
<td>ECM Modulates Toward Minimum</td>
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<td>N/A</td>
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<tr>
<td>ECM Modulates Toward Maximum</td>
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**Fan Coil Unit (4-pipe)**

<table>
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<tr>
<th>Fan On Turns with ECM @Minimum Speed</th>
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<th>1</th>
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</thead>
<tbody>
<tr>
<td>HW Valve Modulates Toward Open</td>
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<td>2</td>
</tr>
<tr>
<td>CHW Valve Modulates Toward Open</td>
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<td>N/A</td>
</tr>
<tr>
<td>ECM Modulates Toward Maximum</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

**Fan Coil Unit (4-pipe) w/ Radiation**

<table>
<thead>
<tr>
<th>Fan On Turns with ECM @Minimum Speed</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiation Valve Modulates Toward Open</td>
<td>N/A</td>
<td>1</td>
</tr>
<tr>
<td>HW Valve Modulates Toward Open</td>
<td>N/A</td>
<td>3</td>
</tr>
<tr>
<td>CHW Valve Modulates Toward Open</td>
<td>2</td>
<td>N/A</td>
</tr>
<tr>
<td>ECM Modulates Toward Maximum</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

**Chilled Beam with Zone Pump (2-pipe Cooling)**

<table>
<thead>
<tr>
<th>CHW Valve Modulates Toward Open</th>
<th>1</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHW Pump Turns On</td>
<td>2</td>
<td>N/A</td>
</tr>
</tbody>
</table>

**Chilled Beam with Zone Pump (4-pipe)**

<table>
<thead>
<tr>
<th>CHW Valve Modulates Toward Open</th>
<th>1</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHW Pump Turns On</td>
<td>2</td>
<td>N/A</td>
</tr>
</tbody>
</table>

**Chilled Beam (2-pipe Cooling)**

| CHW Valve Modulates Toward Open       | 1   | N/A |

**Chilled Beam (4-pipe)**

| CHW Valve Modulates Toward Open       | 1   | N/A |

**Finned Tube Radiation**

<p>| Radiation Valve Modulates Toward Open | N/A | 1   |</p>
<table>
<thead>
<tr>
<th>Equipment and Action</th>
<th>Occupied / Daytime Unoccupied Cool Mode Priority</th>
<th>Occupied / Daytime Unoccupied Heat Mode Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>4-pipe Chilled Beam w/ VAV w/ Reheat and FTR</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VAV Damper Controls to Constant Volume</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>CB HW Valve Modulates Toward Open</td>
<td>N/A</td>
<td>1</td>
</tr>
<tr>
<td>CHW Pump Turns On</td>
<td>2</td>
<td>N/A</td>
</tr>
<tr>
<td>CB CHW Valve Modulates Toward Open</td>
<td>1</td>
<td>N/A</td>
</tr>
<tr>
<td>HW Pump Turns On</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Radiation Valve Modulates Toward Open</td>
<td>N/A</td>
<td>2</td>
</tr>
<tr>
<td>VAV HW Valve Modulates Toward Open</td>
<td>N/A</td>
<td>3</td>
</tr>
<tr>
<td><strong>2-pipe FCU w/ VAV w/ Reheat and FTR</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fan On Turns with ECM @Minimum Speed</td>
<td>2</td>
<td>N/A</td>
</tr>
<tr>
<td>Radiation Valve Modulates Toward Open</td>
<td>N/A</td>
<td>2</td>
</tr>
<tr>
<td>FCU CHW Valve Modulates Toward Open</td>
<td>3</td>
<td>N/A</td>
</tr>
<tr>
<td>FCU ECM Modulates Toward Maximum</td>
<td>4</td>
<td>N/A</td>
</tr>
<tr>
<td>VAV HW Valve Modulates Toward Open</td>
<td>N/A</td>
<td>3</td>
</tr>
<tr>
<td>Damper Modulates Toward Minimum</td>
<td>N/A</td>
<td>1</td>
</tr>
<tr>
<td>Damper Modulates Toward Maximum</td>
<td>1</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>4-pipe FCU w/ VAV and FTR</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fan On Turns with ECM @Minimum Speed</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Radiation Valve Modulates Toward Open</td>
<td>N/A</td>
<td>2</td>
</tr>
<tr>
<td>FCU CHW Valve Modulates Toward Open</td>
<td>3</td>
<td>N/A</td>
</tr>
<tr>
<td>FCU HW Valve Modulates Toward Open</td>
<td>N/A</td>
<td>4</td>
</tr>
<tr>
<td>FCU ECM Modulates Toward Maximum</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Damper Modulates Toward Minimum</td>
<td>N/A</td>
<td>1</td>
</tr>
<tr>
<td>Damper Modulates Toward Maximum</td>
<td>1</td>
<td>N/A</td>
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</table>
3.14 CV Boxes

CV Boxes Typical Hardwired and Software Points

<table>
<thead>
<tr>
<th>Point</th>
<th>Type</th>
<th>Alarm</th>
<th>Short Term Trend</th>
<th>Long Term Trend</th>
<th>On Graphic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space Temperature</td>
<td>AI</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Space Temperature Adjustment</td>
<td>AI</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Space Humidity</td>
<td>AI</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Space CO2</td>
<td>AI</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Velocity Measurement</td>
<td>AI</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Discharge Temperature</td>
<td>AI</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Reheat Valve</td>
<td>AO</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>VAV Damper</td>
<td>AO</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Radiation Valve</td>
<td>AO</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>VAV Flow</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>VAV Flow Setpoint</td>
<td>SW</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Base Temperature Setpoint</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Space Temperature Setpoint</td>
<td>SW</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Discharge Temperature Setpoint</td>
<td>SW</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Heating Setpoint</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Cooling Setpoint</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Mode</td>
<td>SW</td>
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<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Occupied Status</td>
<td>SW</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

1. CV Box (without Reheat Coil) Sequence of Operation:
   a. The BMS shall modulate the CV box flow to maintain a constant flow setpoint.
   b. When the source AHU is off, the BMS shall modulate the CV box closed.

2. CV Box (without Reheat Coil) and Radiation Sequence of Operation
   a. Occupied Cooling Mode:
      1) The BMS shall modulate the CV box flow to maintain a constant flow setpoint.
      2) The BMS shall start to close the radiation control valve to maintain occupied space temperature setpoint.
   b. Occupied Heating Mode:
      1) The BMS shall modulate the CV box flow to maintain a constant flow setpoint.
      2) The BMS shall start to open the radiation control valve to maintain occupied space temperature setpoint.
c. Daytime Unoccupied Cooling Mode:
   1) The BMS shall modulate the CV box flow to maintain a constant flow setpoint.
   2) The BMS shall start to close the radiation control valve to maintain daytime unoccupied space temperature setpoint.

d. Daytime Unoccupied Heating Mode:
   1) The BMS shall modulate the CV box flow to maintain a constant flow setpoint.
   2) The BMS shall start to open the radiation control valve to maintain occupied space temperature setpoint.

e. Unoccupied Cooling Mode (with the source AHU on):
   1) The BMS shall modulate the CV box flow to maintain a constant flow setpoint.
   2) The BMS shall modulate the radiation control valve fully closed until space temperature has reached 3°F below unoccupied space temperature setpoint.

f. Unoccupied Heating Mode (with the source AHU on):
   1) The BMS shall modulate the CV box flow to maintain a constant flow setpoint.
   2) The BMS shall modulate the radiation control valve fully open until space temperature has reached 3°F above unoccupied space temperature setpoint.

g. When the source AHU is off, the BMS shall modulate the CV box closed and close the radiation control valve.

3. CV Box (with Reheat Coil) Sequence of Operation:

   a. Occupied Cooling Mode:
      1) The BMS shall modulate the CV box flow to maintain a constant flow setpoint.
      2) The BMS shall start to close the reheat coil control valve to maintain occupied space temperature setpoint.

   b. Occupied Heating Mode:
      1) The BMS shall modulate the CV box flow to maintain a constant flow setpoint.
      2) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain occupied space temperature setpoint.
      3) The BMS shall then start to open the reheat coil control valve to maintain discharge temperature setpoint.

   c. Daytime Unoccupied Cooling Mode:
1) The BMS shall modulate the CV box flow to maintain a constant flow setpoint.
2) The BMS shall start to close the reheat coil control valve to maintain occupied space temperature setpoint.

d. Daytime Unoccupied Heating Mode:
1) The BMS shall modulate the CV box flow to maintain a constant flow setpoint.
2) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain occupied space temperature setpoint.
3) The BMS shall then start to open the reheat coil control valve to maintain discharge temperature setpoint.

e. Unoccupied Cooling Mode (with the source AHU on):
1) The BMS shall modulate the CV box flow to maintain a constant flow setpoint.
2) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain occupied space temperature setpoint.
3) The BMS shall then start to open the reheat coil control valve to maintain discharge temperature setpoint.

f. Unoccupied Heating Mode (with the source AHU on):
1) The BMS shall modulate the CV box flow to maintain a constant flow setpoint.
2) The BMS shall modulate the reheat coil control valve fully closed until space temperature has reached 3°F below unoccupied space temperature setpoint.

g. When the source AHU is off, the BMS shall modulate the VAV box closed and close the reheat coil control valve.

4. CV Box (with Reheat Coil) and Radiation Sequence of Operation:

a. Occupied Cooling Mode:
1) The BMS shall modulate the CV box flow to maintain a constant flow setpoint.
2) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain occupied space temperature setpoint.
3) The BMS shall first start to close the reheat coil control valve to maintain occupied discharge temperature setpoint.
4) Once the reheat coil control valve is fully closed, the BMS shall then start to close the radiation control valve to maintain discharge temperature setpoint.

b. Occupied Heating Mode:
1) The BMS shall modulate the CV box flow to maintain a constant flow setpoint.
2) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain occupied space temperature setpoint.
3) The BMS shall first start to open the radiation control valve to maintain discharge temperature setpoint.
4) Once the radiation control valve is fully closed, the BMS shall then start to open the reheat coil control valve to maintain discharge temperature setpoint.

c. Daytime Unoccupied Cooling Mode:

1) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain daytime unoccupied space temperature setpoint.
2) The BMS shall first start to close the reheat coil control valve to maintain discharge temperature setpoint.
3) Once the reheat coil control valve is fully closed, the BMS shall then start to close the radiation control valve to maintain discharge temperature setpoint.

d. Daytime Unoccupied Heating Mode:

1) The BMS shall modulate the CV box flow to maintain a constant flow setpoint.
2) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain daytime unoccupied space temperature setpoint.
3) The BMS shall first start to open the radiation control valve to maintain discharge temperature setpoint.
4) Once the radiation control valve is fully closed, the BMS shall then start to open the reheat coil control valve to maintain discharge temperature setpoint.

e. Unoccupied Cooling Mode (with the source AHU on):

1) The BMS shall modulate the CV box flow to maintain a constant flow setpoint.
2) The BMS shall modulate the reheat coil and radiation control valves fully closed until space temperature has reached 3°F below unoccupied space temperature setpoint.

f. Unoccupied Heating Mode (with the source AHU on):

1) The BMS shall modulate the CV box flow to maintain a constant flow setpoint.
2) The BMS shall modulate the reheat coil and radiation control valves fully open until space temperature has reached 3°F above unoccupied space temperature setpoint.

g. When the source AHU is off, the BMS shall modulate the VAV box closed and close the radiation and reheat coil control valves.

5. CV (Return Air) Box Sequence of Operation

a. The BMS shall modulate the CV box flow to maintain a constant flow setpoint.
3.15 VAV Boxes

VAV Boxes Typical Hardwired and Software Points

<table>
<thead>
<tr>
<th>Point</th>
<th>Type</th>
<th>Alarm</th>
<th>Short Term Trend</th>
<th>Long Term Trend</th>
<th>On Graphic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space Temperature</td>
<td>AI</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Space Temperature Adjustment</td>
<td>AI</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
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<tr>
<td>Space Humidity</td>
<td>AI</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Space CO2</td>
<td>AI</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Velocity Measurement</td>
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<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Discharge Temperature</td>
<td>AI</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Reheat Valve</td>
<td>AO</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>VAV Damper</td>
<td>AO</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Radiation Valve</td>
<td>AO</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<td>VAV Flow</td>
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<tr>
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<td>VAV Flow Maximum</td>
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<td>Space Temperature Setpoint</td>
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<td>Discharge Temperature Setpoint</td>
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<td>Yes</td>
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<td>Heating Setpoint</td>
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<td>Cooling Setpoint</td>
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<td>Mode</td>
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<td>Occupied Status</td>
<td>SW</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

1. VAV Box (without Reheat Coil) Sequence of Operation:

   a. Occupied Cooling Mode:

      1) The BMS shall start to modulate the VAV box flow from its minimum flow setpoint up toward its maximum flow setpoint to maintain occupied space temperature setpoint.

   b. Daytime Unoccupied Cooling Mode:

      1) The BMS shall start to modulate the VAV box flow from its minimum flow setpoint up toward its maximum flow setpoint to maintain daytime unoccupied space temperature setpoint.

   c. Unoccupied Cooling Mode (with the source AHU on):

      1) The BMS shall modulate the VAV box flow to its maximum flow setpoint until space temperature has reached 3°F below unoccupied space temperature setpoint.
d. CO2 Control (applicable in Occupied Mode only):

1) The BMS shall prioritize CO2 override over cooling.
2) The BMS shall modulate the VAV box flow toward its maximum to maintain acceptable room CO2 levels (<825 ppm).

e. When the source AHU is off, the BMS shall modulate the VAV box closed.

2. VAV Box (without Reheat Coil) and Radiation Sequence of Operation:

a. Occupied Cooling Mode:

1) The BMS shall first start to close the radiation control valve to maintain occupied space temperature setpoint.
2) Once the valve is fully closed, the BMS shall then start to modulate the VAV box flow from its minimum flow setpoint up toward its maximum flow setpoint to maintain occupied space temperature setpoint.

b. Occupied Heating Mode:

1) The BMS shall first start to modulate the VAV box flow from its maximum flow setpoint down toward its minimum flow setpoint to maintain occupied space temperature setpoint.
2) Once the VAV box is at its minimum flow, the BMS shall then start to open the radiation control valve to maintain occupied space temperature setpoint.

c. Daytime Unoccupied Cooling Mode:

1) The BMS shall first start to close the radiation control valve to maintain daytime unoccupied space temperature setpoint.
2) Once the valve is fully closed, the BMS shall then start to modulate the VAV box flow from its minimum flow setpoint up toward its maximum flow setpoint to maintain daytime unoccupied space temperature setpoint.

d. Daytime Unoccupied Heating Mode:

1) The BMS shall first start to modulate the VAV box flow from its maximum flow setpoint down toward its minimum flow setpoint to maintain daytime unoccupied space temperature setpoint.
2) Once the VAV box is at its minimum flow, the BMS shall then start to open the radiation control valve to maintain occupied daytime unoccupied space temperature setpoint.
e. Unoccupied Cooling Mode (with the source AHU on):

1) The BMS shall modulate the radiation control valve fully closed and modulate the VAV box flow to its maximum flow setpoint until space temperature has reached 3°F below unoccupied space temperature setpoint.

g. CO2 Control (applicable in Occupied Modes only):

1) The BMS shall prioritize CO2 override over heating and cooling.
2) The BMS shall modulate the VAV box flow toward its maximum to maintain acceptable room CO2 levels (<825 ppm).

h. When the source AHU is off, the BMS shall modulate the VAV box closed and close the radiation control valve.

3. VAV Box (with Reheat Coil) Sequence of Operation:

a. Occupied Cooling Mode:

1) The BMS shall first start to close the reheat coil control valve to maintain occupied space temperature setpoint.
2) Once the reheat coil control valve is fully closed, the BMS shall then start to modulate the VAV box flow from its minimum flow setpoint up toward its maximum flow setpoint to maintain occupied space temperature setpoint.

b. Occupied Heating Mode:

1) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain occupied space temperature setpoint.
2) The BMS shall first start to modulate the VAV box flow from its maximum flow setpoint down toward its minimum flow setpoint to maintain discharge temperature setpoint.
3) Once the VAV box is at its minimum flow, the BMS shall then start to open the reheat coil control valve to maintain discharge temperature setpoint.

c. Daytime Unoccupied Cooling Mode:

1) The BMS shall first start to close the reheat coil control valve to maintain daytime unoccupied space temperature setpoint.
2) Once the reheat coil control valve is fully closed, the BMS shall then start to modulate the VAV box flow from its minimum flow setpoint up toward its
maximum flow setpoint to maintain daytime unoccupied space temperature setpoint.

d. Daytime Unoccupied Heating Mode:

1) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain daytime unoccupied space temperature setpoint.
2) The BMS shall first start to modulate the VAV box flow from its maximum flow setpoint down toward its minimum flow setpoint to maintain discharge temperature setpoint.
3) Once the VAV box is at its minimum flow, the BMS shall then start to open the reheat coil control valve to maintain discharge temperature setpoint.

e. Unoccupied Cooling Mode (with the source AHU on):

1) The BMS shall modulate the reheat coil control valve fully closed and modulate the VAV box flow to its maximum flow setpoint until space temperature has reached 3°F below unoccupied space temperature setpoint.

f. Unoccupied Heating Mode (with the source AHU on):

1) The BMS shall modulate the reheat coil control valve fully open and modulate the VAV box flow to its minimum flow setpoint until space temperature has reached 3°F above unoccupied space temperature setpoint.

g. CO2 Control (applicable in Occupied Modes only):

1) The BMS shall prioritize CO2 override over heating and cooling.
2) The BMS shall modulate the VAV box flow toward its maximum to maintain acceptable room CO2 levels (<825 ppm).

h. When the source AHU is off, the BMS shall modulate the VAV box closed and close the reheat coil control valve.

4. VAV Box (with Reheat Coil) and Radiation Sequence of Operation:

a. Occupied Cooling Mode:

1) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain occupied space temperature setpoint.
2) The BMS shall first start to close the reheat coil control valve to maintain occupied discharge temperature setpoint.
3) Once the reheat coil control valve is fully closed, the BMS shall then start to close the radiation control valve to maintain discharge temperature setpoint.
4) Once the radiation control valve is fully closed, the BMS shall then start to modulate the VAV box flow from its minimum flow setpoint up toward its maximum flow setpoint to maintain discharge temperature setpoint.
b. Occupied Heating Mode:

1) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain occupied space temperature setpoint.
2) The BMS shall first start to modulate the VAV box flow from its maximum flow setpoint down toward its minimum flow setpoint to maintain discharge temperature setpoint.
3) Once the VAV box is at its minimum flow, the BMS shall then start to open the radiation control valve to maintain discharge temperature setpoint.
4) Once the radiation control valve is fully closed, the BMS shall then start to open the reheat coil control valve to maintain discharge temperature setpoint.

c. Daytime Unoccupied Cooling Mode:

1) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain daytime unoccupied space temperature setpoint.
2) The BMS shall first start to close the reheat coil control valve to maintain discharge temperature setpoint.
3) Once the reheat coil control valve is fully closed, the BMS shall then start to close the radiation control valve to maintain discharge temperature setpoint.
4) Once the radiation control valve is fully closed, the BMS shall then start to modulate the VAV box flow from its minimum flow setpoint up toward its maximum flow setpoint to maintain discharge temperature setpoint.

d. Daytime Unoccupied Heating Mode:

1) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain daytime unoccupied space temperature setpoint.
2) The BMS shall first start to modulate the VAV box flow from its maximum flow setpoint down toward its minimum flow setpoint to maintain discharge temperature setpoint.
3) Once the VAV box is at its minimum flow, the BMS shall then start to open the radiation control valve to maintain discharge temperature setpoint.
4) Once the radiation control valve is fully closed, the BMS shall then start to open the reheat coil control valve to maintain discharge temperature setpoint.

e. Unoccupied Cooling Mode (with the source AHU on):

1) The BMS shall modulate the reheat coil and radiation control valves fully closed and modulate the VAV box flow to its maximum flow setpoint until space temperature has reached 3°F below unoccupied space temperature setpoint.
f. Unoccupied Heating Mode (with the source AHU on):
   1) The BMS shall modulate the reheat coil and radiation control valves fully open and modulate the VAV box flow to its minimum flow setpoint until space temperature has reached 3°F above unoccupied space temperature setpoint.

g. CO2 Control (applicable in Occupied Modes only):
   1) The BMS shall prioritize CO2 override over heating and cooling.
   2) The BMS shall modulate the VAV box flow toward its maximum to maintain acceptable room CO2 levels (<825 ppm).

h. When the source AHU is off, the BMS shall modulate the VAV box closed and close the radiation and reheat coil control valves.

5. VAV (Return Air) Box Sequence of Operation:
   a. In most cases, the BMS will control the return VAV to track the corresponding supply VAV CFM to provide a room offset.
   b. Occupied Mode:
      1) The BMS shall modulate the VAV box damper to maintain airflow setpoint.
   c. Unoccupied Mode (with the source AHU on):
      1) The BMS shall modulate the VAV box damper to maintain airflow setpoint.
   d. When the source AHU is off, the BMS shall modulate the VAV box closed.
3.16 Fan Coil Units

Fan Coil Units Typical Hardwired and Software Points

<table>
<thead>
<tr>
<th>Point</th>
<th>Type</th>
<th>Alarm</th>
<th>Short Term Trend</th>
<th>Long Term Trend</th>
<th>On Graphic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space Temperature</td>
<td>AI</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
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<td>Yes</td>
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<td>Discharge Temperature</td>
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<tr>
<td>ECM Minimum Setpoint</td>
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<td>ECM Maximum Setpoint</td>
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<td>No</td>
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<tr>
<td>Condensate Level Switch (where required*)</td>
<td>DI</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
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<tr>
<td>Heating Valve</td>
<td>AO</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
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<td>Cooling Valve</td>
<td>AO</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Radiation Valve</td>
<td>AO</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Fan Start/Stop (not required with ECM)</td>
<td>DO</td>
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<td>AO</td>
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<td>Yes</td>
<td>Yes</td>
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<td>Base Temperature Setpoint</td>
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<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Space Temperature Setpoint</td>
<td>SW</td>
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<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Discharge Temperature Setpoint</td>
<td>SW</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Heating Setpoint</td>
<td>SW</td>
<td>No</td>
<td>No</td>
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<tr>
<td>Cooling Setpoint</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
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<tr>
<td>Mode</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Occupied Status</td>
<td>SW or DI</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

* Refer to MIT Design Standards 230000-HVAC for further details.

1. Fan Coil Units (2-pipe Cooling Only) Sequence of Operation:
   a. When space the temperature is in the deadband and the ECM has been at its minimum position, with the cooling coil control valve fully closed, for fifteen minutes, the BMS shall de-energize the fan.
   b. Occupied Cooling Mode:
      1) The fan shall be on in occupied mode with the ECM in its minimum position.
      2) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain occupied space temperature setpoint.
3) The BMS shall first start to modulate the cooling coil control valve open to maintain discharge temperature setpoint.
4) Once the cooling coil control valve is fully open, the BMS shall then start to modulate the fan coil unit ECM from its minimum speed setpoint up toward its maximum speed setpoint to maintain discharge temperature setpoint.

c. Daytime Unoccupied Cooling Mode:

1) The fan shall be on in occupied mode with the ECM in its minimum position.
2) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain daytime unoccupied space temperature setpoint.
3) The BMS shall first start to modulate the cooling coil control valve open to maintain discharge temperature setpoint.
4) Once the cooling coil control valve is fully open, the BMS shall then start to modulate the fan coil unit ECM from its minimum speed setpoint up toward its maximum speed setpoint to maintain discharge temperature setpoint.

d. Unoccupied Cooling Mode:

1) The BMS shall energize the fan, modulate the fan coil unit ECM to its maximum speed setpoint, and modulate the cooling coil control valve fully open until space temperature has reached 3°F below unoccupied space temperature setpoint.

e. CO2 Control (applicable in Occupied Mode only):

1) The BMS shall prioritize CO2 override over cooling.
2) The BMS shall modulate the ECM toward its maximum speed setpoint to maintain acceptable room CO2 levels (<825 ppm).

2. Fan Coil Units (2-pipe) and Radiation Sequence of Operation:

a. When the space temperature is in the deadband and the ECM has been at its minimum position, with the cooling coil and radiation control valves fully closed, for fifteen minutes, the BMS shall de-energize the fan.

b. Occupied Cooling Mode:

1) The fan shall be on in occupied mode with the ECM in its minimum position.
2) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain occupied space temperature setpoint.
3) The BMS shall first start to close the radiation control valve to maintain discharge temperature setpoint.
4) Once the radiation control valve is fully closed, the BMS shall then start to open the cooling coil control valve to maintain discharge temperature setpoint.
5) Once the cooling coil control valve is fully open, the BMS shall then start to modulate the fan coil unit ECM from its minimum speed setpoint up toward its maximum speed setpoint to maintain discharge temperature setpoint.
c. Occupied Heating Mode:

1) The fan shall be off in occupied heating mode.
2) The BMS shall then start to open the radiation control valve to maintain occupied space temperature setpoint.

d. Daytime Unoccupied Cooling Mode:

1) The fan shall be on in daytime unoccupied mode with the ECM in its minimum position.
2) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain daytime unoccupied space temperature setpoint.
3) The BMS shall first start to close the radiation control valve to maintain discharge temperature setpoint.
4) Once the radiation control valve is fully closed, the BMS shall then start to open the cooling coil control valve to maintain discharge temperature setpoint.
5) Once the cooling coil control valve is fully open, the BMS shall then start to modulate the fan coil unit ECM from its minimum speed setpoint up toward its maximum speed setpoint to maintain discharge temperature setpoint.

e. Daytime Unoccupied Heating Mode:

1) The fan shall be off in daytime unoccupied heating mode.
2) The BMS shall then start to open the radiation control valve to maintain daytime unoccupied space temperature setpoint.

f. Unoccupied Cooling Mode:

1) The BMS shall energize the fan, modulate the fan coil unit ECM to its maximum speed setpoint, modulate the radiation control valve fully closed, and modulate the cooling coil control valve fully open until space temperature has reached 3°F below unoccupied space temperature setpoint.

g. Unoccupied Heating Mode:

1) With the fan off and the cooling coil control valve fully closed, the BMS shall modulate the radiation control valve fully open, until space temperature has reached 3°F above unoccupied space temperature setpoint.

h. CO2 Control (applicable in Occupied Modes only):

1) The BMS shall prioritize CO2 override over heating and cooling.
2) The BMS shall modulate the ECM toward its maximum speed setpoint to maintain acceptable room CO2 levels (<825 ppm).
3. Fan Coil Units (4-pipe) Sequence of Operation:

a. When the space temperature is in the deadband and the ECM has been at its minimum position, with the cooling coil and hot water coil control valves fully closed, for fifteen minutes, the BMS shall de-energize the fan.

b. Occupied Cooling Mode:

1) The fan shall be on in occupied cooling mode with the ECM in its minimum position.
2) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain occupied space temperature setpoint.
3) The BMS shall first start to close the heating coil control valve to maintain discharge temperature setpoint.
4) Once the heating coil control valve is fully closed, the BMS shall then start to open the cooling coil control valve to maintain discharge temperature setpoint.
5) Once the cooling coil control valve is fully open, the BMS shall then modulate the fan coil unit ECM from its minimum speed setpoint up toward its maximum speed setpoint to maintain discharge temperature setpoint.

c. Occupied Heating Mode:

1) The fan shall be on in occupied heating mode with the ECM in its minimum position.
2) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain occupied space temperature setpoint.
3) The BMS shall first start to close the cooling coil control valve to maintain discharge temperature setpoint.
4) Once the cooling coil control valve is fully closed, the BMS shall then start to open the heating coil control valve to maintain discharge temperature setpoint.
5) Once the heating coil control valve is fully open, the BMS shall then modulate the fan coil unit ECM from its minimum speed setpoint up toward its maximum speed setpoint to maintain discharge temperature setpoint.

d. Daytime Unoccupied Cooling Mode:

1) The fan shall be on in daytime unoccupied cooling mode with the ECM in its minimum position.
2) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain daytime unoccupied space temperature setpoint.
3) The BMS shall first start to close the heating coil control valve to maintain discharge temperature setpoint.
4) Once the heating coil control valve is fully closed, the BMS shall then start to open the cooling coil control valve to maintain discharge temperature setpoint.
5) Once the cooling coil control valve is fully open, the BMS shall then modulate the fan coil unit ECM from its minimum speed setpoint up toward its maximum speed setpoint to maintain discharge temperature setpoint.

e. Daytime Unoccupied Heating Mode:

1) The fan shall be on in daytime unoccupied heating mode with the ECM in its minimum position.
2) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain daytime unoccupied space temperature setpoint.
3) The BMS shall first start to close the cooling coil control valve to maintain discharge temperature setpoint.
4) Once the cooling coil control valve is fully closed, the BMS shall then start to open the heating coil control valve to maintain discharge temperature setpoint.
5) Once the heating coil control valve is fully open, the BMS shall then modulate the fan coil unit ECM from its minimum speed setpoint up toward its maximum speed setpoint to maintain discharge temperature setpoint.

f. Unoccupied Cooling Mode:

1) The BMS shall energize the fan, modulate the fan coil unit ECM to its maximum speed setpoint, modulate the heating coil control valve fully closed, and modulate the cooling coil control valve fully open until space temperature has reached 3°F below unoccupied space temperature setpoint.

g. Unoccupied Heating Mode:

1) The BMS shall energize the fan, modulate the fan coil unit ECM to its maximum speed setpoint, modulate the heating coil control valve fully open, and modulate the cooling coil control valve fully closed until space temperature has reached 3°F above unoccupied space temperature setpoint.

h. CO2 Control (applicable in Occupied Modes only):

1) The BMS shall prioritize CO2 override over heating and cooling.
2) The BMS shall modulate the ECM toward its maximum speed setpoint to maintain acceptable room CO2 levels (<825 ppm).

4. Fan Coil Units (4-pipe Heating & Cooling) and Radiation Sequence of Operation:

a. When the space temperature is in the deadband and the ECM has been at its minimum position, with the cooling coil, hot water coil, and radiation control valves fully closed, for fifteen minutes, the BMS shall de-energize the fan.

b. Occupied Cooling Mode:
1) The fan shall be on in occupied cooling mode with the ECM in its minimum position.
2) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain occupied space temperature setpoint.
3) The BMS shall first start to close the radiation control valve to maintain discharge temperature setpoint.
4) Once the radiation control valve is fully closed, the BMS shall then start to close the heating coil control valve to maintain discharge temperature setpoint.
5) Once the heating coil control valve is fully closed, the BMS shall then start to open the cooling coil control valve to maintain discharge temperature setpoint.
6) Once the cooling coil control valve is fully open, the BMS shall then modulate the fan coil unit ECM from its minimum speed setpoint up toward its maximum speed setpoint to maintain discharge temperature setpoint.

c. Occupied Heating Mode:

1) The fan shall be on in occupied heating mode with the ECM in its minimum position.
2) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain occupied space temperature setpoint.
3) The BMS shall first start to close the cooling coil control valve to maintain discharge temperature setpoint.
4) Once the cooling control valve is fully closed, the BMS shall then start to open the radiation control valve to maintain discharge temperature setpoint.
5) Once the radiation control valve is fully open, the BMS shall then start to open the heating coil control valve to maintain discharge temperature setpoint.
6) Once the heating coil control valve is fully open, the BMS shall then modulate the fan coil unit ECM from its minimum speed setpoint up toward its maximum speed setpoint to maintain discharge temperature setpoint.

d. Daytime Unoccupied Cooling Mode:

1) The fan shall be on in daytime unoccupied cooling mode with the ECM in its minimum position.
2) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain daytime unoccupied space temperature setpoint.
3) The BMS shall first start to close the radiation control valve to maintain discharge temperature setpoint.
4) Once the radiation control valve is fully closed, the BMS shall then start to close the heating coil control valve to maintain discharge temperature setpoint.
5) Once the heating coil control valve is fully closed, the BMS shall then start to open the cooling coil control valve to maintain discharge temperature setpoint.
6) Once the cooling coil control valve is fully open, the BMS shall then modulate the fan coil unit ECM from its minimum speed setpoint up toward its maximum speed setpoint to maintain discharge temperature setpoint.
e. Daytime Unoccupied Heating Mode:

1) The fan shall be on in daytime unoccupied heating mode with the ECM in its minimum position.
2) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain daytime unoccupied space temperature setpoint.
3) The BMS shall first start to close the cooling coil control valve to maintain discharge temperature setpoint.
4) Once the cooling control valve is fully closed, the BMS shall then start to open the radiation control valve to maintain discharge temperature setpoint.
5) Once the radiation control valve is fully open, the BMS shall then start to open the heating coil control valve to maintain discharge temperature setpoint.
6) Once the heating coil control valve is fully open, the BMS shall then modulate the fan coil unit ECM from its minimum speed setpoint up toward its maximum speed setpoint to maintain discharge temperature setpoint.

f. Unoccupied Cooling Mode:

1) The BMS shall energize the fan, modulate the fan coil unit ECM to its maximum speed setpoint, modulate the heating coil and radiation control valves fully closed, and modulate the cooling coil control valve fully open until space temperature has reached 3°F below unoccupied space temperature setpoint.

g. Unoccupied Heating Mode:

1) The BMS shall energize the fan, modulate the fan coil unit ECM to its maximum speed setpoint, modulate the heating coil and radiation control valves fully open, and modulate the cooling coil control valve fully closed until space temperature has reached 3°F above unoccupied space temperature setpoint.

h. CO2 Control (applicable in Occupied Modes only):

1) The BMS shall prioritize CO2 override over heating and cooling.
2) The BMS shall modulate the ECM toward its maximum speed setpoint to maintain acceptable room CO2 levels (<825 ppm).
### 3.17 Chilled Beams

#### Chilled Beam Typical Hardwired and Software Points

<table>
<thead>
<tr>
<th>Point</th>
<th>Type</th>
<th>Alarm</th>
<th>Short Term Trend</th>
<th>Long Term Trend</th>
<th>On Graphic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space Temperature</td>
<td>AI</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Space Temperature Adjustment</td>
<td>AI</td>
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<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Space Humidity</td>
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<td>Space CO2</td>
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<td>Booster Pump Start/Stop</td>
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<td>Yes</td>
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<td>Yes</td>
<td>Yes</td>
</tr>
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<td>Cooling Valve</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Radiation Valve</td>
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<td>Yes</td>
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<td>Base Temperature Setpoint</td>
<td>SW</td>
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<td>No</td>
<td>No</td>
<td>Yes</td>
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<tr>
<td>Space Temperature Setpoint</td>
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<td>Yes</td>
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<tr>
<td>Heating Setpoint</td>
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<td>No</td>
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<td>Cooling Setpoint</td>
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<td>Mode</td>
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<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Occupied Status</td>
<td>SW or DI</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Outside Air Dewpoint</th>
<th>CHW Discharge Setpoint</th>
</tr>
</thead>
<tbody>
<tr>
<td>55°F</td>
<td>59°F</td>
</tr>
</tbody>
</table>

1. Chilled Beam with Zone Pump (2-pipe Cooling) Sequence of Operation:

   a. Occupied Cooling Mode:

   1) The BMS shall use actual space temperature to reset the CHW pump discharge temperature setpoint and use this to maintain occupied space temperature setpoint. The BMS shall reset the CHW pump discharge temperature setpoint between its maximum setpoint of 74°F and a minimum setpoint established by taking the maximum of two dew point calculations, outside air dew point reset calculation in following table, space dew point (as calculated from T&RH sensors in return duct) plus 2°F:
### Outside Air Dewpoint

<table>
<thead>
<tr>
<th>Outside Air Dewpoint</th>
<th>CHW Discharge Setpoint</th>
</tr>
</thead>
<tbody>
<tr>
<td>52°F</td>
<td>55°F</td>
</tr>
<tr>
<td>55°F</td>
<td>59°F</td>
</tr>
</tbody>
</table>

2) The BMS shall first modulate the cooling coil control valve open to maintain CHW pump discharge temperature setpoint.
3) The BMS shall then energize the CHW booster pump.

**b. Daytime Unoccupied Cooling Mode:**

1) The BMS shall use actual space temperature to reset the CHW pump discharge temperature setpoint and use this to maintain daytime unoccupied space temperature setpoint. The BMS shall reset the CHW pump discharge temperature setpoint between its maximum setpoint of 74°F and a minimum setpoint established by taking the maximum of two dew point calculations. Outside air dew point reset calculation in following table, space dew point (as calculated from T&RH sensors in return duct) plus 2°F.

<table>
<thead>
<tr>
<th>Outside Air Dewpoint</th>
<th>CHW Discharge Setpoint</th>
</tr>
</thead>
<tbody>
<tr>
<td>55°F</td>
<td>59°F</td>
</tr>
<tr>
<td>52°F</td>
<td>55°F</td>
</tr>
</tbody>
</table>

2) The BMS shall first modulate the cooling coil control valve open to maintain CHW pump discharge temperature setpoint.
3) The BMS shall then energize the CHW booster pump.

**c. Unoccupied Cooling Mode:**

1) The BMS shall use actual space temperature to reset the CHW pump discharge temperature setpoint and use this to maintain unoccupied space temperature setpoint. The BMS shall reset the CHW pump discharge temperature setpoint between its maximum setpoint of 74°F and a minimum setpoint established by taking the maximum of two dew point calculations. Outside air dew point reset calculation in following table, space dew point (as calculated from T&RH sensors in return duct) plus 2°F.

<table>
<thead>
<tr>
<th>Outside Air Dewpoint</th>
<th>CHW Discharge Setpoint</th>
</tr>
</thead>
<tbody>
<tr>
<td>55°F</td>
<td>59°F</td>
</tr>
<tr>
<td>52°F</td>
<td>55°F</td>
</tr>
</tbody>
</table>
2) The BMS shall first modulate the cooling coil control valve open to maintain CHW pump discharge temperature setpoint until space temperature has reached 3°F below unoccupied space temperature setpoint.
3) The BMS shall then energize the CHW booster pump.

d. Unoccupied Dewpoint Control Mode:
1) If space dewpoint in any of the rooms in the zones served rises above 59°F, the BMS shall modulate the associated VAV box fully open until the space dewpoint reaches 56°F.

e. Extreme Humidity Control Mode (dewpoint >57°F (occupied mode), dewpoint >59°F (unoccupied mode) as measured in the space or return duct):
1) The BMS shall first de-energize the CHW booster pump.
2) The BMS shall then modulate the cooling coil control valve fully closed.

2. Chilled Beam with Zone Pump (4-pipe Heating & Cooling) Sequence of Operation:

a. Occupied Cooling Mode:
1) The BMS shall use actual space temperature to reset the CHW pump discharge temperature setpoint and use this to maintain occupied space temperature setpoint. The BMS shall reset the CHW pump discharge temperature setpoint between its maximum setpoint of 74°F and a minimum setpoint established by taking the maximum of two dew point calculations. Outside air dew point reset calculation in following table, space dew point (as calculated from T&RH sensors in return duct) plus 2°F.

<table>
<thead>
<tr>
<th>Outside Air Dewpoint</th>
<th>CHW Discharge Setpoint</th>
</tr>
</thead>
<tbody>
<tr>
<td>55°F</td>
<td>59°F</td>
</tr>
<tr>
<td>52°F</td>
<td>55°F</td>
</tr>
</tbody>
</table>

2) The BMS shall first start to modulate the cooling coil control valve open to maintain CHW pump discharge temperature setpoint.
3) The BMS shall then energize the CHW booster pump and de-energize the HW booster pump
4) The BMS shall then modulate the heating coil control valve fully closed.

b. Occupied Heating Mode:
1) The BMS shall first start to modulate the heating coil control valve open to maintain HW pump discharge temperature setpoint of 120°F.
2) The BMS shall then energize the HW booster pump and de-energize the CHW booster pump.

3) The BMS shall then modulate the cooling coil control valve fully closed.

4) Additionally, the heating mode utilizes a VAV box with reheat coil and/or perimeter radiation control valve as described above in the VAV section.

c. Daytime Unoccupied Cooling Mode:

1) The BMS shall use actual space temperature to reset the CHW pump discharge temperature setpoint and use this to maintain daytime unoccupied space temperature setpoint. The BMS shall reset the CHW pump discharge temperature setpoint between its maximum setpoint of 74°F and a minimum setpoint established by taking the maximum of two dew point calculations. Outside air dew point reset calculation in following table, space dew point (as calculated from T&R sensors in return duct) plus 2°F.

<table>
<thead>
<tr>
<th>Outside Air Dewpoint</th>
<th>CHW Discharge Setpoint</th>
</tr>
</thead>
<tbody>
<tr>
<td>55°F</td>
<td>59°F</td>
</tr>
<tr>
<td>52°F</td>
<td>55°F</td>
</tr>
</tbody>
</table>

2) The BMS shall first start to modulate the cooling coil control valve open to maintain CHW pump discharge temperature setpoint.

3) The BMS shall then energize the CHW booster pump and de-energize the HW booster pump.

4) The BMS shall then modulate the heating coil control valve fully closed.

d. Daytime Unoccupied Heating Mode:

1) The BMS shall first start to modulate the heating coil control valve open to maintain HW pump discharge temperature setpoint of 120°F.

2) The BMS shall then energize the HW booster pump and de-energize the CHW booster pump.

3) The BMS shall then modulate the cooling coil control valve fully closed.

4) Additionally, the heating mode utilizes a VAV box with reheat coil and/or perimeter radiation control valve as described above in the VAV section.

e. Unoccupied Cooling Mode:

1) The BMS shall use actual space temperature to reset the CHW pump discharge temperature setpoint and use this to maintain unoccupied space temperature setpoint. The BMS shall reset the CHW pump discharge temperature setpoint between its maximum setpoint of 74°F and a minimum setpoint established by
taking the maximum of two dew point calculations. Outside air dew point reset calculation in following table, space dew point (as calculated from T&RH sensors in return duct) plus 2°F.

<table>
<thead>
<tr>
<th>Outside Air Dewpoint</th>
<th>CHW Discharge Setpoint</th>
</tr>
</thead>
<tbody>
<tr>
<td>55°F</td>
<td>59°F</td>
</tr>
<tr>
<td>52°F</td>
<td>55°F</td>
</tr>
</tbody>
</table>

2) The BMS shall first modulate the cooling coil control valve open to maintain CHW pump discharge temperature setpoint until space temperature has reached 3°F below unoccupied space temperature setpoint.

3) The BMS shall then energize the CHW booster pump and de-energize the HW booster pump.

4) The BMS shall then modulate the heating coil control valve fully closed.

f. Unoccupied Heating Mode:

1) The BMS shall first start to modulate the heating coil control valve open to maintain HW pump discharge temperature setpoint of 120°F until space temperature has reached 3°F above unoccupied space temperature setpoint.

2) The BMS shall then energize the HW booster pump and de-energize the CHW booster pump.

3) The BMS shall then modulate the cooling coil control valve fully closed.

4) Additionally, the heating mode utilizes a VAV box with reheat coil and/or perimeter radiation control valve as described above in the VAV section.

g. Unoccupied Dewpoint Control Mode:

1) If space dewpoint in any of the rooms in the zones served rises above 59°F, the BMS shall modulate the associated VAV box fully open until the space dewpoint reaches 56°F.

h. Extreme Humidity Control Mode (dewpoint >57°F (occupied mode), dewpoint >59°F (unoccupied mode) as measured in the space or return duct):

1) The BMS shall de-energize the CHW booster pump.

2) The BMS shall modulate the cooling coil control valve fully closed.

3. Chilled Beam (2-pipe Cooling) Sequence of Operation:

a. Occupied Cooling Mode:

1) The BMS shall modulate the cooling coil control valve open to maintain occupied space temperature setpoint.
b. Unoccupied Cooling Mode:

1) The BMS shall modulate the cooling coil control valve fully open until space temperature has reached 3°F above unoccupied space temperature setpoint.

c. Unoccupied Dewpoint Control Mode:

1) If space dewpoint in any of the rooms in the zones served rises above 59°F, the BMS shall modulate the associated VAV box fully open until the space dewpoint reaches 56°F.

d. Extreme Humidity Control Mode (dewpoint >57°F (occupied mode), dewpoint >59°F (unoccupied mode) as measured in the space or return duct):

1) The BMS shall modulate the cooling coil control valve fully closed.

4. Chilled Beam (4-pipe Heating & Cooling) Sequence of Operation:

a. Occupied Cooling Mode:

1) The BMS shall first modulate the heating coil control valve fully closed.
2) The BMS shall then modulate the cooling coil control valve open to maintain occupied space temperature setpoint.

b. Occupied Heating Mode:

1) The BMS shall first modulate the cooling coil control valve fully closed.
2) The BMS shall then modulate the heating coil control valve open to maintain occupied space temperature setpoint.

c. Daytime Unoccupied Cooling Mode:

1) The BMS shall first modulate the heating coil control valve fully closed.
2) The BMS shall then modulate the cooling coil control valve open to maintain daytime unoccupied space temperature setpoint.

d. Daytime Unoccupied Heating Mode:

1) The BMS shall first modulate the cooling coil control valve fully closed.
2) The BMS shall then modulate the heating coil control valve open to maintain daytime unoccupied space temperature setpoint.

e. Unoccupied Cooling Mode:
1) The BMS shall first modulate the heating coil control valve fully closed.
2) The BMS shall then modulate the cooling coil control valve open until space temperature has reached 3°F below unoccupied space temperature setpoint.

f. Unoccupied Heating Mode:

1) The BMS shall first modulate the cooling coil control valve fully closed.
2) The BMS shall then modulate the heating coil control valve open until space temperature has reached 3°F above unoccupied space temperature setpoint.

g. Unoccupied Dewpoint Control Mode:

1) If space dewpoint in any of the rooms in the zones served rises above 59°F, the BMS shall modulate the associated VAV box fully open until the space dewpoint reaches 56°F.

h. Extreme Humidity Control Mode (dewpoint > 57°F (occupied mode), dewpoint > 59°F (unoccupied mode) as measured in the space or return duct):

1) The BMS shall modulate the cooling coil control valve fully closed.

3.18 Finned Tube Radiation

Finned Tube Radiation Typical Hardwired and Software Points

<table>
<thead>
<tr>
<th>Point</th>
<th>Type</th>
<th>Alarm</th>
<th>Short Term Trend</th>
<th>Long Term Trend</th>
<th>On Graphic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space Temperature</td>
<td>Al</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Space Temperature Adjustment</td>
<td>Al</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Radiation Valve</td>
<td>AO</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Base Temperature Setpoint</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Space Temperature Setpoint</td>
<td>SW</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Heating Setpoint</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Cooling Setpoint</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Mode</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Occupied Status</td>
<td>SW or DI</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

1. Finned Tube Radiation Sequence of Operation:

a. Occupied Cooling Mode:

1) The BMS shall start to modulate the radiation control valve closed to maintain occupied space temperature setpoint.

b. Occupied Heating Mode:
1) The BMS shall start to modulate the radiation control valve open to maintain occupied space temperature setpoint.

c. Daytime Unoccupied Cooling Mode:

1) The BMS shall start to modulate the radiation control valve closed to maintain daytime unoccupied space temperature setpoint.

d. Daytime Unoccupied Heating Mode:

1) The BMS shall start to modulate the radiation control valve open to maintain daytime unoccupied space temperature setpoint.

e. Unoccupied Cooling Mode:

1) The BMS shall modulate the radiation control valve fully closed to maintain unoccupied space temperature setpoint.

f. Unoccupied Heating Mode:

1) The BMS shall modulate the radiation control valve fully open to maintain unoccupied space temperature setpoint.

### 3.19 Unit Heaters

I. Hot Water, Steam, or Electric Unit Heater / Cabinet Unit Heaters:

a. Key Concepts:

1) Unit heaters and cabinet unit heaters shall have local control.
2) A temperature sensor, located in each room served by the unit heaters or cabinet unit heaters, shall be monitored by the BMS.

b. Sequence of Operation (Hot Water and Steam)

1) Unit Heaters and cabinet unit heaters are locally controlled by a room thermostat, pipe mounted aqua-stat (hydronic) or pressure switch (steam), and two-position control valve.
2) When the temperature in the space is below the room thermostat setpoint, the control valve shall open. On a rise in water temperature above the aqua-stat or pressure switch setpoint, the fan shall be energized.
3) When the temperature in the space is below the room thermostat setpoint, the control valve shall close. On a fall in water temperature below the aqua-stat or pressure switch setpoint, the fan shall be de-energized.
Typical Unit Heaters Hardwired and Software Points

<table>
<thead>
<tr>
<th>Point</th>
<th>Type</th>
<th>Alarm</th>
<th>Short Term Trend</th>
<th>Long Term Trend</th>
<th>On Graphic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space Temperature</td>
<td>AI</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

2. Hot Water, Steam, or Electric Unit Heater / Cabinet Unit Heater (BMS Controlled):
   
a. Key Concepts:
   1) If the project requires, unit heaters and cabinet unit heaters shall be controlled by the BMS.
   
b. Sequence of Operation (Hot Water and Steam):
   1) The BMS shall control the unit heaters and cabinet unit heaters as follows:
   2) When the temperature in the space is below the space temperature setpoint, the control valve shall open and the fan shall be energized.
   3) When the temperature in the space is above the space temperature setpoint, the control valve shall close and the fan shall be de-energized.

Typical BMS Controlled Unit Heaters Hardwired and Software Points

<table>
<thead>
<tr>
<th>Point</th>
<th>Type</th>
<th>Alarm</th>
<th>Short Term Trend</th>
<th>Long Term Trend</th>
<th>On Graphic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space Temperature</td>
<td>AI</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Unit Heater Fan Status</td>
<td>DI</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Unit Heater Fan On/Off</td>
<td>DO</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Control Valve Open/Closed</td>
<td>DO</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

3. Split DX Units:
   
a. Key Concepts:
   1) Split air conditioning units shall have local control.
   2) A temperature sensor, located in each room served by the split DX units, shall be monitored by the BMS.
   3) DX units shall be capable of being integrated to the BMS via a common communication protocol such as Modbus or BACnet.
   
b. Sequence of Operation:
   1) Packaged Control.
Typical Split DX Units Hardwired and Software Points

<table>
<thead>
<tr>
<th>Point</th>
<th>Type</th>
<th>Alarm</th>
<th>Short Term Trend</th>
<th>Long Term Trend</th>
<th>On Graphic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space Temperature</td>
<td>Al</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

4. Building Heating Hot Water Systems:

a. Key Concepts:
   1) In most cases, steam and medium temperature hot water are supplied from MIT’s central plant.
   2) The pumps are designed to operate in a duty/standby arrangement.

b. Sequence of Operation, General:
   1) The BMS shall energize the duty pump. Only one pump is required to run to maintain the system.
   2) The BMS shall switch the duty/standby alternation bi-monthly.
   3) Upon pump failure, the BMS shall energize the standby pump and generate an alarm.
   4) The BMS shall linearly reset the hot water supply temperature setpoint as follows:

<table>
<thead>
<tr>
<th>Outside Air Temperature</th>
<th>HW Supply Temperature Setpoint</th>
</tr>
</thead>
<tbody>
<tr>
<td>32°F</td>
<td>180°F (adjustable)</td>
</tr>
<tr>
<td>65°F</td>
<td>140°F (adjustable)</td>
</tr>
</tbody>
</table>

c. Differential Pressure Controls:
   1) The BMS shall first modulate the pump VFD to maintain system differential pressure setpoint.
   2) If the VFD is at its minimum for five minutes (adjustable) and the system differential pressure is still above setpoint, the BMS shall then begin to modulate the differential pressure valve open to maintain system differential pressure setpoint.
   3) If the BMS modulates the duty pump VFD speed to 90% or greater for more than five minutes (adjustable) without the differential pressure setpoint being reached,
the BMS shall energize the standby pump (initially at minimum speed) and begin to increase VFD speed to maintain differential pressure setpoint. The BMS shall de-energize the duty pump and generate a pump failure alarm.

d. Temperature Controls:

1) The BMS shall modulate the 1/3, 2/3 steam valves to maintain hot water supply temperature setpoint. In order to keep the steam load stable, the BMS shall sequence the valves in the following arrangement:

<table>
<thead>
<tr>
<th>1/3 Valve (%Open)</th>
<th>2/3 Valve (%Open)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-75%</td>
<td>0%</td>
</tr>
<tr>
<td>0%</td>
<td>0%-100%</td>
</tr>
<tr>
<td>0-100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

### Typical Building Heating Hardwired and Software Points

<table>
<thead>
<tr>
<th>Point</th>
<th>Type</th>
<th>Alarm</th>
<th>Short Term Trend</th>
<th>Long Term Trend</th>
<th>On Graphic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pump Status</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Pump Amps</td>
<td>AI</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Pump Runtime</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>HOA Switch</td>
<td>DI</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>HWS Temperature</td>
<td>AI</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>HWR Temperature</td>
<td>AI</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>1/3 Steam Valve Position</td>
<td>AI</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>2/3 Steam Valve Position</td>
<td>AI</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Differential Pressure Valve Position</td>
<td>AI</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Differential Pressure</td>
<td>AI</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>VFD Modulation</td>
<td>AO</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>VFD Fault</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Pump Start/Stop</td>
<td>DO</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>1/3 Steam Valve</td>
<td>AO</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>2/3 Steam Valve</td>
<td>AO</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Differential Pressure Valve</td>
<td>AO</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>HWS Temperature Setpoint</td>
<td>SW</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Differential Pressure Setpoint</td>
<td>SW</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>VFD Speed Feedback</td>
<td>SW</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
5. Building Chilled Water Systems:

a. Key Concepts:

1) In most cases, chilled water is supplied from MIT’s central plant directly to HVAC loads and chilled water booster pumps are not required.
2) Building pump pairs are designed to operate in a duty/standby arrangement.
3) Pump sets can either be booster pumps (in series with the central plant pumps) or they can be deployed to create a recirculating loop within the building to serve process loads and other situations such as chilled beam operation or environmental rooms (simulating a condenser water loop) where an elevated temperature is required.

b. Sequence of Operation, General:

1) The BMS shall energize the duty pump. Only one pump is required to run to maintain the system differential pressure.
2) The BMS shall switch the duty/standby alternation bi-monthly.
3) Upon, pump failure, the BMS shall energize the standby pump and generate an alarm.

c. Booster Pumps in Series – Differential Pressure Control:

1) The BMS shall monitor differential pressure across the load. The supply (high) pressure sensor shall be located after the pump discharge but before the building load. The return (low) pressure sensor shall be located on the common circuit return line.
2) The BMS shall modulate the pump VFD to maintain system differential pressure setpoint.
3) If the differential pressure is greater than 5 psi (adjustable) above setpoint for more than 10 minutes (adjustable) while the duty pump is running at minimum speed, the shall de-energize the duty pump.
4) If the differential pressure is below setpoint, the BMS shall energize the duty pump (initially at its lowest speed).
5) The BMS shall then begin to increase the duty pump VFD speed to maintain system differential pressure setpoint.
6) If the BMS modulates the duty pump VFD speed to 90% or greater for more than five minutes (adjustable) without the differential pressure setpoint being reached, the BMS shall energize the standby pump (initially at minimum speed) and begin to increase VFD speed to maintain differential pressure setpoint. The BMS shall de-energize the duty pump and generate a pump failure alarm.

d. Secondary Loops with Heat Exchanger:
1) The BMS shall monitor supply temperature to the process load after the heat exchanger.

2) The BMS shall modulate the primary side control valve to maintain secondary supply temperature setpoint.

3) If primary pumps are required they shall operate as follows:
   a) If the control valve has been commanded to 90% or greater for more than 5 minutes (adjustable) without the secondary supply temperature setpoint being reached, the BMS shall first energize the primary side duty pump (initially at minimum speed) and modulate the chilled water valve fully open, and then modulate the VFD speed to maintain the secondary supply temperature setpoint.
   b) If the BMS modulates the duty pump VFD speed to 90% or greater for more than five minutes (adjustable) without the secondary supply temperature setpoint being reached, the BMS shall energize the standby pump (initially at minimum speed) and begin to increase VFD speed to maintain secondary supply temperature setpoint.
   c) If the secondary supply temperature is below setpoint for more than ten minutes (adjustable) while the duty pump is running at minimum speed, the BMS shall de-energize the duty pump. The BMS shall modulate the chilled water valve toward fully closed to maintain secondary supply temperature setpoint.

4) The preferred method is to control the process temperature at a fixed offset from primary chilled water supply temperature (because the primary chilled water temperature varies throughout the year from 42°F to 50°F). Ideally process supply temperature should be as high as possible in order to have better year round stability (55°F or higher is preferred for stability and better primary chilled water utilization. Temperatures above 55°F also reduce condensation on process equipment piping and components.

e. Secondary Loops (with elevated temperatures) without Heat Exchanger:
   1) These systems commonly utilize a pump set with a modulating control valve returning chilled water to the central plant. The BMS controls the temperature supply to the process by modulating this valve which allows plant chilled water supply to bleed into the system.
   2) The BMS shall monitor supply temperature to the load after the circulating pump.
   3) The BMS shall modulate the chilled water return valve to maintain recirculated system supply water temperature setpoint.
   4) The BMS shall modulate the duty pump VFD speed to maintain system differential pressure setpoint.
   5) If the BMS modulates the duty pump VFD speed to 90% or greater for more than five minutes (adjustable) without the differential pressure setpoint being reached, the BMS shall energize the standby pump (initially at minimum speed) and begin
to increase VFD speed to maintain differential pressure setpoint. The BMS shall
de-energize the duty pump and generate a pump failure alarm.

Typical Chilled Water Hardwired and Software Points

<table>
<thead>
<tr>
<th>Point</th>
<th>Type</th>
<th>Alarm</th>
<th>Short Term Trend</th>
<th>Long Term Trend</th>
<th>On Graphic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pump Status</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Pump Amps</td>
<td>AI</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Pump Runtime</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>HOA Switch</td>
<td>DI</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>VFD Fault</td>
<td>DI</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>CHWS Temperature</td>
<td>AI</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>CHWR Temperature</td>
<td>AI</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Differential Pressure Valve Position</td>
<td>AI</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Supply Temperature Valve Position</td>
<td>AI</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Differential Pressure</td>
<td>AI</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>VFD Modulation</td>
<td>AO</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Pump Start/Stop</td>
<td>DO</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Differential Pressure Valve</td>
<td>AO</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Differential Pressure Setpoint</td>
<td>SW</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Supply Temperature Valve</td>
<td>AO</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Supply Temperature Setpoint</td>
<td>SW</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>VFD Speed Feedback</td>
<td>SW</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

6. Life Safety Equipment Control:

a. Stairwell Pressurization Fan:

1) The fire alarm system shall control and monitor the fan.

b. Stairwell Pressurization Fan with Temperature Control (if required due to stack effect – to be determined by MEP design consultant)

1) The fire alarm system shall control and monitor the fan.
2) The BMS shall modulate the reheat coil to maintain a discharge temperature setpoint (as determined by the MEP design consultant).

c. Fire/Smoke Dampers:

1) The fire alarm system shall control and monitor the fire/smoke dampers.
2) It is MIT’s preference that when BMS has no integration to the fire/smoke dampers that power and control wiring for the fire/smoke dampers shall be installed by the division 26 electrical contractor.
d. Fireman’s Override Panel:
   1) If required, a fireman’s override panel will allow for firefighter override of selected fans and dampers.
   2) The BMS shall monitor fireman’s override fan position switch status (both on and off) from the fireman’s override panel.
   3) Power wiring for the fireman’s override panel shall be installed by the division 26 electrical contractor.
   4) Control wiring from the fireman’s override panel to the respective fans and dampers shall be installed by the division 26 electrical contractor and closely coordinated with BMS contractor.
   5) Control wiring from the fireman’s override fan position switches to the BMS shall be installed by the BMS contractor.

7. Equipment Restart Following a Fire Alarm:
   a. Provide a software program that will restart equipment shut down as the result of a fire alarm system (FAS) event following the return to normal conditions. When equipment is shut down by the FAS the BMS controlled relay shall be immediately placed in the "OFF" state such that the equipment cannot restart when the FAS relay enables startup of the equipment.
   b. If equipment is shut down by the FAS or by the BMS as the result of a fire alarm, then the shutdown shall not be annunciated as an alarm condition.
   c. Following the return to normal indication at the FAS, the BMS shall automatically initiate the restart of all equipment shut down by the FAS.
   d. The restart of the equipment shall be subject to all the software protection functions such as the minimum "off" time and the operator defined time delay requirements between successive equipment starts. Provide timing delays between equipment restart after a whole building shut down.
   e. The BMS shall turn on the equipment in a logically ordered sequence to avoid power surges and mechanical shortcomings (i.e., CHW/HW equipment should start before AHUs).
   f. Special care must be given to buildings with mixed BMS platforms to ensure the equipment responds appropriately after the fire alarm is cleared.

8. Equipment Restart Following a Power Failure:
   a. Provide a program that will facilitate the restart of equipment following a power failure.
   b. Equipment restart following a power failure shall be determined by monitoring of the associated automatic transfer switch.
c. Following the restoration of power, the BMS shall automatically initiate the restart of all equipment.

d. The restart of the equipment shall be subject to all the software protection functions such as the minimum "off" time and the operator defined time delay requirements between successive equipment starts. Provide timing delays between equipment restart after a whole building shut down.

e. The BMS shall turn on the equipment in a logically ordered sequence to avoid power surges and mechanical shortcomings (i.e., CHW/HW equipment should start before AHUs).

f. Special care must be given to buildings with mixed BMS platforms to ensure the equipment responds appropriately after the power is restored.

### 3.20 Miscellaneous Monitoring

1. Provide the following Miscellaneous Monitoring:

   a. Key Concepts:

      1) Miscellaneous monitoring will vary from project to project depending on the criticality of the space and user requirements.

**Typical Miscellaneous Monitoring Hardwired and Software Points**

<table>
<thead>
<tr>
<th>Point</th>
<th>Type</th>
<th>Alarm</th>
<th>Short Term Trend</th>
<th>Long Term Trend</th>
<th>On Graphic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lab Equipment Status (i.e., Freezers)</td>
<td>DI</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Dust Collector Start/Stop</td>
<td>DO</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Dust Collector Status</td>
<td>AI</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Air Compressor Alarm</td>
<td>DI</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Air Compressor Supply Pressure</td>
<td>AI</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Air Compressor Receiver Tank Pressure</td>
<td>AI</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>PRV Alarms (if applicable)</td>
<td>DI</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Low Pressure Steam Pressure</td>
<td>AI</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Heat Trace Loss of Power Alarm</td>
<td>DI</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Heat Trace Low Temperature Alarm</td>
<td>DI</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Heat Trace Trouble Alarm</td>
<td>DI</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Generator Alarm</td>
<td>DI</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Vacuum Pump Alarm</td>
<td>DI</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Sewage Ejector Pump Alarm</td>
<td>DI</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Sewage Ejector Pump High Level Alarm</td>
<td>DI</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Sump Pump Alarm</td>
<td>DI</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Pit High Level Alarm</td>
<td>DI</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Condensate Pump Alarm</td>
<td>DI</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Condensate High Level Alarm</td>
<td>DI</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Condensate Tank Conductivity</td>
<td>AI</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Domestic Water Heater Status</td>
<td>DI</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Domestic Water Temperature</td>
<td>AI</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
3.21 BMS Integration with Other Systems

It is recommended the BMS integrates to the systems listed below when present. BMS integration with other standalone systems should be reviewed on a case by case basis to with the project team to ensure that they meet design requirements and align with project budgets.

1. Phoenix Celeris Laboratory Airflow and Control System (LAFCS).
2. Aircuity Air Quality System.
3. Boiler(s).
4. Chiller(s).
5. VFD(s).
6. Computer Room Air Conditioning (CRAC) Units.
7. Emergency Generator / Fuel Oil System.
8. PI Metering Platform.
11. Lighting Control System.
12. BTU Meters.
14. Packaged Air Handling Units.
15. Building Analytics.

The following page describe each system above in more detail.
1. **Phoenix Celeris Laboratory Airflow and Control System (LAFCS):**

   a. The communication interface shall allow the BMS read/write capabilities.
   b. The BMS shall be able to ramp back the LAFCS for the purpose of energy saving schemes without impact on safety or the working environment.
   c. It shall be the responsibility of the BMS contractor to review requirements and coordinate with the LAFCS contractor for this integration. This integration shall be done via BACnet IP or LonWorks IP.
   d. Typical LAFCS Software Points shall be as follows:

<table>
<thead>
<tr>
<th>Point</th>
<th>Type</th>
<th>Alarm</th>
<th>Short Term Trend</th>
<th>Long Term Trend</th>
<th>On BMS Graphic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space Temperature</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Space Temperature Setpoint</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Space Humidity</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Space Humidity Setpoint</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Volumetric Airflow Offset</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Volumetric Airflow Offset Setpoint</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Exhaust Air Valve Airflow Setpoint</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Supply Air Valve Airflow</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Supply Air Valve Airflow Setpoint</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Return Air Valve Airflow Setpoint</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Return Air Valve Airflow</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Supply Air Discharge Temperature</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Local Alarm</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Fume Hood Airflow Alarm</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Fume Hood Control Air Valve Position</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Fume Hood Sash Position</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Fume Hood Face Velocity</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Fume Hood Purge Mode</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Fume Hood Exhaust Air Valve Airflow</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Fume Hood Exhaust Air Valve Airflow</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Occupancy Status</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Communication Alarm</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
2. **Aircuity Air Quality System:**

   a. The communication interface shall allow the BMS read capabilities.
   
   b. The BMS shall be able to adjust the HVAC systems based on data from the air quality system for the purpose of energy saving schemes without impact on the safety or the working environment.
   
   c. It shall be the responsibility of the BMS contractor to review requirements and coordinate with the Air Quality System contractor for this integration. This integration shall be done via BACnet IP or LonWorks IP.
   
   d. Typical Aircuity Software Points shall be as follows:

<table>
<thead>
<tr>
<th>Point</th>
<th>Type</th>
<th>Alarm</th>
<th>Short Term Trend</th>
<th>Long Term Trend</th>
<th>On BMS Graphic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outside Air Temperature</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Outside Air Humidity</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Outside Air Enthalpy</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Supply Air Temperature</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Supply Air Humidity</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Supply Air Enthalpy</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Return Air Temperature</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Return Air Humidity</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Return Air Enthalpy</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Space Temperature</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Space Humidity</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Carbon Monoxide</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>VOC</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Sensor Suite Trouble Alarm</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>System Trouble Alarm</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Communication Alarm</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
3. **Boiler(s):**

   a. The BMS shall be able to start and stop boilers via a hardwired point based on the sequence of operations program. This start / stop command shall not override any internal safeties that are for the purpose of protecting the equipment or people in the vicinity.

   b. The communication interface shall allow the BMS read capabilities.

   c. It shall be the responsibility of the BMS contractor to review requirements and coordinate with the boiler manufacturer for this integration. This integration shall be done via BACnet IP, BACnet MSTP, or Modbus IP.

   d. Typical Hardware/Software Points shall be as follows:

<table>
<thead>
<tr>
<th>Point</th>
<th>Type</th>
<th>Alarm</th>
<th>Short Term Trend</th>
<th>Long Term Trend</th>
<th>On BMS Graphic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler Enable/Disable Command</td>
<td>DO</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Burner Status</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Burner Control</td>
<td>SW</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Hot Water Supply to Building</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Hot Water Supply from Boilers</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Hot Water Return to Boilers</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Hot Water Return from Building</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Boiler Alarm</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Stack Temperature</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Boiler Isolation Valve</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Boiler Isolation Valve Status</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
4. **Chiller(s):**

   a. The BMS shall be able to start and stop chillers via a hardwired point based on the sequence of operations program. This start / stop command shall not override any internal safeties that are for the purpose of protecting the equipment or people in the vicinity.

   b. The communication interface shall allow the BMS read capabilities.

   c. It shall be the responsibility of the BMS contractor to review requirements and coordinate with the chiller manufacturer for this integration. This integration shall be done via BACnet IP or BACnet MSTP.

   d. Typical Software Points shall be as follows:

<table>
<thead>
<tr>
<th>Point</th>
<th>Type</th>
<th>Alarm</th>
<th>Short Term Trend</th>
<th>Long Term Trend</th>
<th>On BMS Graphic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chiller Start/Stop Command</td>
<td>DO</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Chiller Reset Signal</td>
<td>AO</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Local Schedule</td>
<td>SW</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Occupancy</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Remote Start Control</td>
<td>SW</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Run Status Code</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Alarm Value</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>System Alarm Code</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Entering Condenser Temperature</td>
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<td>Yes</td>
<td>Yes</td>
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<td>Motor Winding Temperature</td>
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<td>Yes</td>
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<td>Yes</td>
<td>Yes</td>
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<td>Chilled Water Deadband</td>
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<td>Chilled Water Delta T</td>
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<td>No</td>
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</table>
5. **VFD(s):**

   a. The BMS shall be able to start and stop and control the VFD speed via a hardwired point based on the sequence of operations program.
   b. The communication interface shall allow the BMS read capabilities.
   c. It shall be the responsibility of the BMS contractor to review requirements and coordinate with the VFD manufacturer for this integration. This integration shall be done via BACnet IP or BACnet MSTP.
   d. Typical Software Points shall be as follows:

<table>
<thead>
<tr>
<th>Point</th>
<th>Type</th>
<th>Alarm</th>
<th>Short Term Trend</th>
<th>Long Term Trend</th>
<th>On BMS Graphic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start / Stop</td>
<td>DO</td>
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<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Speed Modulation</td>
<td>AO</td>
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<td>Yes</td>
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<tr>
<td>Status (Current Sensor)</td>
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<td>Yes</td>
<td>Yes</td>
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<td>VFD Fault</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<td>HOA Not in Auto</td>
<td>DI</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>VFD in Bypass</td>
<td>DI</td>
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<td>Yes</td>
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<td>Yes</td>
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<td>Forward / Reverse Status</td>
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<td>Output Frequency Hz</td>
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<td>No</td>
<td>No</td>
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<tr>
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<td>SW</td>
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<td>No</td>
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<tr>
<td>Motor Voltage V</td>
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<td>No</td>
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<td>Yes</td>
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<tr>
<td>Motor Current A</td>
<td>SW</td>
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<tr>
<td>Motor Torque %</td>
<td>SW</td>
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<td>Drive Thermal State %</td>
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<td>Energy Counter kWh</td>
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<td>No</td>
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<td>Run Time</td>
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<td>Last Error Code</td>
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</table>
6. **Computer Room Air Conditioning (CRAC) Units:**

   a. The communication interface shall allow the BMS read capabilities.
   
   b. It shall be the responsibility of the BMS contractor to review requirements and coordinate with the CRAC manufacturer for this integration. This integration shall be done via BACnet IP or BACnet MSTP.
   
   c. Typical Software Points shall be as follows:

   ![Table showing typical software points for CRAC units]

<table>
<thead>
<tr>
<th>Point</th>
<th>Type</th>
<th>Alarm</th>
<th>Short Term Trend</th>
<th>Long Term Trend</th>
<th>On BMS Graphic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space Temperature</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<td>Space Humidity</td>
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<tr>
<td>Unit Status</td>
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<td>Yes</td>
<td>Yes</td>
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<td>General Alarm</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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</table>

7. **Emergency Generator / Fuel Oil Systems:**

   a. The communication interface shall allow the BMS read capabilities.
   
   b. It shall be the responsibility of the BMS contractor to review requirements and coordinate with the emergency generator / fuel oil system manufacturer for this integration. This integration shall be done via BACnet IP, Modbus TCP/IP, or Modbus RTU.
   
   c. Typical Software Points shall be as follows:

   ![Table showing typical software points for emergency generator/fuel oil systems]

<table>
<thead>
<tr>
<th>Point</th>
<th>Type</th>
<th>Alarm</th>
<th>Short Term Trend</th>
<th>Long Term Trend</th>
<th>On BMS Graphic</th>
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<tr>
<td>AC Voltmeter</td>
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<td>Running-time Meter</td>
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<td>Generator Running</td>
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<td>Generator Control ‘not-in-auto’ Mode Alarm</td>
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<td>Generator Current, per-phase</td>
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<td>Generator Voltage, phase-to-phase &amp; phase-neutral</td>
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<td>per-phase &amp; three-phase total</td>
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<td>Engine Run Hours</td>
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<td>Fuel Tank High-Level Alarm</td>
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<td>Fuel Tank Water Alarm</td>
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<td>No</td>
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<td>Fuel Tank Interstitial alarm</td>
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<td>Fuel Oil Leak Detection (multiple points)</td>
<td>SW</td>
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<td>Fuel Oil Pump Status</td>
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<td>Fuel Oil Overfill Alarm</td>
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<td>Generator Overload Alarm</td>
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<td>Failure of Communication Link</td>
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<td>Engine Exhaust Temperature</td>
<td>SW</td>
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</tbody>
</table>

8. **PI Metering Platforms:**
   a. Meters that measure incoming chilled water flow, incoming hot water flow, incoming steam flow, incoming natural gas flow, electrical data, are wired to a data gathering PLC and communicated to the PI historian located in the central plant.
   b. The provision of meters and the gathering panel vary from project, however, the BMS contractor generally wires these meters to the PI gathering data panel.
   c. The communication interface shall allow the BMS read capabilities.
   d. It shall be the responsibility of the BMS contractor to review requirements and coordinate with the PI manufacturer for this integration. This integration shall be done via Modbus TCP/IP.
## Typical PI Metering Platform Software Points

<table>
<thead>
<tr>
<th>Point</th>
<th>Type</th>
<th>Alarm</th>
<th>Short Term Trend</th>
<th>Long Term Trend</th>
<th>On BMS Graphic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WATER</strong></td>
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</tr>
<tr>
<td>Chilled Water Consumption</td>
<td>SW</td>
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<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Chilled Water Flow</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Chilled Water Pressure</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Chilled Water Temperature</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Chilled Water Delta T</td>
<td>SW</td>
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<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Condensate Flow</td>
<td>SW</td>
<td>No</td>
<td>No</td>
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<td>Yes</td>
</tr>
<tr>
<td><strong>STEAM</strong></td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Steam Consumption</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Steam Flow</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Steam Pressure</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Steam Temperature</td>
<td>SW</td>
<td>No</td>
<td>No</td>
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<td>Yes</td>
</tr>
<tr>
<td><strong>GAS &amp; FULE</strong></td>
<td></td>
<td></td>
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<tr>
<td>Natural Gas Consumption</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Natural Gas Flow</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>ELECTRICAL</strong></td>
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<tr>
<td>Real Energy kWhr</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
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<tr>
<td>Demand Real Power D kW</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
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<tr>
<td>True Power Factor Total</td>
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<td>No</td>
<td>No</td>
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<tr>
<td>Current Ph A</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
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<tr>
<td>Current Ph B</td>
<td>SW</td>
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<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Current Ph C</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Current Neutral</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Current 3-Ph Average</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Current Apparent RMS</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Voltage A-B</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Voltage B-C</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Voltage C-A</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Voltage Average</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Voltage A-N</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Voltage B-N</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Voltage C-N</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Real Power Ph A kW</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Real Power Ph B kW</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Real Power Ph C kW</td>
<td>SW</td>
<td>No</td>
<td>No</td>
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<tr>
<td>Real Power Total F kW</td>
<td>SW</td>
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<td>No</td>
</tr>
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<td>Reactive Power Ph A kVAR</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Reactive Power Ph B kVAR</td>
<td>SW</td>
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<td>No</td>
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<tr>
<td>Reactive Power Ph C kVAR</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
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<tr>
<td>Reactive Power Total kVAR</td>
<td>SW</td>
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<td>No</td>
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<td>No</td>
</tr>
<tr>
<td>Apparent Power Ph A kVA</td>
<td>SW</td>
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<td>No</td>
<td>No</td>
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</tr>
<tr>
<td>Apparent Power Ph B kVA</td>
<td>SW</td>
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<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Apparent Power Ph C kVA</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
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<tr>
<td>Apparent Power Total kVA</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
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<tr>
<td>Frequency</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
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</tbody>
</table>
9. **Building Uninterruptible Power Supply (UPS):**

   a. The communication interface shall allow the BMS read capabilities.
   b. It shall be the responsibility of the BMS contractor to review requirements and coordinate with the lighting control system manufacturer for this integration. This integration shall be done via BACnet IP.
   c. Typical Software Points shall be as follows:

<table>
<thead>
<tr>
<th>Point</th>
<th>Type</th>
<th>Alarm</th>
<th>Short Term Trend</th>
<th>Long Term Trend</th>
<th>On BMS Graphic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication Alarm</td>
<td>SW</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Battery Circuit Open</td>
<td>SW</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Batter Discharging</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Low Battery Shutdown</td>
<td>SW</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Mains 1 Input Switch Open</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Mains 1 Voltage Alarm</td>
<td>SW</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Emergency Off Switch</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Operating On Battery</td>
<td>SW</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Forced Inverter Shutdown</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Inverter Output Switch Open</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
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<tr>
<td>Inverter Stack Overload</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
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<tr>
<td>Inverter Sync with Mains 2</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
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<tr>
<td>Inverter Thermal Override</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Maintenance Bypass</td>
<td>SW</td>
<td>No</td>
<td>No</td>
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</tr>
<tr>
<td>Rectifier Charge Input Volt Alarm</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>System Not Normal</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
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<tr>
<td>Transfer Lockout</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
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</tr>
<tr>
<td>Unsafe Operation</td>
<td>SW</td>
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<td>No</td>
<td>No</td>
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<tr>
<td>KVA</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Load Voltage A-B</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Load Voltage B-C</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Load Voltage C-A</td>
<td>SW</td>
<td>No</td>
<td>No</td>
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<td>KW</td>
<td>SW</td>
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<tr>
<td>Mains 1 Voltage A-B</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Mains 1 Voltage B-C</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
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<tr>
<td>Mains 1 Voltage C-A</td>
<td>SW</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>
10. **Weather Services:**

   a. The communication interface shall allow the BMS read capabilities.

   b. This weather station will replace the more traditional approach of employing a small weather station per building. Each new building will be mapped to this data.

   c. In the near future, the predictive weather modeling will be utilized by MIT.

   1) **Weather Modeling Optimization** – By integrating the BMS with weather modeling for the facility, location predictive analytics can adjust central plant control algorithms and other key mechanical equipment sequences based on approaching weather fronts. The BMS learns and understands the terminal load value of a facility. Then, based on local weather forecasts, the BMS will reduce energy usage by not over compensating for sudden changes that trigger systems to react when not required to do so to maintain comfort and safety. During certain seasons of the year, frequent rapid weather changes can account for substantial excess energy usage.

   2) **Approaching Storm Forecasting** – By integrating the BMS with weather modeling for the facility, the risk of approaching storms can be evaluated. There is an opportunity under extreme weather conditions with high lightning output approaching, to have generators started to ensure no outages occurs.

   3) The BMS shall display via a graphical user interface all approaching weather patterns including rain, wind, lightning, etc. Weather occurrences shall be tracked in near real time.

   4) MIT shall have the ability to manually or via automated sequences take action based on this weather data for the purpose of saving energy or initiating actions to reduce the risk of power failures.

   d. It shall be the responsibility of the BMS contractor to review requirements and coordinate with the weather services provider for this integration. This integration shall be done via web services and Modbus IP.

<table>
<thead>
<tr>
<th>Point</th>
<th>Type</th>
<th>Alarm</th>
<th>Short Term Trend</th>
<th>Long Term Trend</th>
<th>On BMS Graphic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outside Air Temperature</td>
<td>SW</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Outside Air Humidity</td>
<td>SW</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Outside Air Dewpoint</td>
<td>SW</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Wind Speed</td>
<td>SW</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Wind Direction</td>
<td>SW</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
11. **Lighting Control Systems:**
   a. The communication interface shall allow the BMS read capabilities.
   b. The BMS shall be able to monitor the occupancy status of rooms.
   c. It shall be the responsibility of the BMS contractor to review requirements and coordinate with the lighting control system manufacturer for this integration. This integration shall be done via BACnet IP.
   d. Typical Software Points shall be as follows:

<table>
<thead>
<tr>
<th>Point</th>
<th>Type</th>
<th>Alarm</th>
<th>Short Term Trend</th>
<th>Long Term Trend</th>
<th>On BMS Graphic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occupancy Switch</td>
<td>SW</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

12. **BTU Meters:**
   a. The communication interface shall allow the BMS read capabilities.
   b. It shall be the responsibility of the BMS contractor to review requirements and coordinate with the equipment manufacturer for this integration. This integration shall be done via BACnet MSTP.
   c. Typical Software Points shall be as follows:

<table>
<thead>
<tr>
<th>Point</th>
<th>Type</th>
<th>Alarm</th>
<th>Short Term Trend</th>
<th>Long Term Trend</th>
<th>On BMS Graphic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water BTU</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Water Flow</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Water Temperature</td>
<td>SW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

13. **Gas Monitoring:**
   a. The communication interface shall allow the BMS read capabilities.
   b. It shall be the responsibility of the BMS contractor to review requirements and coordinate with the equipment manufacturer for this integration. This integration shall be done via BACnet MSTP.
   c. Typical Software Points shall be as follows:

<table>
<thead>
<tr>
<th>Point</th>
<th>Type</th>
<th>Alarm</th>
<th>Short Term Trend</th>
<th>Long Term Trend</th>
<th>On BMS Graphic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas Level</td>
<td>SW</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Gas High Level Alarm</td>
<td>SW</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>System Alarm</td>
<td>SW</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
14. **Packaged Air Handling Units:**

a. The communication interface shall allow the BMS read/write capabilities.

b. It shall be the responsibility of the BMS contractor to review requirements and coordinate with the equipment manufacturer for this integration. This integration shall be done via BACnet MSTP.

c. The list of software points shall be similar to those listed in the Air Handling Unit section (3.a.viii.1.c.).

15. **Building Analytics (KGS Clockworks)**

a. A consistent point naming convention shall be used such that KGS Clockworks can poll the BMS network and gather the correct information necessary for building analytics.

4. **BUILDING MANAGEMENT SYSTEM IMPLEMENTATION GUIDELINES**

4.1 **BMS Hardware Engineering**

The purpose of the documentation is to provide relevant information to those responsible for designing, installing, implementing, and maintaining the BMS.

The MEP design consultant shall thoroughly review the documentation and identify as many potential areas of non-conformance as possible.

4.2 **Coordination Drawings**

1. If applicable, the BMS contractor shall participate in the development of coordinated drawings with the mechanical and electrical contractors. The mechanical contractor shall indicate all mechanical, plumbing, and fire protection work on the drawings. The electrical contractor shall then add the electrical, fire alarm, and communication system work to the drawings. The BMS contractor shall indicate the required BMS work on the drawings for the following:

   a. Cable tray installed by the BMS contractor.
   
   b. Conduits over 2” installed by the BMS contractor.
   
   c. Sleeves required for BMS work.
   
   d. Devices above the ceiling or below a raised floor requiring access.
   
   e. Control panels.
   
   f. Sensor locations.

2. The BMS contractor shall assist and cooperate with the other trades to ensure a complete and coordinated set of drawings has been generated.
4.3 Building Information Modeling (BIM)

1. If applicable, the BMS contractor shall participate in the development of a Building Information Model with the architects, mechanical and electrical contractors. The mechanical contractor shall indicate all mechanical, plumbing, and fire protection work on the model. The electrical contractor shall then add the electrical, fire alarm, and communication system work to the model. The BMS contractor shall indicate the required BMS work on the model for the following:

   a. Cable tray installed by the BMS contractor.
   b. Conduits over 2 inch installed by the BMS contractor.
   c. Sleeves required for BMS work.
   d. Devices above the ceiling or below a raised floor requiring access.
   e. Control panels.
   f. Sensor Locations.

2. The BMS contractor shall assist and cooperate with the other trades to ensure a complete model has been generated.

4.4 Shop Drawings

1. The BMS contractor shall prepare all shop drawings in Visio Professional or AutoCAD software. Drawings shall be 11”x17”. The BMS contractor shall furnish an electronic copy (in PDF format) of the shop drawings. Information shall have appropriate indices and tabs.

2. The BMS hardware design package shall include the following:

   a. **Valve Schedule:** The valve schedule shall contain each valve's unique tag name, size, flow coefficient $K_v$ ($C_v$), pressure drop at specified flow rate, spring range, actuator size and close-off pressure to torque data. The valve schedule shall contain actuator selection data supported by calculations of the force required to move and seal the valve, access and clearance requirements.

   b. **Damper Schedule:** The damper schedule shall contain each damper's unique tag name, type (opposed or parallel blade), nominal and actual sizes, orientation of axis and frame, direction of blade rotation, actuator size and spring ranges, operation rate, location of actuators and damper end switches, arrangement of sections in multi-section dampers, and methods of connecting dampers, actuators, and linkages. The damper schedule shall include the AMCA 500-D maximum leakage rate at the operating static-pressure differential.

   c. **Flow Meter Schedule:** The flow meter schedule shall contain the unique tag name, manufacturer, model number, part number, descriptive name, and sizing information for each flow meter

   d. **Air Flow Station Schedule:** The air flow station schedule shall contain the unique tag name, manufacturer, model number, part number, descriptive name, and duct size for each air flow station.

   e. **Drawing Index and Drawing Legend:** The drawing index shall list all BMS contractor drawings, including the drawing number, sheet number, drawing title. The drawing
legend shall show and describe all symbols, abbreviations, and acronyms used on the
BMS drawings.

f. **Riser Diagram of Building Control Network**: The riser diagram of the building control
network shall show all network cabling, BMS hardware, and network hardware
including:

1) All BMS hardware with room number, unique identifiers, and common
descriptive names including:

   a) Network controller naming format shall include the building number and
      successive instance number (within the building) and shall be similarly
      named in software. Examples include: M01_AS01, M01_AS02,
      M05_LGR01.

   b) Field controller naming format shall include the building, location, and
      system and shall be similarly named in software. Examples include:
      M01_Rm701_AH1, E62_Rm305_FCU.

2) All computer and network hardware with room number, unique identifiers, and
descriptive names.

3) All BMS network cabling and power wiring (can be shown as a depiction on
   each piece of BMS hardware and does not have to depict the actual routing of the
   network).

4) All other devices connected to the BMS IP or MSTP network.

5) IP address(es) as applicable for each piece of network hardware and computer
   hardware.

6) If a small project is done within an existing building, the BMS contractor shall
   add the necessary revisions to an overall building riser. The added architecture
   can be circled or redlined with a project description to show when it was added.
   A riser showing one controller with a note saying to connect to nearest existing
   controller is not acceptable.

3. **Control System Schematic Drawings**: The control system schematic drawings shall be
   in the same form as the MEP design consultant’s control system schematic drawings with
   the BMS contractor providing updated information and detail as required. A control
   system schematic shall be submitted for each system controlled or monitored by the
   BMS.

4. **Controller, Motor Starter and Relay Wiring Drawing**: The controller wiring drawings
   shall be functional wiring drawings which show the interconnection of conductors and
cables to each controller and to the identified terminals of input and output devices,
starters and package equipment. The wiring drawings shall show all necessary jumpers,
ground connections, and the labels of all conductors. Sources of power required for
control systems and for packaged equipment control systems shall be identified back to
the panel board circuit breaker number, controller enclosures, magnetic starter, or
packaged equipment control circuit. Each power supply and transformer not integral to a
controller, starter, or packaged equipment shall be shown. Wiring drawings shall be
submitted for each system controlled or monitored by the BMS. Typical wiring drawings shall be acceptable as long as the systems they represent are clearly marked.

5. **Control Panel Layout Drawing:** Control panel layout drawings shall be to scale with all devices shown in their proposed positions. All control devices shall be identified by name. All terminal strips, control transformers, IP connection points, devices and wire channels shall be shown.

6. **Points List:** A Points List shall be submitted for each system controlled or monitored by the BMS. The Points List shall include, name, description, range, engineering units, and alarm(s). An effort shall be made to streamline the point naming convention for similar points from similar systems. This will facilitate MIT’s ability to use BMS global search and replace tools make mass changes should our standards evolve and requiring functionality or setpoint changes.

7. **Sequence of Operation:** The HVAC control system sequence of operation shall be in the same format as the MEP design consultant’s sequence of operation and shall refer to the devices by their unique identifiers/tags. No operational deviations from specified sequences shall be permitted without prior written approval of the MEP design consultant. Sequence of operation shall be submitted for each system controlled by the BMS.

3. Submit electronic copy (in PDF format) of the hardware submittal data and shop drawings (Item #2) to the MEP design consultant for review prior to ordering or fabrication of the equipment.

4. A piecemeal hardware submittal process shall be acceptable prior to complete comprehensive final submission as follows:

   a. Equipment submittals (if applicable).
   b. In-line device schedules (i.e., valves, dampers, flow stations, flow meters requiring long times).
   c. First shop drawing submission of each typical system.
   d. Control panel layout drawings.
   e. Sample software graphic display screens.

5. The MEP design consultant shall make corrections, if required, and return to the BMS contractor. The BMS contractor shall then resubmit with the corrected or additional data. This procedure shall be repeated until all corrections are made to the satisfaction of the MEP design consultant and the shop drawings are fully approved.

6. The following is a list of post construction submittals that shall be updated to reflect any changes during construction and re-submitted as “As-Built”:

   a. System architecture/riser drawing.
   b. System control schematic drawing for each controlled system.
   c. Points list for each controlled system.
   d. Wiring drawing for individual components.
   e. Control panel layout drawings.
   f. Sequence of operation.
4.5 Software Engineering

1. The BMS software design package shall include the following:

   a. **Graphic Samples:** A representation of each type of graphic for the project. At a minimum include one of each different type for MIT approval:

      1) Rise Diagram.
      2) Floor Plan.
      3) Air Handling Units.
      4) Hydronic Systems.
      5) Terminal Units.

   b. **Comprehensive Alarm List:** A matrix or spreadsheet containing full alarm list of alarms to be used, containing the following:

      1) Root Point.
      2) Alarm Name.
      3) Alarm Type.
      4) Alarm Level.
      5) Alarm Messaging.
      6) Alarm Routing.
      8) Alarm Time Delay.
      9) Alarm Log Display Parameters.

   c. **Integration Matrix:** A detailed listing of each type of interface/integration (i.e., BACnet, Modbus, etc.) required for the project showing all available points and the following for each point:

      1) Is point mapped to graphic?
      2) Is point alarmed?
      3) Is point trended?

2. Submit electronic copy (in PDF format) of the software submittal data (Item #1) to MIT prior to software implementation.

3. A piecemeal software submittal process shall be acceptable prior to complete comprehensive final submission as follows:

   b. Alarm list.
   c. Integration matrix.

4. All communication between the BMS File Servers, BMS Workstations, and Network Controllers shall be via BACnet/IP and in accordance with ASHRAE 135 (except where proprietary Continuum expansion is required).
5. For equipment requiring IP addresses, the BMS contractor shall coordinate with MIT to obtain IP addresses.

6. The BMS contractor shall use a consistent software naming convention from system to system and campus-wide that is easily understood. An example would be that “SupAirTemp” is used to represent supply air temperature.

7. The BMS contractor shall create modular programs that meet the intent of the sequence of operation. The software code shall be commented such that it is easily understood. A consistent software coding approach should be for similar systems campus-wide.

8. The BMS contractor shall establish network object bindings as necessary to support software functionality:
   a. BACnet objects used for display on currently active displays shall be updated (via COV) as necessary to meet display requirements.
   b. BACnet objects used for currently active trends shall be updated (via COV) as necessary to meet trend interval requirements.
   c. BACnet alarm objects shall be bound from the device originating the alarm to the software. Alarms shall use the acknowledged service.

9. The BMS contractor shall create color graphic display screens as follows:
   a. Color graphic display screen of a listing of buildings. Include “hot link” navigation buttons (activated with one mouse click) on the graphics that allow MIT to get to a specific building.
   b. Color graphic display screen of building riser. Include “hot link” navigation buttons (activated with one mouse click) on the graphics that allow MIT to get to specific floor or equipment displays, and critical monitoring displays.
   c. At least one color graphic display screen per floor. The status of environmental condition on the floor as well as smoke conditions and lighting conditions shall be displayed on the graphic. Include “hot link” navigation buttons (activated with one mouse click) on the graphics and outlined equipment blocks that allow MIT to get to a default home page as well as systems that are on the floor.
   d. One color graphic display screen for each system controlled or monitored by the BMS. The status of each input and output shall be displayed on the graphic. Include “hot link” navigation buttons (activated with one mouse click) on the graphics that allow MIT to get to the home page graphic, a floor level graphics, parent and child equipment, and critical monitoring displays.
      1) Graphic display screens for similar systems should be similar (i.e., similar sizing and layout).
      2) Graphic display screens for applicable systems should contain system PM numbers.
      3) Graphic display screens for systems should contain a link to the applicable sequence of operations.
e. “Hot link” buttons shall get the user to the respective graphics page in one front end keyboard or mouse click.

f. Special attention shall be given to match existing graphic color schemes and layouts already in use at MIT. Graphics added to existing buildings (which already contain graphics) shall maintain to same look and feel.

g. Graphics file name format shall be as follows:

1) ABCD_123456789_abc:

   a) Where ABCD = Building (i.e., M02).

   b) Where 123456789 =

      1) Riser or,

      2) Floor# or,

      3) System Description (i.e., Rm169, AHU2).

   c) Where abc = additional text after room or additional equipment (i.e., VAV, FCU).
d) Examples include: M02_AHU01, E15_Rm239_FCU.

2) The file name of the graphic should support being used as inventory management field and fall into one of the following categories:

a) Navigation.
b) Riser.
c) Floor Plan.
d) System.
e) Room.
f) User Interface.
g) Template.
h) Balancing
i) Test Graphic.

h. Separate tabs shall be employed for less critical points, such as those from the BMS BACnet interface to a VFD.
i. Points that are derived from a software interface as opposed to hardwired that are not on a separate tab must be clearly identified as such through either notes or a specific color scheme/strategy.
j. Text box backgrounds of contrasting color shall be used for points or values that are typically grouped together (i.e., fan control).
k. Units for values shall be left aligned after the actual value.
l. Graphics orientation shall be as follows (see appendix for examples):

1) Building riser graphics shall be in 2-D.
2) Air handling unit graphics shall be 2-D with a 3-D “shadow effect”.
3) Room level component graphics (i.e., VAVs, FCUs, and Chilled Beams) shall be 2-D with a 3-D “shadow effect”.
4) Hydronic and specialty systems shall be in 2-D.
Colors shall be as detailed below.

<table>
<thead>
<tr>
<th>Graphic</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Background</td>
<td>Black</td>
</tr>
<tr>
<td>2) Floor Plans</td>
<td>Green (StruxureWare)</td>
</tr>
<tr>
<td></td>
<td>Yellow or Sky Blue (Continuum)</td>
</tr>
<tr>
<td></td>
<td>Gray (Siemens)</td>
</tr>
<tr>
<td></td>
<td>Gray (ALC)</td>
</tr>
<tr>
<td>3) Systems</td>
<td></td>
</tr>
<tr>
<td>Ductwork</td>
<td>Light Gray</td>
</tr>
<tr>
<td>Chilled Water S&amp;R</td>
<td>Blue/Light Blue</td>
</tr>
<tr>
<td>Hot Water S&amp;R</td>
<td>Red/Light Red</td>
</tr>
<tr>
<td>Glycol S&amp;R</td>
<td>To follow CHW and/or HW</td>
</tr>
<tr>
<td>Steam Line</td>
<td>Gray</td>
</tr>
<tr>
<td>Condensate Line</td>
<td>Gray</td>
</tr>
<tr>
<td>Fuel Oil</td>
<td>Orange</td>
</tr>
<tr>
<td>Other Gases</td>
<td>TBD</td>
</tr>
<tr>
<td>Process Lines</td>
<td>TBD</td>
</tr>
<tr>
<td>4) Equipment</td>
<td></td>
</tr>
<tr>
<td>Boilers</td>
<td>Manufacturer’s Standard</td>
</tr>
<tr>
<td>Water Chillers</td>
<td>Manufacturer’s Standard</td>
</tr>
<tr>
<td>Glycol Chillers</td>
<td>Manufacturer’s Standard</td>
</tr>
<tr>
<td>Cooling Towers</td>
<td>Manufacturer’s Standard</td>
</tr>
<tr>
<td>Air Compressors</td>
<td>Manufacturer’s Standard</td>
</tr>
<tr>
<td>Air Dryers</td>
<td>Manufacturer’s Standard</td>
</tr>
<tr>
<td>All Fire Fighting</td>
<td>Manufacturer’s Standard</td>
</tr>
<tr>
<td>Pumps &amp; Motors</td>
<td>Manufacturer’s Standard</td>
</tr>
<tr>
<td>Fire Pumps</td>
<td>Manufacturer’s Standard</td>
</tr>
<tr>
<td>Switch Gear</td>
<td>Manufacturer’s Standard</td>
</tr>
<tr>
<td>Transformers</td>
<td>Manufacturer’s Standard</td>
</tr>
<tr>
<td>Air Handlers</td>
<td>Gray</td>
</tr>
<tr>
<td>Exhaust Fans</td>
<td>Gray</td>
</tr>
<tr>
<td>VAVs</td>
<td>Manufacturer’s Standard</td>
</tr>
<tr>
<td>Fan Coil Units</td>
<td>Manufacturer’s Standard</td>
</tr>
<tr>
<td>Chilled Beams</td>
<td>Manufacturer’s Standard</td>
</tr>
<tr>
<td>Tanks</td>
<td>Manufacturer’s Standard</td>
</tr>
<tr>
<td>4) Instrumentation</td>
<td></td>
</tr>
<tr>
<td>Temperature</td>
<td>Purple</td>
</tr>
<tr>
<td>Humidity</td>
<td>Orange</td>
</tr>
<tr>
<td>CO2</td>
<td>Yellow</td>
</tr>
<tr>
<td>Pressure</td>
<td>Green</td>
</tr>
<tr>
<td>Airflow</td>
<td>Bronze</td>
</tr>
<tr>
<td>Water Flow</td>
<td>Bronze</td>
</tr>
<tr>
<td>Fire/Smoke</td>
<td>Red</td>
</tr>
</tbody>
</table>
10. The BMS contractor shall configure user accounts which include usernames, passwords, and permission levels for all authorized users. After final acceptance of system, the BMS contractor shall work with MIT to remove all temporary user names and passwords that were required for commissioning purposes. User accounts shall be as follows:

   a. BMS Administrator / BMS Analyst (access to everything available).
   b. Engineer (access to everything available except administrator privileges).
   c. Technician (same as engineer except no ability to modify programs).
   d. View Only.
   e. Special Cases (i.e., a professor wants control of his space).

11. The BMS contractor shall configure alarm handling as detailed in the sequence of operation. The BMS contractor shall coordinate alarm strategy with MIT via the submittal process described above.

   a. Alarm levels shall be as follows (how they appear in the alarm log is detailed under each):

      1) Life Safety (Toxic Gas):

         a) Alarm: Bold Purple Text with Orange Highlight Color Band.
         b) Acknowledged (still in alarm): Bold Purple Text.
         c) Unacknowledged Return to Normal: Purple Text.
         d) Fault: Blue Text.

      2) Life Safety (Fire Alarm):

         c) Unacknowledged Return to Normal: Black Text.
         d) Fault: Blue Text.

      3) Critical (Animal Labs):

         a) Alarm: Bold Black Text with Yellow Highlight Color Band.
         b) Acknowledged (still in alarm): Black Text with Yellow Highlight Color Band.
         c) Unacknowledged Return to Normal: Black Text.
         d) Fault: Blue Text.

      4) Critical (Research Labs):
a) Alarm: Bold Black Text with Aqua Highlight Color Band.
c) Unacknowledged Return to Normal: Black Text.
d) Fault: Blue Text.

5) Critical (Mechanical Equipment):

a) Alarm: Bold Black Text with Aqua Highlight Color Band.
c) Unacknowledged Return to Normal: Black Text.
d) Fault: Blue Text.

6) Critical (Office/Classroom):

a) Alarm: Bold Black Text with Aqua Highlight Color Band.
c) Unacknowledged Return to Normal: Black Text.
d) Fault: Blue Text.

7) Warning (Animal Labs):

a) Alarm: Bold Red Text.
b) Acknowledged (still in alarm): Red Text.
c) Unacknowledged Return to Normal: Black Text.
d) Fault: Blue Text.

8) Warning (Major Equipment):

a) Alarm: Bold Red Text.
b) Acknowledged (still in alarm): Red Text.
c) Unacknowledged Return to Normal: Black Text.
d) Fault: Blue Text.

9) Standard Alarming:

a) Alarm: Bold Red Text.
b) Acknowledged (still in alarm): Red Text.
c) Unacknowledged Return to Normal: Disappears from Alarm Log.
d) Fault: Blue Text.

10) Maintenance Alarm:

a) Alarm: Bold Red Text.
b) Acknowledged (still in alarm): Red Text.
c) Unacknowledged Return to Normal: Disappears from Alarm Log.
d) Fault: Blue Text.

11) Information Alarm:

a) Alarm: Bold Red Text
b) Acknowledged (still in alarm): Red Text
c) Unacknowledged Return to Normal: Disappears from Alarm Log
d) Fault: Blue Text.

b. Alarms shall be as detailed in Appendix B alarm table. This is a living list and should be amended periodically to reflect actual conditions. In general the alarm types should be as follows:

<table>
<thead>
<tr>
<th>Alarm Type</th>
<th>Alarm Functionality</th>
<th>Application Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change of State</td>
<td>The change of state alarm monitors the state of changes of digital values. You configure the alarm to trigger when the variable changes its state to true or false.</td>
<td>This type of alarm is used for digital status alarming or alarms configured in code that trigger digital alarm flags.</td>
</tr>
<tr>
<td>Change of Value</td>
<td>The change of value alarm occurs under the following conditions:</td>
<td>This type of alarm is used for alarms where the values can have the same +/- alarm values.</td>
</tr>
<tr>
<td></td>
<td>• The absolute value of the monitored variable changes by an amount that is equal to or greater than the value displayed in the Increment property and the condition remains in that state for the time identified in the time delay property.</td>
<td></td>
</tr>
<tr>
<td>Floating Limit</td>
<td>This alarm is triggered when the monitored value exceeds or falls below the values as determined by the current value of the setpoint referenced, upper</td>
<td>This type of alarm is used this for point values that require different offset values for the high and low alarm limits.</td>
</tr>
<tr>
<td></td>
<td>deviation limit, lower deviation limit and the deadband.</td>
<td></td>
</tr>
<tr>
<td>--------------------------</td>
<td>---------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Out of Range</td>
<td>This alarm is triggered when the referenced point falls outside the upper limit and lower limits.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>This alarm type is used for values where the normal range may float but the alarm is a hard value such a critical space temperature alarm, high alarm of 80°F, low alarm of 60°F.</td>
<td></td>
</tr>
<tr>
<td>Communication Alarm</td>
<td>This alarm is triggered when a controller loses it communication.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>This alarm should be used for all controllers.</td>
<td></td>
</tr>
</tbody>
</table>

c. Alarms should generally have the following guidelines (refer to the appendix for further detailed information):

1) AHU Supply Temperature +5°F from setpoint.
2) AHU/EF Static Pressure +20% from setpoint.
3) AHU Discharge Relative Humidity > 85%.
4) AHU Heating Coil Discharge Temperature < 40°F.
5) Hydronic Differential Pressure +20% from setpoint.
6) Hydronic Supply/Return Temperatures +5°F from setpoint.
7) Animal Quarters Airflow +20% from setpoint.
8) Animal Quarters Differential Pressure +0.0001” w.c. from setpoint.
9) Animal Quarters Temperature +3°F from setpoint.
10) Animal Quarters Relative Humidity +10% from setpoint.
11) Laboratory Airflow +20% from setpoint.
12) Laboratory Temperature +5°F from setpoint.
13) Laboratory Relative Humidity +20% from setpoint.
14) Office Temperature +10°F from setpoint.
15) Classroom Temperature +10°F from setpoint.
16) Conference Room CO2 > 825 ppm.

d. Alarms shall be set up with suitable time delays to avoid nuisance alarms.
e. Alarms shall be linked to their applicable graphic, such that upon alarm indication, a user can open the graphic link from the alarm viewer.

12. The BMS contractor shall configure the scheduling function of the BMS software to schedule systems as shown in the sequence of operation and as required for the building.

a. For critical buildings that must be on 24/7, no schedules are required.
b. For systems that turn on and off, provide daily occupancy schedules 8:00AM-6:00PM, exclusive of any required start-up/transition time.

13. The BMS contractor shall create trends and reports for required points as shown in the sequence of operation and as specified. The approach shall be as follows:

a. Short term trending (done at the controller level): Trends shall be set for up all hardwired I/O and setpoint variables, and other key calculated values (i.e., enthalpy) as follows:

1) For mechanical systems, instantaneous reading at every fifteen minute interval for a total period of three days.
2) For room level systems, instantaneous reading at every fifteen minute interval for a total period of one day minimum. Ideally MIT would prefer this to be three days, if the controller has the memory to support this.
3) Digital value and non-resetting setpoints may be trended on change of value, while analog values and resetting setpoints shall be instantaneously trended.

b. Long term trending (at the server or workstation): All short term trends shall be archived for 365 days, at which time they can be written over by the newest data.

c. Grouping of trends strategy shall be deployed for short term trending to assist in troubleshooting via trend graphs as follows:

1) **Terminal Unit Distribution for Offices:**
   a) Temperature (contains all key trended values related to temperature).
   b) Flow (contains all key trended values related to flow).
   c) Occupancy (contains all key trended values related to occupancy).

2) **Terminal Unit Distribution for Laboratories and Animal Quarters:**
   a) Temperature (contains all key trended values related to temperature).
   b) Flow (contains all key trended values related to flow).
   c) Room Pressure/Offset (contains all key trended values related to room pressure).
   d) Occupancy (contains all key trended values related to occupancy and lighting).
   e) Fume Hood operating parameters.

3) **AHU:**
   a) Supply Air Temperature (contains all key trended values related to temperature).
   b) Economizer Control.
   c) Pre-heat Coil Valve Control (includes Face and Bypass control).
   d) Cooling Coil Valve Control.
   e) Heating Coil Valve Control.
f) Heat Recovery Control.
g) Supply Air Fan Control (contains all key trended values related to fan control).
h) Return Air Fan Control (contains all key trended values related to fan control).
i) Humidification Control (contains all key trended values related to humidification).
j) Occupancy (contains all key trended values related to occupancy).

4) **Exhaust Fans:**
   a) Exhaust Air Fan Control (contains all key trended values related to fan control).

5) **Heat Exchangers:**
   a) Supply Temperature (contains all key trended values related to temperature).
   b) Return Temperature (contains all key trended values related to temperature).
   c) Pump Control (contains all key trended values related to pump control).
   d) Differential Pressure (contains all key trended values related to pump control).

6) **Chilled Water:**
   a) Pump Control (contains all key trended values related to pump control).
   b) Differential Pressure {plant and local} (contains all key trended values related to pump control).

14. **BACnet Naming and Address Convention:**

   a. The BMS contractor shall coordinate with MIT and provide unique naming and addressing for BACnet networks and devices as follows:

   1) **Controller-Device/Network Numbering:**

      a) The BMS contractor shall assign unique numbers to each new network and controller/device installed on the BACnet network based on the following:

      | Manufacturer | Instance ID    | Network #          |
      |--------------|---------------|--------------------|
      | SE           | 100,000-299,999 | 30,000-49,999      |
      | Siemens      | 300,000-399,999 | 50,000-59,999      |
      | Lutron       | 400,000-599,999 | same as manufacturers |
2) **MAC Addresses:**

   a) Every BACnet device shall have an assigned and documented MAC Address unique to its network.
   b) For Ethernet networks, the BMS contractor shall document the MAC Address assigned at its creation.
   c) For MSTP networks, the BMS contractor shall assign from the MAC Address from a range as indicated by manufacturer’s documentation.

3) **UDP Port Number:**

   a) The BMS contractor shall set every BACnet Building Controller (B-BC) and BACnet Router UDP port number to 47808 (BAC0) or a different UDP legal port number if needed.

4) **Device Object Identifier Property Number:**

   a) The BMS contractor shall assign unique Device "Object_Identifier" property numbers or device instances for each device on the BACnet network.

5) **Object Name Property Text (Other than Device Objects):**

   a) The Object Name property field shall support 32 minimum printable characters.
   b) The BMS contractor will provide object naming convention consistent with BMS manufacturer’s standards.

6) **Object Identifier Property Number (Other than Device Objects):**

   a) The BMS contractor shall assign Object Identifier property numbers as shown or at the BMS contractor’s discretion.

15. **Minimum BACnet Object Requirements:**

   a. **Use of Standard BACnet Objects:**

   1) For the following points and parameters, the BMS contractor shall use standard BACnet objects:

      a) Hardwired I/O wired to native BACnet controllers.
b) Setpoints.
c) Calculated values.
d) Equipment status.
e) PID loop parameters.
f) Alarms.
g) Trends.
h) Schedules.

b. **BACnet Object Description Property:**

1) The Object Description property shall support 32 minimum printable characters.
2) For each BACnet object, the BMS contractor shall complete the description property field using a brief, narrative, plain English description specific to the object and project application (i.e., "AHU On").

c. **Analog Input, Output, and Value Objects:**

1) The BMS contractor shall create Description and/or Device Type text strings that match the signal type and engineering units shown on the drawings.

d. **Binary Input, Output, and Value Objects:**

1) The BMS contractor shall create Inactive Text and Active Text property descriptions that match the conditions shown on the drawings.

e. **Calendar Objects:**

1) For devices with scheduling capability, the BMS contractor shall create Calendar Objects as required with ten-entry capacity and enable the writeable Date List property and support all calendar entry data types.

f. **Schedule Objects:**

1) The BMS contractor shall use Schedule Objects for all building system scheduling.

g. **Loop Object or Equals:**

1) The BMS contractor shall use Loop Objects or equivalent BACnet objects in each applicable field device for PID control.

h. **Trend Objects:**

1) The BMS contractor shall use Trend Objects for all building system trending.

16. **Minimum BACnet Service Requirements:**
a. **Command Priorities:**

1) The BMS contractor shall use commandable BACnet objects to control machinery and systems, providing the priority levels listed below:

<table>
<thead>
<tr>
<th>Priority Level</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Manual-Life Safety</td>
</tr>
<tr>
<td>2</td>
<td>Automatic-Life Safety</td>
</tr>
<tr>
<td>3</td>
<td>(User Defined)</td>
</tr>
<tr>
<td>4</td>
<td>(User Defined)</td>
</tr>
<tr>
<td>5</td>
<td>Critical Equipment Control</td>
</tr>
<tr>
<td>6</td>
<td>Minimum On/Off</td>
</tr>
<tr>
<td>7</td>
<td>(User Defined)</td>
</tr>
<tr>
<td>8</td>
<td>Manual Operator</td>
</tr>
<tr>
<td>9</td>
<td>(User Defined)</td>
</tr>
<tr>
<td>10</td>
<td>(User Defined)</td>
</tr>
<tr>
<td>11</td>
<td>Load Shedding</td>
</tr>
<tr>
<td>12</td>
<td>(User Defined)</td>
</tr>
<tr>
<td>13</td>
<td>(User Defined)</td>
</tr>
<tr>
<td>14</td>
<td>(User Defined)</td>
</tr>
<tr>
<td>15</td>
<td>(User Defined)</td>
</tr>
<tr>
<td>16</td>
<td>(User Defined)</td>
</tr>
</tbody>
</table>

b. **Alarming:**

1) Alarm Priorities:

a) The BMS contractor shall coordinate alarm and event notification with MIT.

2) Notification Class:

The BMS contractor shall enable writeable Priority, Ack Required, and Recipient List properties of Notification Class objects.

3) Event Notification Message Texts:

The BMS contractor shall use condition specific narrative text and numerical references for alarm and event notification.

4) Updating Displayed Property Values.

5) The BMS contractor shall create the graphic display screens to receive property values based on receipt of confirmed and unconfirmed Change of Value notifications. The COV increment shall be adjustable using BACnet services and shall be setup as 0.5 for all values except differential or static pressure which should be 0.1.
4.6 BMS Installation

1. General Installation Requirements:

   a. Building Management System:

      1) The BMS shall be completely installed, tested in accordance with the commissioning section of this standards document, and ready for operation.
      2) The BMS contractor shall ensure penetrations and mounting holes in the building exterior required for the BMS installation are watertight.
      3) The BMS contractor shall ensure that there is sufficient access for all BMS devices. All control system devices shall be located such that they can be accessed for to calibration, removal, or repair.
      4) The BMS contractor shall ensure that the BMS installation does not interfere with the clearance requirements for mechanical and electrical system operation and maintenance.

   b. BMS Controller Requirements:

      1) All BMS controllers shall be installed in enclosure except for BMS controllers used to control terminal units.
      2) The BMS contractor shall provide a unique BMS controller for each major piece of equipment. Exhaust fans and miscellaneous monitoring may reside on controllers designated for other major equipment.
      3) Control software algorithm and inputs and outputs for a single system or piece of equipment shall reside on a single controller. Control loops shall not rely on the network for control.
      4) The quantity of controllers connected on one secondary MSTP network shall not exceed 75 percent of maximum node capacity published by the BMS manufacturer. If necessary, provide additional hardware, over and above that shown on MEP design consultant’s drawings, to meet this requirement.
      5) I/O Point Capacity:

         a) BMS contractor shall provide I/O point capacity required for system control plus spare I/O points in each control panel. Spare I/O shall not be required for terminal unit controllers.
         b) Spare I/O point capacity shall be defined as terminal connections, which are ready to accept digital or analog inputs, dry contacts for digital outputs, and variable voltage or current terminals for analog outputs. Universal type points are acceptable for both discrete and analog type points.
         c) Minimum spare I/O points in each control panel shall be as follows:

              1) (1) Digital Input.
2) (1) Digital Output.
3) (1) Analog Input.
4) (1) Analog Output.

c. **BMS Controller Enclosure Layout:**

1) BMS controller enclosure shall be built to UL508A Standards in a UL certified panel factory with appropriate labels.
2) Terminal strips shall be located either horizontally in upper half of the back panel or vertically.
3) All power greater than 50VAC shall not be exposed in panel. In order to prevent accidental shock or Arc Flash, this power must be covered so that it cannot be touched when BMS controller enclosure door is open.
4) The control panel shall contain a utility 3 prong 120VAC outlet that is individually overload protected.
5) 24 VDC and 120 VAC, wire, cable, and devices shall be separated by 6 inches minimum.
6) Wire and cable shall be enclosed in wireways or bundled w/ wire ties and secured to the back panel. This does not apply to wire exiting wireways, to terminal strips, or to panel mounted devices.
7) BMS controllers shall be spaced according to manufacturer's requirements with at least 2 inches minimum between controllers and other devices on panel and 1 inch between controller front and door mounted devices. Ensure adequate space is allowed for device heat dissipation and for future expansion modules.
8) Each BMS controller in the enclosure should have its own power toggle switch as well as a master power switch to shut off power in the entire panel.
9) Each BMS controller in the enclosure should have an inline circuit overload protection device (Circuit Breaker).
10) BMS controller or control devices shall not be mounted on the sides of the enclosure.
11) BMS controller enclosures shall not be used as a wire pass-through to an adjacent panel.
12) Labels inside enclosures shall be attached using adhesive and shall not be hand written.

d. **BMS Controller Enclosure Mounting:**

1) The BMS contractor shall mount BMS controller enclosures on walls with suitable brackets or on a self-supporting stand. Where possible, the top of the BMS controller enclosures shall be no higher than six feet above the finished floor. There may some exceptions such as when a fan coil unit controller is mounted above the ceiling near the actual fan coil unit.
2) BMS controller enclosure locations shall be field coordinated with the architect/MEP design consultant and adhere to applicable codes and regulations.
3) The BMS contractor shall mount the BMS controller enclosures so that the panel
do not obstruct.

4) All penetrations on BMS controller enclosures installed outside shall be made at the bottom of the enclosure.

e. BMS Field Devices:

1) General:
   a) All control devices shall be installed in accordance with their manufacturer's instructions and as specified and shown.
   b) Control devices installed in piping shall be provided with required manual valves for shutoff, equalization, purging, and calibration.
   c) Control devices located outside shall have a weather shield.

2) Control Valves:
   a) The BMS contractor shall work with the mechanical contractor to ensure that the control valves are installed in accordance with the manufacturer's installation instructions.
   b) Control valves for steam shall be installed such that their actuators are orientated at a 45° angle.

3) Dampers:
   a) The BMS contractor shall work with the mechanical contractor to ensure that the dampers are installed in accordance with the manufacturer's installation instructions.
   b) Dampers shall move freely without undue stress due to twisting or other installation error.
   c) Damper blades shall open completely and close completely.

4) Damper Actuators:
   a) Damper actuators shall not be mounted in the air stream.
   b) Actuators shall be installed so that their action seals the damper and moves the blades smoothly.
   c) Multiple actuators shall not be connected to a common drive shaft.

5) Room Sensors:
   a) Room sensor locations shall be field coordinated with the architect/MEP design consultant for best coverage, access for the user, and adherence to applicable codes and regulations.
   b) Room sensor backboxes shall be sealed to provide air tight separation from the wall cavity.
   c) Temperature and humidity sensors for vivarium spaces or critical
laboratory areas shall be mounted in the exhaust air duct.

d) All other thermostats, temperature, humidity, and CO2 room sensors for non-critical areas shall be wall mounted.

6) Duct Averaging Temperature Sensors:

a) Sensors mounted in air streams where stratification exists shall be averaging type as specified.

b) The BMS contractor shall mount the averaging sensor across the duct area in a "Z" pattern using appropriate mounting clips.

7) Duct Humidity Sensors:

a) If possible, the BMS contractor shall install duct humidity sensors in supply air ducts at least 10 feet downstream of the humidifier.

8) Air Flow Stations:

a) The BMS contractor shall work with the mechanical contractor to ensure that the air flow stations are installed in accordance with the manufacturer's installation instructions.

9) Flow Meters:

a) The BMS contractor shall work with the mechanical contractor to ensure that the flow meters are installed in accordance with the manufacturer's installation instructions.

10) Low Limit Temperature Switches (Freezestats):

a) Freezestats shall be provided on AHUs with cooling coils to sense the temperature at the location shown.

b) A sufficient number of freezestats shall be installed to provide complete coverage of the duct section.

c) A minimum of two freezestats per coil shall be required even if coverage size only requires one.

d) Built-in manual reset switches shall be accessible locations so they can be easily be reset.

e) The BMS contractor shall install the freezestat sensing element in a serpentine pattern and in accordance with the manufacturer's installation instructions. The installation of a freezestat shall allow for full coverage of a coil including the bottom six inches.

11) Duct Smoke Detectors:

a) Duct smoke detectors shall be provided by the fire alarm contractor and
located in supply and return air ducts in accordance with the fire alarm system specification.

b) The BMS contractor shall connect the BMS to the auxiliary contacts of the air handling unit’s duct smoke detectors or dedicated ZAMs as required for system safeties and to provide alarms to the BMS.

f. **Labels and Tags:**

1) Labels and tags shall match to the naming convention shown on the as-built drawings.

2) Laminated plastic nameplates shall be provided for all BMS controller and transformer enclosures. Laminated plastic shall be 0.125 inch thick, white with black center core. Nameplates shall be a minimum of 1 by 3 inch with minimum 0.25 inch high engraved block lettering. Enclosures shall be named as shown on drawings or as follows:

   a) **BMS Controller Enclosures:** BMS-X where X represents the controlled system.

   b) **BMS Transformer Enclosures:** BMS-PWR-X, where X represents the equipment being powered.

3) All BMS hardware located in enclosures shall be properly labeled.

4) All BMS sensors and actuators shall be tagged.

   a) Room sensors shall have a laminated index card sized sheet with instructions for use as approved by the MIT project manager.

   b) Each room sensor shall have an identification number tag in a discrete location.

5) Tags shall be plastic or metal and shall be attached directly to each device (i.e., sensors) or attached by a metal chain (i.e., valves), when not in finished spaces. In finished spaces, tags can be put inside the cover of the device.

G. **Wires and Cables:**

1) Wire and Cable shall be installed without splices between control devices and in accordance with NFPA 70 and NFPA 90A.

2) Penetrations required in fire-rated construction shall be firestopped in accordance with the firestopping specifications.

3) Instrumentation grounding shall be installed per the device manufacturer’s instructions and as necessary to prevent ground loops, noise, and surges from adversely affecting operation of the system.

4) Cables and wires shall be tagged at both ends, with tagging matching the tags on the BMS control drawings.

5) Electrical work shall be as specified in the electric section of this standards document. Wiring external to enclosures shall be run as follows:
a) Wiring required in mechanical spaces and inside air handling unit casings shall be installed in conduit.
b) Wiring other than low-voltage control and low-voltage network wiring shall be installed in conduit.
c) Low-voltage control and low-voltage network wiring not in accessible suspended ceilings shall be installed in conduit unless there is another means of access (i.e., access doors.)
d) Low-voltage control and low-voltage network wiring in accessible suspended ceilings over occupied spaces can be installed in conduit or can be plenum rated cable as detailed:

   1) Plenum rated cable in accessible suspended ceilings over occupied spaces may be run without conduit or raceways.
   2) Plenum rated cable shall be routed along building structure lines using Bridal Rings, J-hooks or other mounting methods as approved by the MEP design consultant.
   3) Use of wire-ties for attaching cabling to duct brackets, piping, ceiling grid supports or structure is not acceptable. Diagonal routing is also not allowed.

h. Sensing Tubing:

   1) General:

      a) Sensing tubing installed outside shall be hard copper.
      b) Sensing tubing shall be concealed except in mechanical rooms and other areas where other tubing and piping is exposed.
      c) Sensing tubing in mechanical/electrical rooms shall be routed so that the lines are easily traceable.
      d) All sensing tubing and sensing tubing bundles, exposed to view shall be installed neatly in lines parallel to the lines of the building.
      e) Sensing tubing shall be purged prior to final connection to control devices.
      f) Sensing tubing shall be tagged at both ends, with tagging matching the tags on the BMS control drawings.

   2) Copper Tubing:

      a) Copper tubing shall be hard-drawn in exposed areas and either hard-drawn or annealed in concealed areas.
      b) Only tool-made bends shall be used.
      c) Fittings for copper tubing shall be brass or copper solder joint type except at connections to apparatus, where fittings shall be brass compression type.
3) Plastic Tubing:

a) Plastic tubing shall be run within covered raceways or conduit except when otherwise specified.

b) Plastic tubing shall not be used for applications where the tubing could be subjected to a temperature exceeding 130°F.

c) Fittings for plastic tubing shall be for instrument service and shall be brass or acetal resin of the compression or barbed push-on type.

d) Except in walls and exposed locations, plastic multi-tube instrument tubing bundle without conduit or raceway protection may be used where a number of air lines run to the same points. The multi-tube bundle must be enclosed in a protective sheath, run parallel to the building lines, and adequately supported.

4) Sensing Tubing for Space Pressure:

a) Sensing tubing for space pressure applications shall be plastic or copper tubing. Horizontal and vertical runs of plastic tubing or soft copper tubing shall be installed in raceways or rigid conduit dedicated to tubing. Dedicated raceways, conduit, and hard copper tubing not installed in raceways shall be supported every 6 feet for horizontal runs and every 8 feet for vertical runs.

5) Sensing Tubing for Liquid and Steam:

a) Sensing tubing for connection of sensing elements and transmitters to liquid and steam lines shall be copper with brass compression fittings.

6) Sensing Tubing for Duct Pressure or Flow:

a) Connections to sensing elements in ductwork shall be plastic tubing.

4.7 Existing Controls Coordination

1. The BMS contractor shall ensure that existing controls which are to be reused are tested and calibrated for proper operation. Existing controls which are found to be defective shall be noted to MIT and the CM. The BMS contractor shall not be responsible for any material or labor costs associated with the repair of existing controls.

2. Switchover from the existing control system to the new BMS must be coordinated with MIT.

3. The BMS contractor shall include demolition of the existing controls no longer required after the new BMS is in place and functioning properly.

4. When the incumbent/existing BMS for a building is replaced, superseded hardware as-builts and software code/graphics shall edited/removed by MIT.
4.8 BMS Commissioning

1. General:

   a. This section details the procedures required to ready the BMS for the CxA’s Functional Performance Testing. There shall be three main parts to this effort. The first part shall be an Installation Verification, the second part shall be Start-up Testing, and the third part shall be an Operational Verification that shall include executing Sequence of Operation Tests which are similar to the CxA’s Functional Performance Testing.

   b. A turnover checklist similar to the one in Appendix C shall be prepared by the BMS contractor. It is expected that this checklist will be filled out by the BMS contractor and signed-off by MIT’s BMS personnel. The first part of the checklist should be complete prior to the last walkthrough steps. When completed and signed off this checklist will be part of the as-built documentation.

2. Coordination:

   a. Coordination with the Testing & Balancing (TAB) contractor:

      1) Coordinate with the TAB contractor to obtain and fine tune control settings that are determined from balancing procedures. Record and implement the following control settings as obtained from TAB contractor:

         a) Calibration parameters (including coefficients and offsets) for flow control devices such as VAV boxes and flow measuring stations.

         b) Optimum duct static pressure setpoints for VAV air handling units.

         c) Optimum differential pressure setpoints for variable speed pumping systems.

         d) Minimum outside air damper settings for air handling units.

   b. Coordination with CxA and MIT:

      1) The BMS contractor shall prepare a list of all point types and recommended alarming strategies and setpoints for review by the CxA and MIT. Points list with alarming strategy shall be provided prior to the first applicable Sequence of Operation Test. MIT shall use this alarm list to provide direction to the BMS contractor for alarm strategies and setpoints. The BMS contractor shall have alarm setpoints entered and documented in the testing protocols prior to execution of any applicable Sequence of Operation Tests.

      2) The BMS contractor shall submit screenshots of all graphic displays (only one example of a graphic display screenshot is required for repetitive equipment like VAV boxes or fan coil units) with points displayed for review by the CxA and MIT. Graphic display screenshots with attached points shall be provided prior to execution of any applicable Sequence of Operation Tests. MIT shall use these graphic display screenshot samples to provide direction to the BMS contractor for the required final graphic display screens.
3. Installation Verification:

   a. General:

      1) Each I/O device and local device (both field mounted as well as those located in control panels) shall be inspected and verified for proper installation.

      2) A checkout sheet itemizing each device shall be filled out, dated, and submitted to the CxA as part of the Installation Verification test documentation.

      3) The BMS contractor shall perform a full-loop test at each I/O point. Each point shall be tested back to its respective graphic display screen. While performing the loop test the BMS contractor shall also:

         a) Verify proper electrical voltages and amperages.
         b) Verify that all control circuits are free from faults.
         c) Verify integrity/safety of all electrical connections.
         d) Check and set zero and span adjustments for all transducers and transmitters.
         e) For actuators and associated valves and dampers:

            1) Verify the stroke and range is as required and matches the programmed ranges.
            2) Verify adequate installation including free movement throughout full stroke of the actuator.
            3) From the BMS graphic display screen, command the valve or damper closed and verify that valve or damper is fully closed.
            4) From the BMS graphic display screen, command the valve or damper open and verify position is fully opened.
            5) From the BMS graphic display screen, command the actuator to one halfway position. If actual valve or damper position doesn't reasonably correspond, troubleshoot the problem.
            6) Where dampers work in unison, verify proper control without overlap.
            7) Verify the appropriate fail position both for device power failure and system failure.

         f) Verify each digital output is wired and configured correctly by making a comparison between the control command at the graphic display screen and the status of the controlled device.

         g) Verify each digital input point is wired and configured correctly by making a comparison of the state of the sensing device and the graphic display screen.

         h) For outputs to control devices not provided by the BMS (i.e. VFDs) and feedback from them, verify that ranges of operation match at the BMS. When applicable, coordinate with representative of the respective manufacturer and obtain their approval of the proper installation.
i) Verify that all safety devices trip at appropriate conditions. Adjust setpoints as required.

j) Calibrate, set, and test all digital and analog sensing and actuating devices. The BMS contractor shall calibrate each sensor per the procedure in detailed below.

k) For BMS control panels:

1) Verify that devices are properly installed with adequate spacing for maintenance.

2) Verify that all devices are properly labeled in accordance with the BMS panel drawings.

3) Verify that wiring and tubing are run in a neat and workman-like manner, either bound or enclosed in panduit.

4) Verify that terminations are safe, secure, and labeled in accordance with the BMS panel drawings.

5) Verify that power supplies have proper voltage ranges in accordance with the BMS panel drawings.

6) Verify adequate grounding of all BMS control panels and devices.

7) Run self-diagnostic routines and ensure BMS controllers are functional.

8) Verify controller is properly communicating on communication network.

b. Sensor Checkout and Calibration:

1) General Checkout: Verify that all sensor locations are appropriate for the tolerances specified for the device and are away from causes of erratic operation.

2) General Calibration (for applicable areas and devices):

a) Calibrate each device by making a comparison between the BMS graphic display screen and the reading at the device, using a calibrated test instrument. (Calibration certificates for test instruments shall be provided if requested.) Record the measured value and displayed value for each device on the check-out sheet.

b) For precision grade instrumentation, a factory calibration certificate is required.

3) Air and water flow sensor calibration shall be performed in collaboration with the TAB contractor. The TAB contractor or the mechanical contractor shall be responsible for the coordination of the entry of calibration coefficients into the BMS and for recording of the parameters entered.
4. Start-up Testing:
   
a. Current Switch Status Adjustment:
   
   1) Adjust all current switches to indicate status at minimum flow condition and show no status when device is off.
   
b. Loop Tuning:
   
   1) The BMS contractor shall tune each control loop in a manner consistent with that described in the ASHRAE FUN IP. Tuning shall consist of adjustment of the proportional, integral, and where applicable, the derivative (PID) settings to provide stable closed-loop control.
   
   2) For all control loops, the BMS contractor shall tune the loops to ensure the fastest stable response without hunting, offset, or overshoot with the tolerances defined below. Except from a startup, maximum allowable variance from setpoint for controlled variables under normal load fluctuations shall be as follows:

   a) Duct air temperature: ±1°F.
   b) Space temperature: +/- 3°F within 3 minutes and control within +/- 2°F.
   c) Chilled water temperature: +/- 1°F.
   d) Hot water temperature: +/- 2°F.
   e) Duct pressure: +/- 0.25" w.g.
   f) Water pressure: +/- 1 psid.
   g) Duct humidity: +/- 3 percent when adding humidity.
   h) Space humidity: +/- 5 percent when adding humidity to control.
   i) Terminal air flow control: +/- 5 percent of setpoint.
   j) Space Pressurization: +/- 0.03" w.g. with no door or window movements.
   k) Steam Pressure: +/- 3 psig.
   l) Water Level: +/- 5 percent tank height.

   3) Within 3 minutes of any upset (for which the system has the capability to respond) in the control loop, the tolerances shall be maintained with exceptions as noted.
   
   4) Loop tuning shall take place during periods of high gain.
   
   5) Maintain a record of control loops that require tuning at alternate times of year.
   
   6) Document all loop tuning by capturing text, short interval trends, or screen shots of trend graphs documenting the final response.

   a) Trend Logs:

   1) Trends logs are historical archives stored in the BMS that document the operation of the systems and equipment. Trends can be interval recordings of system I/O parameters or Change of Value based trends that record when a system value changes by more than a specified threshold.
2) Sample times indicated as COV (±) or change of value mean that the changed parameter only needs to be recorded after the value changes by the amount listed. When output to the trending file, the latest recorded value shall be listed with any given time increment record.

3) Data shall include a single row of field headings and the data thereafter shall be contiguous. Each record shall include a date and time field. Recorded parameters for a given piece of equipment or component shall be trended at the same intervals.

4) Trending Requirements: As described in previous sections

5) Trending to document Sequence of Operation Tests may require a more frequent interval than final trending requirements. Coordinate with the CxA to determine the correct intervals to prove operational testing and modify intervals as required.

6) The BMS contractor shall set up the trends logs, ensure they are being stored properly, and then, if requested by the CxA, forward the data in electronic format to the CxA. Data shall be forwarded in one of the following formats:

   a) Microsoft EXCEL Spreadsheet (.xls)
   b) Comma Separated Value (.csv or .txt) preferably with quotes delimiting text fields and # delimiting date/time fields

7) The CxA shall analyze trend logs of the system operating parameters to evaluate normal system functionality.

8) The BMS contractor shall allow the CxA BMS access to view the trend log data and allow downloading to a remote location. The BMS contractor shall also provide instruction for accessing the trend logs.

b) Trend Graphs:

1) Trend graphs are generally used to facilitate and document testing. The BMS contractor shall prepare controller and workstation software to display graphical trends.

2) On the trend graphs, lines shall be labeled and shall be distinguishable from each other by using either different line types, or different line colors.

3) Indicate engineering units of the y-axis values; e.g. °F, inches w.g., Btu/lb, percent wide open, etc. The y-axis scale shall be set such that all trended values are in a readable range.

4) Trend outside air temperature, humidity, and enthalpy during each period in which any other points impacted by these parameters are trended.
5) All points trended for one HVAC subsystem (e.g. air handling unit, chilled water system, etc.) shall be trended during the same trend interval. On renovation projects with existing to remain controls on air or water generation equipment, these trend graphs need only address the new BMS renovation work.

6) Each graph shall be clearly labeled with HVAC subsystem title, date, and times.

7) The BMS contractor shall forward the trend graphs as part of the CxA BMS Pre-Requisite Package to the CxA for review.

5. Operational Verification:

a. For BMS control panels:

1) Verify the spare memory allocation to ensure adequate capacity is available for the intended function.

2) With the BMS operating normally, verify the reporting time to the BMS graphic display screen for an alarm triggered at the controller is within the tolerances specified.

3) Verify standalone performance of controllers by disconnecting the controller from the BMS network. Verify the loss of communications is reported to the BMS and upon restoration of communication the alarm clears and locally stored trending information is sent to the BMS.

4) Disconnect power from the controller.

   a) Verify that all outputs and devices fail to their proper positions/states.
   b) Verify that buffered memory is held through power outage.

b. From Graphical User Interface:

1) Verify that all hot buttons on the graphic display screens are functional and that the navigation strategy is logical.

   a) I/O bindings to graphic display screens shall be verified in the loop testing section.

2) Duplicate I/O bindings such as temperature readings on a floor plan shall be verified.

3) Verify that trend archiving is functional.

4) Verify that real time and historical trends are accessible and viewable in graph format.

5) Verify that the alarm logging and printing (if applicable) is functional.

6) Verify alarm functionality and proper time delays. (Actual individual alarms are tested in the Sequence of Operation Tests).

7) Verify that outgoing alarm annunciation is functional (i.e., text, phone, email).

8) Verify that required third party software applications are installed and are
9) Verify software interfaces communicate and check response time. If applicable, test watchdog programs.

10) Verify the following response times:

   a) It shall take no more than ten seconds from the time an alarm is generated at a device or controller until the BMS software provides notification and the alarm is displayed.

   b) It shall take no more than twenty seconds from the time of initiation of a control action command from the workstation to display of the resulting status change on the workstation.

11) Verify that all custom programs are editable from the operator workstation.

12) Verify upload, download, and backup and restore capabilities from the operator workstation.

13) Verify schedules are set up and working.

14) Verify security and permissions are set up and functional.

15) Verify all required BMS reports are set up and functional.

16) Verify software interfaces communicate and check response time. If applicable, test watchdog programs.

17) Where operator interface displays information mapped via a software interface:

   a) Verify the displayed points are correct and the values are properly bound.

   b) Verify delays in displaying changes of state are as specified.

   c) Verify BACnet object properties and parameters are readable and writable as required.

   d) Verify all BACnet services are provided as required.

   e) Confirm change of value reporting thresholds are set optimally and not such that they inhibit the transmission speed.

   f) Verify that after a resumption of normal state after a power failure, the interfaces resume normal communication without manual intervention.

18) Verify all specified actions in the sequence of operation control by using the Sequence of Operation Tests to record results. The test protocols shall explain, step-by-step, the actions and expected results that shall demonstrate that the control system performs in accordance with the sequence of operation. If required for execution of the testing protocols, BMS test equipment used shall be properly documented. The documentation shall include manufacturer, model number, calibration parameters, calibration expiration, and on what test the device was used.

   a) 100% of major equipment (AHUs, hydronics) must be sequence tested.

   b) 20% of each different sequence instance for terminal equipment must be tested.
19) Verify that the BMS can be accessed from the internet and the display is consistent with a hard client workstation.

6. CxA BMS Pre-Requisite Package:

a. The BMS contractor shall prepare a CxA BMS Pre-Requisite Package that includes the following:

1) Installation Verification Check-Out Sheets (Full Loop Test Check-Out Sheets).
2) Start-up Testing Trend Graphs (proving tuned loops).
3) Operational Verification Sequence of Operation Tests (proving adherence to sequence).

b. Failures and repairs shall be documented with test results that prove compliance. This shall be completed, submitted, and approved prior to Cx activities.

7. CxA Review of BMS Implementation:

a. Commissioning related training session is specified below:

1) BMS Final Systems Operation Training: The BMS contractor shall conduct a session to present the final sequence of operation programmed into the control system. This session is typically presented on site by the primary BMS technician that implemented the BMS for the project. The session shall basically present:

a) Control System Architecture.
b) Location of BMS control panels.
c) Schematic control configuration of the systems.
d) Final programmed sequence of operation: The BMS contractor shall present the written sequence of operation and explain the programming that accomplishes the sequence of operation.
e) Start-up and shut down procedures.
f) Common troubleshooting tips.
g) Log-on and BMS graphic display screen navigation.
h) Alarm viewing.
i) Trend viewing.
j) Report generation.

2) The BMS contractor shall use the project control drawings as training guide.

8. BMS Readiness Testing:

a. Demonstrate the readiness of the BMS and all related components and systems for Cx activities to the satisfaction of the CxA and MIT.

b. Demonstration shall not be scheduled unless:
1) All BMS hardware and software submittals are approved.
2) The CxA BMS Pre-Requisite Package is approved.

c. The BMS contractor shall supply all required personnel and test equipment for the demonstration. The BMS personnel performing the demonstration must be competent with and knowledgeable of all project-specific hardware, software, as well as the systems the BMS controls and monitors.

d. Readiness testing shall involve a small representative sampling of testing selected by MIT and the CxA that has already been completed as part of the Installation Verification, Start-up Testing, and Operational Verification.

e. The selected sampling of tests shall again be executed following the same procedures used in the Installation Verification, Start-up Testing, and Operational Verification. Sample testing may include:

1) Verify graphic display screens, alarms, trends, and reports are installed as specified.
2) Verify that I/O on control drawings is displayed on the correct BMS graphic display screen and can be commanded as required.
3) Verify correct calibration of input devices using the same methods specified in the Start-up Testing.
4) Verify all BMS software programs and hardwired I/O exist at respective field panels.
5) Verify the BMS controllers automatically recover from power failures, as specified.
6) Verify the stand-alone operation of BMS controllers upon loss of connectivity to the network.
7) Re-execution of the Sequence of Operation Tests.
8) Verify required trend graphs and logs are set up and perform per the requirements.

9. Proof of BMS Stability:

a. Performance Test:

1) The system shall operate properly for three days (or a mutual agreeable duration) without malfunction, without alarms caused by control action or device failure, and with smooth and stable control of systems and equipment. The BMS contractor shall maintain a log of all alarms generated by the BMS. For each alarm received, contractor shall explain the cause of the alarm and the corrective action taken. The BMS contractor shall provide this analysis within one week after the test. On renovation projects with existing to remain controls on air or water generation equipment, this test need only address the new BMS renovation work. However, deficiencies uncovered by the BMS contractor should be reported to MIT.
2) Special care must be given to address nuisance alarms. Projects will not be
accepted by MIT with unexplained alarms and/or nuisance alarms.

10. BMS Cx Phase Activities:

a. After receipt and/or review of the CxA BMS Pre-Requisite Package and approval of the BMS readiness testing and stability testing, the CxA shall determine if the system is ready for formal Functional Performance Testing.

1) If the systems are not ready for functional performance testing, the BMS contractor shall correct problems and provide notification to the CxA that all problems have been corrected. The proof of BMS stability period shall be restarted at a mutually scheduled time. This process shall be repeated until the CxA issues notice that the BMS is ready for Functional Performance Testing.

2) At the discretion of the CxA, minor issues highlighted by the CxA may be addressed by the BMS contractor and not prevent the Functional Performance Testing from starting.

3) It is also possible for partial submission and approval, so that certain systems may be started in accordance with the overall Cx schedule.

b. Requirements for assistance with Functional Performance Testing are specified in the commissioning specification. The BMS contractor shall provide support to the CxA during testing as specified.

c. During the Cx phase, the BMS contractor shall allow remote access by the CxA to view trend logs or trend graphs.

11. Additional Cx Support (System Optimization Assistance):

a. In addition to the support required during the Cx phase, the BMS contractor shall provide the services of a BMS controls technician to the CxA at the project site for a total of at least 8 hours (depending on the project size). The purpose of this resource is to make changes, enhancements, additions to the BMS and to create reports recommended by the CxA during the Cx phase. Requests for assistance shall be in 4 hour blocks at a minimum. The CxA shall notify the BMS contractor at least one week in advance of each day of requested assistance.

b. The BMS controls technician provided shall be thoroughly trained in the programming and operation of the BMS as it is specifically implemented on this project.

12. Additional Testing:

a. Opposite Season Testing (if required): Within six months of completion of the Cx phase, the CxA shall schedule and conduct opposite season functional testing. The BMS contractor shall support this testing and address any deficiencies identified.
4.9 Training

1. General:
   
a. Training courses shall be conducted as described below in the maintenance, service, and operation of the system, including specified hardware and software. The training shall be oriented to the specific system(s) provided for this project.

b. The length of the training sessions detailed below shall be determined by the MEP design consultant and MIT on a project by project basis. MIT’s System Performance and Turnover group shall coordinate the training.

c. Training Course Documentation:
   
   1) The BMS contractor shall prepare training documentation that shall consist of:
      
      a) Course Attendee List.
      
      b) Training Manuals: Training manuals shall include an agenda, detailed objectives for the course, and a description of the subject matter for part of the course. Training manuals shall be delivered for each trainee with two additional manuals turned over to the project site.

2. BMS Instrument Technician Training:
   
a. The BMS Instrument Technician training course shall be taught at the project site. This training shall be targeted towards the BMS Instrument Technicians in the day-to-day operation and basic maintenance of the BMS. Typical HVAC systems shall be treated as a group, with instruction on the physical layout of one such system. This course shall be taught to three shifts. The training at a minimum shall include:
      
      1) General system architecture.
      2) Functional operation of the system.
      3) System start-up procedures.
      4) Graphics navigation.
      5) Schedule configuration.
      6) Trend configuration.
      7) Reports generation.
      8) Alarm reporting and acknowledgements.
      9) Perform point overrides and override release.
      10) Retrieval of historical trends and logs.
      11) Web-access to BMS.
      12) Maintenance procedures:

      a) Locations and layout of typical BMS controller enclosure.
      b) Locations and layout of sampling of terminal equipment.
      c) Location of typical control end devices.
      d) Calibration, adjustment, commissioning, tuning, repair procedures.
      e) Calibration frequency.
3. BMS Analyst Training:

   a. The BMS Analyst training course shall be taught at the project site. This training shall be targeted towards the BMS Analysts in management of the BMS. This course shall be taught to one shift. The training at a minimum shall include:

   1) General system architecture.
   2) Functional operation of the system.
   3) System start-up procedures.
   4) Graphics navigation.
   5) Schedule configuration.
   6) Trend configuration.
   7) Reports generation.
   8) Alarm reporting and acknowledgements.
   9) Perform point overrides and override release.
   10) Retrieval of historical trends and logs.
   11) Web-access to BMS.
   12) Software diagnostics.
   13) Disaster recovery procedures.

4. BMS Operator Training:

   a. The BMS Operator training course shall be taught at the project site. This training shall be targeted towards the BMS Operators in the day-to-day operation of the BMS. This course shall be taught to three shifts. The training at a minimum shall include:

   1) Functional operation of the system.
   2) Graphics navigation.
   3) Schedule configuration.
   4) Alarm reporting and acknowledgements.
   5) Perform point overrides and override release.

4.10 Final Documentation (Operations and Maintenance Manuals)

1. The intent of the operation and maintenance documentation is to provide MIT with complete information on the BMS as it was installed. The record documentation shall be in such detail that a person familiar with a BMS installation of this nature shall be able to perform any operating, maintenance, or engineering functions with respect to this BMS without having to contact the BMS contractor or obtain any additional documentation.

2. The BMS contractor shall submit electronic copy (in PDF format) of the operation and maintenance manual that include the following three sections:
a. **Project Completion/Closeout for BMS Document (Part A & B).**

b. **BMS Hardware As-Built Information:**

1) Riser Diagram of Building Control Network.
2) As-built control schematic drawing for each controlled system.
3) As-built wiring drawings for all components.
4) As-built drawings for each control panel layout.
5) Installation details for each I/O device.
6) Product data sheet for each component.
7) Installation data sheet for each component.
8) As-built sequence of operation for each system.
9) Procedures for HVAC system start-up, operation, and shut-down.
10) Printouts of configuration settings for all devices.
11) Routine maintenance/calibration checklist: The routine maintenance checklist shall be arranged in a spreadsheet with the device tag, type of device, maintenance frequency, calibration frequency, and a notes field.

c. **BMS Software As-Built Information:**

1) Copy of all graphic display screens created during the execution of the project.
2) Alarm list.
3) List of virtual points configured from each software interface.

d. **BMS Operational Information**

1) Product manuals for the key software tasks (**if new**):
   a) Operating the system.
   b) Administering the system.
   c) Application programming.
   d) Setting up the report server.
   e) Report creation.
   f) Graphics creation.

2) List of recommended maintenance tasks associated with the system servers, operator workstations, data servers (**if new**):
   a) Define the task with recommended frequency.
   b) Reference the product manual that includes instructions on executing the task.

3) Contact information of the BMS contractor and service representatives for equipment and control systems (**if new**).
4) Licenses, guarantees, and warranty documents for equipment and systems (**if new**).
## APPENDIX A: BUILDING LIST

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<th>Schneider Continuum Alen Control ALC</th>
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## APPENDIX B: ALARM TABLE

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<td>Fault Mech. Room Space Temp sensor out of range</td>
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<td><strong>Space CO2 High</strong></td>
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<td>5m</td>
<td>n/a</td>
<td>1200 ppm</td>
<td>n/a</td>
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<td><strong>Space Dew Point Critical</strong></td>
<td><strong>Floating Limit</strong></td>
<td><strong>Alarm Space Dew Point Critical</strong></td>
<td>1m</td>
<td>n/a</td>
<td>CHWS+1°</td>
<td>n/a</td>
<td>1°F</td>
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<td>Condition</td>
<td>Action</td>
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<td>Unit</td>
<td>Value</td>
<td>Unit</td>
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<tr>
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<td>Floating Limit</td>
<td>Alarm Space Dew Point High</td>
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<td>n/a</td>
<td>CHWS- 1°F</td>
<td>1°F</td>
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<tr>
<td><strong>Space Temp</strong></td>
<td>Change of Value</td>
<td>Alarm Space Temp Out of Range</td>
<td>10m</td>
<td>10°F</td>
<td>n/a</td>
<td>n/a</td>
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<td>Fault Space Temp sensor malfunction</td>
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<td><strong>Stairwell Space Temp</strong></td>
<td>Out of Range</td>
<td>Alarm Stairwell Space Temp Out Of Range</td>
<td>10m</td>
<td>n/a</td>
<td>90°F</td>
<td>50°F</td>
<td>2°F</td>
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<td>RTN Stairwell Space Temp Returned to Normal</td>
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<tr>
<td><strong>Chilled Water Hi Temp Alarm</strong></td>
<td>Out of Range</td>
<td>Alarm Hi Chilled water temp</td>
<td>15m</td>
<td>n/a</td>
<td>60°F</td>
<td>45°F</td>
<td>2°F</td>
<td>n/a</td>
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<tr>
<td>RTN Hi Chilled water Temp Returned to Normal</td>
<td>Fault CHW sensor malfunction</td>
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<td><strong>Chilled Water Hi Temp Alarm</strong></td>
<td>Out of Range</td>
<td>Alarm Hi Chilled water temp</td>
<td>15m</td>
<td>n/a</td>
<td>60°F</td>
<td>45°F</td>
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<td>n/a</td>
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<tr>
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<td>Fault CHW sensor malfunction</td>
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<tr>
<td><strong>Differential Pressure</strong></td>
<td>Out of Range</td>
<td>Alarm Differential Pressure is Out of Range</td>
<td>5m</td>
<td>n/a</td>
<td>+5 PSI</td>
<td>-5 PSI</td>
<td>2 PSI</td>
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<td>RTN Differential Pressure has Returned to Normal</td>
<td>Fault System config malfunction</td>
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<td>Hot Water Supply Temp</td>
<td>Out of Range</td>
<td>Alarm HW Supply Temp is Out of Range</td>
<td>5m</td>
<td>n/a</td>
<td>+95°F</td>
<td>50°F</td>
<td>2°F</td>
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<td>HX 1,2 Pumps off</td>
<td>Change of State</td>
<td>Alarm Both HX Pumps have Failed</td>
<td>15s</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
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<td>MAHU SA temp out of range</td>
<td>Out of Range</td>
<td>Alarm MAHU SA Temp out of Range</td>
<td>15m</td>
<td>n/a</td>
<td>+10°F</td>
<td>-10°F</td>
<td>n/a</td>
<td>n/a</td>
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<tr>
<td>Modulating Valve Position</td>
<td>Floating Limit</td>
<td>Alarm Valve Position Deviation From Command</td>
<td>5m</td>
<td>n/a</td>
<td>+10%</td>
<td>-10%</td>
<td>5%</td>
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<td>Pump Status</td>
<td>Change of State</td>
<td>Alarm Pump status does not Match Command</td>
<td>30s</td>
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<td>n/a</td>
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<td>Steam Pressure Low</td>
<td>Out of Range</td>
<td>Alarm Steam Pressure is in Alarm</td>
<td>5m</td>
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<td>n/a</td>
<td>7 PSI</td>
<td>2 PSI</td>
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<td>VFD Fault</td>
<td>Change of State</td>
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<td>5s</td>
<td>n/a</td>
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<td>Fault System config malfunction</td>
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</table>
MIT Project Completion/Closeout for BMS (Part A Completion Checklist)

Project Name: ___________________
Project Manager: _______________

Checklist shall be turned in by BMS contractor Project Manager to MIT at completion. A software scan of the completed checklist shall reside on the server with the as-builds.

<table>
<thead>
<tr>
<th>Item</th>
<th>Responsible</th>
<th>Date:</th>
<th>Signed off by:</th>
<th>Notes:</th>
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</thead>
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<tr>
<td>Pre-Walkthrough</td>
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<tr>
<td>Installation Complete</td>
<td>Hardware Engineer</td>
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<tr>
<td>Check-out sheet complete</td>
<td>Hardware Engineer</td>
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<tr>
<td>Graphics Complete</td>
<td>Hardware Engineer</td>
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<tr>
<td>All links completed</td>
<td>Software Engineer</td>
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<tr>
<td>All floor plans completed</td>
<td></td>
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<tr>
<td>Alarms Enabled &amp; Complete***</td>
<td>Hardware Engineer and/or Software Engineer</td>
<td></td>
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<tr>
<td>Mechanical/Electrical Deficiency list required &amp; forwarded to MIT</td>
<td>Hardware Engineer and/or Software Engineer</td>
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<tr>
<td>Sequence of Operation Tests Complete</td>
<td>Hardware Engineer and/or Software Engineer</td>
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<tr>
<td>Balance Report Complete</td>
<td>Hardware Engineer and/or Software Engineer</td>
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<tr>
<td>All project P&amp;ID Loops are tuned</td>
<td>Hardware Engineer and/or Software Engineer</td>
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<tr>
<td>72 Hour Trends Complete **</td>
<td>Hardware Engineer and/or Software Engineer</td>
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<tr>
<td>Project Fully Commissioned by Schneider Electric</td>
<td>Hardware Engineer and/or Software Engineer</td>
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<tr>
<td>Sequence As-Built (red line)</td>
<td>Hardware Engineer and/or Software Engineer</td>
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<tr>
<td>As-Built (red line) into PM</td>
<td>Hardware Engineer</td>
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<tr>
<td>As-built PDF posted to MIT Server</td>
<td>Hardware Engineer</td>
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<tr>
<td>As-Built delivered to MIT</td>
<td>Project PE/SWE</td>
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<tr>
<td>Drawings in Panel</td>
<td>Hardware Engineer</td>
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<tr>
<td>Panel Labeled</td>
<td>Hardware Engineer</td>
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</table>
** Provide PDF of (72) hours of trends for each system.

*** See next page and attached documents (if any) for alarms that will not reset because of mechanical / electrical design flaws or any other issues that would cause alarms not to reset.
MIT Project Completion/Closeout for BMS (Part A Completion Checklist)

Meeting Date: _____________________  
Project Name: _____________________  
Project Manager: ___________________

To be completed by the BMS contractor and forwarded to MIT once all items are resolved, approved and accepted. A software scan of the completed walkthrough shall reside on the server with the as-builts.

<table>
<thead>
<tr>
<th>Participants</th>
<th>Title</th>
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**Action Items**

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<tr>
<th>Item</th>
<th>Person Responsible</th>
<th>Completion Date</th>
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MIT BMS Representative: ___________________  Date: ________________

END OF DOCUMENT
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APPENDIX A: LIST OF PRODUCTS

APPENDIX B: POWER SYSTEM STUDY - SAMPLE SPECIFICATION
1. ELECTRICAL SYSTEMS GENERAL REQUIREMENTS

1.1 Electrical Systems Mission Statement

The choice of equipment and the design of the installation should be developed assuming an operating life of 40 years is not unusual.

The design will incorporate access to equipment that will allow for easy maintenance, repair and replacement, and day-to-day operation.

Interchangeability and expandability of devices and equipment is required.

As an institute of technology, MIT is always open to new ideas with consideration given to cost, maintenance and safety.

MIT promotes electrical designs and installations that minimize energy usage, maximize quality of illumination, and are not constructed with environmentally damaging materials. Recyclability of materials is an important factor to consider.

1.2 List of Common Electrical Issues

1. All equipment, devices, ballasts, drivers, and lighting fixtures shall be accessible for routine service and replacement.
2. Service equipment shall be above the 26 foot City of Cambridge Datum point and below the fifth floor.
3. Systems (including panelboards, terminal capacity, raceway, physical space) shall be expandable with at least 25 percent spare capacity.
4. Adequate receptacle and circuit coverage shall be provided. Receptacle plan shall be reviewed with end-users.
5. In labs, conduits shall be used between panelboards and surface mounted raceways to allow for future fill capacity and flexibility.
6. Provide grounding means in labs and fume hoods for instrumentation equipment comprised of ground stud or ground bar. Connection via #6 min AWG and green insulated ground to building steel or local panel equipment ground bar.
7. Equipment nameplates shall follow existing building standards or MIT standards. Nameplates shall include equipment name, voltage, source equipment name and location. (e.g. FED FROM DP1, ROOM 2-001). Equipment phenolic engraved nameplates shall be provided for all electrical equipment and fire pump tap section, feeder tap and splice, as follows: as follows: Normal Power – white letters on black field; Life Safety and Legally Required Power – white letters on red field; Optional Standby Power – white letters on orange field.
8. Equipment, devices and circuits shall be labeled including with the room number of the equipment serving the device.
9. Steel fittings shall be used on raceways. Do not use die-cast.
10. All wiring shall be stranded wire with the exception of MI Cable.
11. Corridor, electrical rooms and mechanical room luminaires shall be provided with both normal-fed fixtures and emergency-fed fixtures.
12. Shared neutrals shall not be used.
13. All electrical rooms shall have crash bar hardware and card access. Main electric rooms shall have high and low exit signs at egress doors.
14. Review utility connections with the MIT campus electrical distribution system with the MIT Utilities Group.
15. Always refer to the current Thermatic Folder for Classrooms and Lecture Hall for additional requirements for electrical systems.

2. DESIGN REVIEW CHECKLISTS

2.1 Schematic Design

Provide the following information in the Schematic Design submittal:

1. Preliminary motor and load list. Profile load and give voltages.
   a. Lighting loads.
   b. Power loads.
   c. HVAC loads.
   d. Elevators loads.
   e. Emergency life safety loads including fire pump.
   f. Critical optional standby loads.

2. Engine/generator sizing calculations including step loads.
   a. Life safety.
   b. Legally required loads.
   c. Optional standby.

3. Preliminary watt/SF lighting, receptacle, HVAC, and special purpose loads including support documentation for selection.
4. Preliminary electrical distribution riser diagram:
   a. Show approximate configuration.
   b. Show preliminary distribution equipment sizes for substations and panels.
c. Provide for substations: voltage, bus ratings and transformer sizes.

5. Initial short circuit currents and short circuit bracing for equipment. Contact MIT Utilities for requirements.

6. Programming:
   a. List of electrical spaces and rooms.
   b. Service entrance requirements.
   c. Service provider (MIT or Eversource).
   d. Existing conditions plan, properly documented.

7. Provide overall oneline diagram.

   Signature of Responsible Electrical Engineer ____________________________

   Dated ____________________________

2.2 Design Development

Provide the following information in the Design Development submittal:

1. Final plans including:
   a. Substation and panel final breaker frame sizes and trip sizes.
   b. Final conduit and wire schedules.
   c. Final panelboard schedules with final and per phase loads.
   d. Final lighting fixture schedules.
   e. Final engine/generator sizes.
   f. Final risers and one line diagrams for power distribution system.
   g. Final risers for fire alarm system and communication system.

2. Final specifications.
3. Final motor and load list.
5. Lighting calculations including photometric plots for unique and typical areas.
6. Voltage drop calculations.

   Signature of Responsible Electrical Engineer ____________________________

   Dated ____________________________
2.3 Bid Documents

Provide the following information in the Bid Document submittal:

1. Bid package including specifications and stamped drawings.
2. List of deviations or changes from the 100% design development submittal.
3. Plans, specifications and calculations have been reviewed.

Signature of Responsible Electrical Engineer ____________________________

Dated ____________________________

3. ELECTRICAL DESIGN AND CONSTRUCTION GUIDELINES

3.1 Electrical Studies

The following electrical studies are required for all new buildings and large renovation projects. Refer to Appendix D for sample specification.

1. Provide arc flash hazard analysis study.
2. Provide short circuit and coordination study.
3. Provide short circuit device and evaluation study.

Electrical studies shall be performed in SKM by Commonwealth of Massachusetts licensed professional engineer. Provide 24x36 as-built construction document quality AutoCAD and hard copy SKM risers. Require mounting of 1 hard copy on foam board with clear laminate along with construction document one line drawings in main electric/substation room and main emergency electric room. SKM files shall be turned over to MIT SEG and FIS after necessary revisions have been included.

3.2 Building and Electrical Codes

Refer to the most current codes from the City of Cambridge at the following link: https://www.cambridgema.gov/inspection/codesandmaps/Codes.aspx

1. Building Codes:

2. Energy Codes:

3. Electrical Codes:

### 3.3 Removal and Abandoned Equipment and Wiring

Any unused wiring effected by renovation work as a result of demolition or change in circuit requirements shall be removed back to the branch circuit protective device – and such device shall be identified as a spare.

No unused circuit wiring shall be left in any junction box unless it is designated and identified as spare or future wiring.

### 3.4 Underground Structures, Ductbanks, Cabling, Load Break Loop Switches

Refer to Division 33, Utilities Design Standards.

### 3.5 Substations

Substation and service related equipment shall be above the 26 foot City of Cambridge Datum point and below the fifth floor. All substations shall be double-ended and capable of manual closed transition.

Card access and panic buttons are required for all main electrical rooms. Contact MIT Utilities for current implementation requirements.

Construction of the substations shall be as follows:

1. In general, each unit substation shall be fully rated, with an incoming metal-clad vacuum circuit breaker with RC Snubber, VPE dry-type transformer and low voltage draw-out switchgear.

Switchgear shall have the following features or include provisions for:

1. Rated for 15 KV (as required).
2. Provide Ground Ball Studs to the load side of Medium voltage circuit breakers. AB Chance C4060416.
3. Electric racking motor with a 20 ft or longer remote switch cable for main and all feeder circuit breakers.
4. IR inspection windows, Fluke-CV-300 or equivalent, to be provided to allow viewing of all cable connection points and flexible bus connections.
5. Strip Heaters.
7. Compression Lugs.
8. LED push to test lamps.
9. Power meter with display.
10. Communications card/Gateway.
12. Full height hinged main door with a foot operated door stop.
13. Hinged grounded metal safety barrier.
15. Switch interlock.
16. Permanent switch position indicator.
17. Rating nameplate.
18. Remote operation of all circuit breakers (MV and LV) via either remote panel or delay pistol grip operation. If a remote panel is used the layout shall mimic the arrangement of the switchgear.

Transformer shall have the following features or include provision for:

1. Delta connected on the primary and rated 13,800V.
2. Wye connected on the secondary rated either 480/277V or 208/120V as required by the application.
3. VPE vacuum pressure impregnation and encapsulation (or cast coil).
4. 80 degree C maximum rise.
5. 220 degree class insulation system.
6. Copper windings and bus.
7. Copper ground bus.
8. Fan cooled. The fan cooling package to include digital winding temperature for each phase.
10. Flexible bolted link primary taps.
11. Rating nameplate.

Drawout switchgear shall include:

1. Fully rated and fully drawout metal enclosed air circuit breakers with two step stored energy closing mechanisms and electrically operated rack-out mechanism.
2. Bussing shall be tin plated copper.
3. TVSS shall be provided on each main breaker at each end of the switchgear.
5. Overhead breaker removal crane.
6. Hinged doors.
7. RMS digital trip units and discrete metering package with Mod Bus compatibility.
Standard meter is GE Multilin PQMII-T20-A with MODBUS or approved equal by Schneider/Square D or Eaton.

8. The main breaker(s) and tie breaker shall be drawout type and the same frame size.
9. Feeder breakers shall be draw-out type with one exception:
   a. If the application is approved by the Facilities Department, small loads can be powered by molded case feeder breakers.

10. Ground fault sensing shall be installed the main breakers, tie breakers and feeder breakers. The emergency system and legally required systems will have ground fault indication.
11. The main breakers and the tie breaker on the double-ended substation shall not be Kirk-Keyed together.
12. Minimize the quantity of feeder breaker sizes to allow for interchangeability.
13. 15% minimum spare circuit breakers shall be provided.
14. Each feeder circuit shall supply power to only one primary distribution panel.
15. Except for sprinkler branch protection, there shall be no foreign systems that are not associated with the substations located in the rooms. For example, ventilation ductwork passing through the substation room that does not serve the room will not be allowed.
16. A housekeeping pad shall be provided under the substation and shall be a minimum of 4-inches high.
17. The substation room shall be air-conditioned to 78 degrees F maximum.
18. Lighting fixtures shall be powered from the emergency and normal system in the building. The fixtures are to be located in front of the substation. Additionally, wall mounted battery-pack emergency lighting units shall be located in front of the substation with the heads pointed at the front and along egress paths. Lighting shall be switched at each entrance.
19. There shall be both emergency powered receptacles and normal powered receptacles in the room. Emergency powered receptacles shall be colored red.
20. A telephone outlet shall be provided in the room at 54 inches AFF adjacent to the exit door on the latch side.
21. Room shall have at least one double door. Doors shall be self-closing with panic hardware - notify architect of this requirement.
22. The use of bus duct is acceptable for distribution of power in the building. Where the bus duct passes through building floors, curbs shall be provided around the opening and the opening shall be fire stopped.
23. Solid state micro-processor based electric Meter shall be installed on unit substation main breaker and all feeder breakers. The meter shall have an RS232 communication port and an RS485 communication port with OPEN (and not vendor-proprietary) Modbus protocol. Electric parameters available from OPEN Modbus registers should include: voltage, current, energy consumption, real power, reactive power, apparent power, frequency, and power factor.
24. Electronic Check Metering System: Please add to specifications “All new installations
shall use solid core current transformers and shorting blocks located in the meter compartments so the meters can easily be changed.”

25. Infra-red view ports shall be provided in the rear covers HI and LOW where cable connections are made.

26. Infra-red view ports will be installed at the point of incoming cables.

27. Ground ball studs shall be AB Chance C600-2102 and covers are C4060416.

28. Solid state micro-processor based Electric Meter shall be installed on unit substation main breaker. The meter shall have an RS232 communication port and a RS485 communication port with OPEN Modus protocol. If new switchgear is being installed, the meter installed in front of the main breaker shall be revenue grade. All breakers in the switchgear shall have Modbus communications included and factory wired.

Drawout Style Replacement Circuit Breakers, 600 Amp Frame and Larger:

1. If the project scope requires a connection to an existing circuit breaker (drawout style, 600 Amp Frame and larger) the circuit breaker must be overhauled and a new protection device (must be a GE Entelliguard Trip unit) shall be provided through one of MIT’s approved vendors. Trip functions and settings shall be determined by the engineer of record. Test reports shall be provided prior to shipment from the factory. Coordination settings must be provided to MIT and approved before this circuit breaker will be permitted to carry load current. Approved circuit breaker overhaul and conversion kit installing vendors: EXSTAR & EESCO.

2. An alternative is to have a contractor provide a new retrofit drawout circuit breaker to take the place of the original drawout circuit breaker. This not only replaces the circuit breaker, but it also give MIT a new means for racking in and out. Acceptable manufacturers are Square D/Schnieder Electric, General Electric, Eaton/Cutler Hammer. We have several examples installed across the campus already.

Buildings with Electrical Services provided by the Public Utility:

3. Determination of electrical service shall be decided by MIT Utilities.

4. Service from the electrical public utility shall be provided with transformers determined by MIT Utilities. The service from the transformer is to be brought to distribution switchgear meeting the requirements of the switchgear section for double-ended and single-ended substations.

5. Auto-Power factor correction and transient voltage surge protection on the service shall be provided.

6. The design and layout of the electrical room shall meet the requirements as listed under double-ended and single-ended substations section.
3.5 Emergency and Standby Systems

Generators and main emergency equipment shall be above the 26 foot City of Cambridge Datum point.

Engine-generator sets shall have the following construction:

1. All engine-generators shall be diesel powered.
2. Generator shall be manufactured by: Caterpillar or Cummins.

The following shall be powered from the emergency generator as a minimum and where applicable:

1. Elevators.
2. Life safety system including emergency lighting, exit signage and fire alarm system.
3. Fire pumps.
4. Smoke exhaust fans.
5. Critical research exhaust systems.
6. Critical research and systems.
7. Sump pumps.
8. Sewage ejection pumps.
9. IT network, Tel/Data closets.
10. BMS controlled servers.
11. MIT Security and parking control devices.

Generator sets shall meet the requirements of Massachusetts Electrical Code, NFPA 110 and NFPA 99 (where applicable).

Generator sets shall be rated continuous standby.

On application of any load up to the rated load, the instantaneous voltage dip shall not exceed 20% and recover to + or −2% of rated voltage within one second. Except fire pump 15% dip max per NFPA 20.

The generator shall be capable of sustaining at least 250% of rated current for at least 10 seconds under 3 phase symmetrical short circuit.

The voltage regulator shall be isolated from the load to prevent tracking SCR loads.

The engine shall be furnished with the following accessories:

1. Full flow, bypass spin on oil filters.
2. Oil drain valve and extension.
3. Dry type replaceable air cleaner element and restriction indicator.
4. Spin on fuel filters and strainers and a manual fuel primer pump.
5. Racor fuel strainer/water separators installed in the fuel supply line before engine fuel pump.
6. Cooling system filled with manufacturer recommended percentage of antifreeze and distilled water and coolant additive.
7. Tank type, circulating jacket water heaters to maintain engine at a constant 90°F to 120°F with oil pressure disconnect switches, ball valves on inlets and outlets and steel braided reinforced hoses with threaded connectors.
8. Manifold, turbo and flex insulation blankets.
9. 8D style lead-acid, non-maintenance free batteries with automotive posts sufficient to provide two complete sets of three crank/rest cycles of 15 seconds, 75 seconds total, each at 40°F with at least two year life cycle.
10. Battery conductor total resistance not exceeding .002 ohms including negative and positive leads.
11. A free standing battery rack.
12. Isochronous electronic speed control.
13. 78 ampere minimum battery charging alternator with solid-state voltage regulation.
14. One spare set of hoses, filters, belts, fuses, thermostats and gaskets
15. Two complete Overhaul Literature Kits.
17. A float battery charger shall be provided capable of returning the batteries if fully discharged to 100% of their ampere-hour rating within 24 hours. The charger should have the following features: crank disconnect relay, manual or automatic equalize timer, adjustable charger settings, AC line compensation, automatic overload protection, fused DC output, fuse or breaker protected AC input, automatic DC regulation, and surge suppressor. It shall have a DC ammeter, DC voltmeter, low voltage alarm, high voltage alarm, power failure alarm, summary failure alarm, voltage and High DC voltage. Battery charger wiring shall be permanently connected.
18. The output circuit breaker on the Engine-Generator Set and circuit breakers in series shall be provided with auxiliary contacts to monitor circuit breaker position remotely as a supervisory alarm monitored by the local BMS system and alarmed to MIT Central Operations Center. This function shall be fully tested during on-site start-up and Commissioning.

Engine exhaust silencer shall be critical attenuation grade, aluminized steel double wall construction equal to EM Products (JCS05-1260 with #150 ASA carbon steel flange inlet and outlet connections). Low point drain with MPT threaded end and standard high temperature (1200°F) finish shall be factory furnished. Silencer shall also be furnished with 300 series 4” diameter stainless steel braided flexible pipe connector having temperature and pressure rating to suit for connecting exhaust pipe to engine, 12 inch minimum length with #150 ASA carbon steel flange end connections.
A double wall (secondary containment) steel fuel tank (sub-base if possible) shall be factory furnished integral to each diesel generator. Capacity of the fuel tanks shall be not less than 12 hours but not more than 36 hours with the set operating at full load.

The fuel tank shall be equipped with a removable plate with gasket for inspection and periodic maintenance with a minimum of the following fittings: engine fuel supply, engine fuel return, vent, emergency vent, fuel inlet and fuel drain. A fuel level gauge and low fuel level alarm shall be factory furnished. Piping shall be entirely black iron. Pipe sealant shall be recommended for fuel oil systems and not Teflon based. Indicating type valves shall be installed on both the supply and return lines prior to the flexible lines to the engine. A battery powered normally closed electric fuel solenoid valve and a check valve shall be factory provided on the engine supply line. Manual bypasses shall be installed for all fuel solenoid valves.

Provide fuel filter. Fuel filter shall be removable, full flow bypass spin-on, cartridge type with head piece having provisions for piping connections. The filtering media shall surround a perforated steel center tube backed by a coiled steel support spring to seal the gasketed end face of the throwaway filter element against the head piece.

Provide 50% load bank.

Submittal shall include prototype test certification and specification sheets showing all standard and optional accessories to be supplied, schematic wiring diagrams, dimension drawings, and interconnection diagrams identifying, by terminal number, each required interconnection between the generator set, the transfer switch, and the remote annunciation panel. Also provided are the following drawings and instructions:

1. Bill of material and catalog cuts on each separate piece of equipment.
2. Engine generator setting plan.
3. Wiring schematics for engine control.
4. Generator control panel arrangement and wiring schematics.
5. Lubricating oil specifications.
7. Remote alarm annunciator arrangement and wiring schematics.

The manufacturer shall warrant the emergency generator system for 2 years or 2,000 hours, whichever occurs first, from the date of the site start-up. The local manufacturers’ representative shall provide the first complete annual service per the written maintenance recommendations for the unit at no additional charge in the twelfth month following the date of the startup. Facilities maintenance staff shall be present during the service.

Factory Witness Tests:

1. Provide standard factory tests in accordance with NEMA standards and NFPA standard
110. Check and set all instruments and safety devices. Provide following tests:

a. Generator set test under rated load and power factor for 8 hours for performance and proper functioning of control and interacting circuits.
b. Testing at unity power factor only (resistance banks only) is not acceptable, since KW output is affected by the higher generator efficiency at unity power factor, and the KVAR for motor starting and regulation is not able to be correlated between unity and rated power factor.
c. Fuel Consumption: The Owner shall be notified at least 4 weeks in advance of these tests and shall have the option of witnessing these tests owner cost for air travel, hotel, and meals shall be included in specification. Certified copies of these test results shall be forwarded to the Owner for review.

Site Tests:

1. An installation check, start-up and building load test shall be performed by the manufacturer’s local representative in precise accordance with the acceptance testing procedure outlined in NFPA 110 para. 5-13. Facilities maintenance staff shall be notified of the time and date of the site test and shall be present. The tests shall include:

a. Fuel, lubricating oil and antifreeze shall be checked for conformity to the manufacturer’s recommendations, under the environmental conditions present and expected.
b. Field leveling of generator skid shall be done prior to acceptance testing.
c. Accessories that normally function while the set is standing by shall be tested prior to cranking the engine, including block heaters, battery charger, generator strip heaters, remote annunciation, etc.
d. Check start-up under test mode for exhaust leaks, path of exhaust gases outside the building, cooling air flow, movement during starting and stopping, vibration during running, normal and emergency line-to-line voltage and phase rotation.
e. Test automatic start-up by means of simulated power outage for remote-automatic starting, transfer of the load and automatic shutdown. Prior to this test, all transfer switch timers shall be adjusted for proper system coordination. Engine coolant temperature, air temperature, oil pressure and battery charge level along with generator kilowatts, voltage, amperes and frequency shall be monitored at 20 minute intervals during the eight hour test. An external load bank shall be connected to the system if sufficient building load is unavailable to load the generator to the nameplate kW rating.
f. Test all alarm shutdown circuits by simulating fault or failure conditions.

Provide sound attenuated walk-in enclosure. The enclosure shall be manufactured by Pritchard Brown or Robinson. The enclosure attenuation shall be 25 db at 6 feet minimum.
Automatic transfer switches shall be provided with isolation/bypass switches and shall be manufactured by Russelectric.

In engine/generator rooms, battery-pack wall emergency lighting units shall be provided with lighting fixtures directed at the automatic transfer switch and at the generator control panel.

Dampers and louvers shall fail open. Gravity type louvers shall not be used. The manufacturers recommended maximum static air inlet and outlet pressures shall not be exceeded. Ventilation shall be sufficient to maintain an engine room temperature of not more than 110 deg. F on a 95 deg. F ambient day when measured at any point at least 18 inches from the engine when operating at a sustained 100% load.

The room floor shall be coated with an industrial floor sealant and the walls sealed and painted.

There shall be 30 foot-candles of lighting to all sides of the generator when measured at the floor level.

Heating shall be provided to maintain the generator room at a minimum of 50 deg F. Provide low-temperature alarm set to alarm at below 40 deg F.

An electrical distribution panel containing all of the circuit breakers for all electrical equipment in the generator room (include battery charger, block heaters and lighting) shall be located in or adjacent to the generator room.

A freestanding or wall mounted cabinet shall be provided in the room containing spare parts, service equipment and operation manuals.

A minimum of two 120VAC electrical outlets connected to the emergency power system shall be installed within the generator room.

### 3.6 Distribution Panelboards

Construction of distribution panelboards shall be as follows:

1. Provide door in door.
2. Breakers shall be bolt-in except Square D breakers shall be plug-in.
3. Main breaker shall be provided without ground fault
4. All panels shall be three phase 4-wire, with copper bus and copper neutral and ground bar.

Distribution panelboards shall be located in dedicated rooms and closets.

Feeder circuits to panels shall supply power to only one panel.

Provide with Square D PM 800 meter integral with communication card to distribution panel.
Provide TVSS/SPD integral to the panel. Designers shall account for the circuit breaker required for the TVSS/SPD.

### 3.7 Power and Lighting Panelboards

Construction of power and lighting panelboards shall be as follows:

1. Provide door-in-door type construction.
2. Buses shall be copper including 3 phases, neutral and ground bar.
3. Every panel is to have a main breaker.
4. A separate ground bus shall be provided.
5. A neutral terminal strip shall be provided on each side of the panel.
6. Power panels shall have 200% neutrals.
7. Double tub panel construction is acceptable.
8. Panels shall be 42 pole or 84 pole capacity.
9. As a minimum 20% spare breakers are to be provided.
10. In general, breakers shall not be less than 20 amperes.
11. Breakers shall be bolt-on type.
12. Minibreakers are not allowed.
13. Single pole breakers with handle ties or bails shall not be used in lieu of multipole breakers.

Panelboards are to be located in dedicated rooms and closets. Provide additional space on walls for at least one future panel.

Recessed panels are to have two spare two-inch conduits with pull strings run from the panel to accessible ceiling for future use by MIT. Spare conduits shall terminate in a pull can minimum 6 inch high by 30 inch wide by 30 inch deep.

In new installations there shall be separate power panels and lighting panels.

Neutrals shall not be shared. Each single phase circuit is to have its own neutral.

The feeder cable to a 200% neutral panel shall have a 200% neutral. Transformers – 600 Volts and below.

### 3.8 Transformers

Windings on transformers shall be copper.

No oil-filled transformers.

Insulation system shall be 220C class. Maximum core temperature rise shall be 80C.
3.9 Motors

Coordinate with mechanical engineer to provide high efficiency inverter duty motors appropriate for use and location with consideration of utilization factors as approved by MIT.

Motors driven by VFDs shall be equipped with motor shaft grounding rings at both ends.

3.10 Variable Frequency Drives

Variable frequency drives shall have the following features:

1. Provide MTE matrix harmonic filter with 6 pulse variable frequency drives.
2. Maintenance bypass if required by the mechanical engineer.
3. No limitation on distance between the drive and the motor. Additionally, the motor to be used with the drive shall be an inverter duty motor, not a special drive motor.

3% load reactor.

The drive enclosure is to be NEMA 12.

All drives shall have a lockable disconnect with gasket.

Door-in-door construction with separate incoming power lugs and connections from terminal strips and relays. Side car/hip box construction not allowed.

3.11 Raceways

3/4 inch minimum conduits are required.

EMT shall be provided with steel fittings or Rigid Steel Conduit with threaded fittings for interior. Die-cast fittings are not acceptable.

Outdoor circuits and feeders shall be installed in Rigid Steel Conduit with threaded fittings.

NEMA 4X shall be provided for outdoor pull boxes and electrical equipment.

No conduit is to be embedded in basement floor slabs. Conduit is to be surface mounted.

All surface raceway systems shall be manufactured by Wiremold, Carlon or Hubbell. The use of Wiremold ISO Duct Surface Raceway is prohibited. In general, Wiremold 3000, 4000 and 6000 is preferred (Hubbell and Carlon equivalent are acceptable). Non-metallic surface raceway may be used in special applications.

In laboratories, conduits shall be used between the panelboards and the surface mounted raceways.
Underground branch circuit raceways are to be schedule 40 PVC. Concrete encase with minimum of 3 inches of cover all around. Direct burial of conductors is not allowed.

MC cable is acceptable only for concealed spaces, above ceilings, fishing within walls, and for final connections where not subject to physical damage.

Access shall be provided by the construction team for all junction boxes, pull boxes and splices boxes or where wiring needs to be maintained.

### 3.12 Receptacles and Switches

For requirements for branch circuits, see Power Panelboards and Lighting Panelboards.

For requirements for lighting fixture switching, see Lighting.

Devices are to be specification grade.

Devices shall be rated 20 amperes.

Device plates are to be brushed stainless steel.

All switches shall be rated for 277 volt rated.

Receptacle plans shall be reviewed with the end user and MIT project manager to insure proper coverage for the areas being constructed.

There shall be a maximum of four (4) receptacles per single-phase power circuit.

Receptacles located in hallways and corridors shall be on their own branch circuit and shall not be powered from room branch circuits.

Rooftop receptacles shall be on dedicated branch circuits and not be powered from room branch circuits. Each rooftop receptacle shall be a GFI receptacle and weatherproof with in-use cast covers (plastic not acceptable).

Receptacles shall be provided on roofs with weatherproof cast in-use covers with maximum spacing of 40 feet or as required by Massachusetts Electric Code.

Receptacle plans shall be reviewed with the end user and MIT project manager to insure proper coverage for the areas being constructed.

Each electrical closet shall be provide with (1) receptacle on emergency power.
3.13 600 Volt Cable

All cables shall have copper conductors.

All conductors are to be stranded. Solid conductors shall not be used.

THHN/THWN conductors shall be provided. Insulation to be 90˚C rated with connectors sized for 75˚C ampacity use (90˚C ampacity rating of a conductor is not to be used).

XHHW and RHW cable shall be used for outdoor underground lighting and power installations.

Minimum conductor size to be #12 AWG.

MI cable shall be used for all emergency and legally required standby loads.

No splices shall be allowed for feeders. Feeders shall run continuous from source switchgear\switchboard to load distribution equipment.

MC cable with overall steel armor is acceptable only for concealed spaces, above ceilings, fishing within walls, and for final connections where not subject to physical damage.

3.14 Metering

All new building construction or renovation projects require provisions for the installation of meters and field devices necessary for real-time remote collection of utility data. Direct access to meters for calibration is required.

Solid state micro-processor based Electric Meter shall be installed on unit substation main breaker. The meter shall have an RS232 communication port and a RS485 communication port with OPEN Modus protocol. If new switchgear is being installed, the meter installed in front of the main breaker shall be revenue grade. All breakers in the switchgear shall have Modbus communications included and factory wired.

The MEP design engineering team for the project must prepare a single line metering diagram depicting in detail all equipment, conduit, wiring, (power and network communication) junction boxes, network connections and any other devices necessary for a complete metering system to support the scope of the project. This drawing must clearly define and depict each individual trade’s responsibility and point of connection. The clear assignment of responsibility by trade is critical to proper execution of the metering scope. MIT will collaborate with the MEP team to assist in the development of this diagram to suit the required scope within the arrangement of the building. The diagram must depict the actual path of wiring between devices including the room numbers.
4. LIGHTING STANDARDS

4.1 Lighting General Requirements

As a minimum, all buildings must be designed to The Illuminating Engineering Society of North America (IESNA) lighting level design guidelines outlined in the IESNA Lighting Handbook 10th Edition.

“For additional information on specific requirements for lecture halls and classrooms see Thematic Folder “Classroom Lecture Hall Renovation New Construction Guidelines”

MIT lighting level requirements are:

- Classroom – 30fc maximum avg horizontal on working surface
- Office – 30fc maximum avg horizontal on working surface
- Laboratory – 50fc maximum avg horizontal on working surface
- Corridors – 5-10fc maximum avg horizontal at floor
- Lobbies – 10fc maximum avg horizontal at floor
- Stairwells – 10fc maximum avg horizontal at floor
- Exterior Pathway and Parking – 1fc avg horizontal at grade level

All interior lighting shall have a minimum Color Rendering Index (CRI) of 82.

All interior lighting shall be 3500K color and all exterior lighting shall be 3000K color.

Provide emergency lighting in electrical switchgear rooms, engine-generator rooms, electrical, mechanical, tel\data closets, office and laboratory suites, and toilet rooms.

For lighting connected load power densities, MIT's indoor lighting power density goal is 0.7 w/sf, maximum.

The design team shall prepare and present to MIT for review photometric plots for all spaces no later than the design development phase. The team shall review for compliance to standards prior to submitting to MIT for review.

LED lighting fixture manufacturers shall provide MIT with at least a 5 year warranty or greater, a minimum (CRI of 80); and a color temperature of 3500K. Exterior LED color temperature shall be 3000K.

Drivers shall be Lutron Hi-Lume, where available from lighting manufacturer.

Light fixtures shall be placed where they will be able to be maintained without special equipment to access them.
Provide Electric Battery Units in the tel/data rooms and closets.

4.2 Lighting Controls

Auto-Off, Manual-On vacancy sensors shall be utilized in all non–corridor, non-circulation, non-toilet room, non-laboratory spaces. Sensors shall be set to 15 minute timeouts. These are to be coupled with momentary wall mounted lighting switches. These spaces shall also be provided with dimming controls.

Auto-Off, Auto-On occupancy sensors shall be utilized in laboratories unless the laboratory use requires the lighting to be turned off while the room is occupied in which case Auto-Off, Manual-On vacancy sensors shall be used. Sensors shall be set to 30 minute timeouts. These are to be coupled with momentary wall mounted lighting switches.

Auto-Off, Auto-On occupancy sensors shall be used in all open office areas, corridors, stairwells, lobbies, circulation spaces, and toilet rooms to control Normal power lighting fixtures in these spaces. Sensors shall be set to 15 minute timeouts. Stairwell lighting fixtures may use integral motion sensors and must dim as opposed to turning off. Emergency power lighting fixtures in all corridors, lobbies, circulation spaces, and toilet rooms shall remain uncontrolled.

Daylight sensors shall be installed to provide daylight dimming in all applicable areas. Lighting fixtures coupled with daylight sensors must dim up and down as opposed to turning off and on.

All sensors shall be either Lutron wireless ceiling/wall mounted passive infrared sensors, Lutron wired ceiling/wall mounted dual technology passive infrared and microphonic sensors, or Sensor Switch ceiling/wall mounted dual technology passive infrared and microphonic sensors. Lutron is the preferred manufacturer of these sensors.

All local room level personal dimming controls must be Lutron or Sensor Switch. Lutron is the preferred manufacturer of these local room level personal dimming controls.

All network lighting controls systems must be Lutron or Crestron. Lutron is the preferred manufacturer of these network lighting control systems.

Astronomical timer switch control shall be used to control exterior lighting. Provide a minimum 3 year battery to maintain program memory during a planned or unplanned power outage. The Astronomical timer switches shall be Intermatic ET800 series.

All alternative lighting control strategies must be approved by MIT Systems Engineering Group (FEG) in writing. By completion of design development design stage.
The design development drawings shall provide a narrative or sequence of operation for each space. The narrative shall require the electrical contractor to install, setup, test and adjust the controls to meet the performance intended.

4.3 Lighting Fixtures

The MIT Main Group Building corridor lighting fixtures shall be pendent mounted Nulite Y-MIT-13001 SERIES fixtures mounted perpendicular to the corridor and located approximately every 16 feet on centers. For significant Main Group Buildings lobby, circulation, and corridors, the Visa Midland Crafts round light fixture shall be installed. For Main Group Buildings stairwell lighting fixtures, the pendent mounted XAL Stilo 60 fixture shall be installed.

Pedestrian walkway pole lighting fixtures shall be the Bega 7186 LED pole lighting fixture. Roadway and parking areas pole lighting fixtures shall be the Bega 9499 LED pole lighting fixture. Another approved pole lighting fixture for larger outdoor spaces is the BEGA 8309 LED pole lighting fixture.

All lighting fixtures must be manufactured by an approved major manufacturer and/or be represented by an approved local lighting manufacturer product representative. Approved lighting manufacturer product representative companies are Omnilite, Reflex Lighting, Boston Light Source, and Yusen/Illuminate. Approved major lighting fixture manufacturers are Axis, Finelite, Bega, Signtex, Philips, Hubbell, Eaton, and Acuity.

All LED tubes shall be Type C, LED tubes and remote LED driver. Type A and Type B LED tubes, LED tubes with an integral driver and LED tubes powered by fluorescent ballasts, are not allowed.

All exterior wall pack lighting fixtures must be full cut-off wall packs. Integral motion sensors which dim the lighting fixture to 50% power consumption are acceptable. Sensors shall be set to 15 minute timeouts. Approved fixture for this use are Philips Gardco or Bega equivalent.

Preferred lighting fixtures/technologies are:

- Finelite HPR recessed/surface mounted 1’x4’, 2’x2’, and 2’x4’ lighting fixtures.
- Lutron LED drivers.
- Philips Gardco 121 LED Wall Pack with integral motion sensor.
- Osram Sylvania fluorescent lamp and ballast combinations.
- Philips or Lunera LED Type C tube and remote driver combinations.

Refer to Appendix C List of Products for additional information.
All alternative lighting fixtures/technologies must be approved by MIT Systems Engineering Group (FEG) in writing.

4.1 Exit Signs

All new interior exit signs shall be Sington CRS series, LED edge lit exit sign. Provide all exit signs with mirrored rack or core.

For new exit signs in industrial or back of house spaces, provide the McPhilben Chloride Series, LED edge lit exit sign.
# APPENDIX A: LIST OF PRODUCTS

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APPENDIX B: POWER SYSTEM STUDY - SAMPLE SPECIFICATION

POWER SYSTEM STUDY

PART 1 - GENERAL

1.01 WORK INCLUDED

A. A Short Circuit Study, Protective Device Evaluation Study, and Protective Device Coordination study shall be performed, stamped and signed by a Professional Engineer registered in the Commonwealth of Massachusetts engaged to carry out such studies by the distribution equipment manufacturer. The cost of this study shall be included in the bid of the Electrical Sub-Contractor.

B. The studies shall be submitted to the Architect for review with the distribution equipment shop drawings and shall under no circumstance be submitted after the final release of equipment for manufacture.

C. The studies shall include all portions of the electrical distribution system including any equipment pre-purchased by the owner and installed by the Electrical Contractor, as well as the next 13.8kV primary upstream over-current protection device and all downstream devices in the building including all normal and emergency sources of power and motor loads within the building.

D. The Electrical Subcontractor shall be responsible for coordinating the execution of these studies in a timely manner and shall be responsible for supplying all required data in preparation for the study.

E. The studies shall be performed with SKM Power Tools software and shall be in accordance with the latest applicable IEEE and ANSI standards.

F. The report shall include, but not be limited to a statement of calculation methods and assumptions, the base per unit quantities selected, one-line diagrams, source impedance data, calculations, tabulations, results, conclusions and recommendations.

G. Provide Time-current curves graphically indicating proposed coordination for the system. With each curve, provide a detailed description of particular devices
identifying manufacturer, type, function, and time-current characteristics. Provide associated partial one-line diagram and tabulate recommended device tap, time dial, pickup, instantaneous, and time delay settings.

H. Include all adjustable settings for ground fault and recommendations for settings and delays for these devices.

I. Include phase and ground coordination of the engine-generator devices. Show the generator decrement curve and damage curve along with the operating characteristics of the protective devices. Obtain the required information from the generator manufacturer and include the generator actual impedance values, time constants, and current boost data in the study. Do not use typical values for the generator.

J. The Electrical Sub-Contractor shall make all the final adjustments to overcurrent devices as recommended in the study. The Electrical Sub-Contractor shall prepare and install all Arc Flash labels in accordance with the results of the Power System Study.

1.02 STUDY REPORT

A. The results of the power study report shall be summarized in a final report. Six (6) bound copies of the final report shall be submitted to the Architect and MIT Senior Electrical Engineer for review.

B. The report shall contain the following sections and documents:

1. Descriptions, purpose, basis and scope of the study.

2. Tabulations of circuit breakers, fuses and other protective device ratings versus calculated short circuit duties, and commentary regarding same.

3. Protective device time versus current coordination curves, tabulations of relay and circuit breaker trip settings, fuse selections, fuse selection and commentary regarding same.

4. A table listing all settable /adjustable devices with the values they are set to and the date the work was completed by the Electrical Sub-Contractor.

5. Fault current calculations including a definition of terms and guide for interpretation of computer printout.

6. Provide (2) compact disk copies of entire SKM model file including device library, system one-line diagram, impedance diagrams, available short circuit currents, coordination curves for each section of the distribution system, arc flash
energies and boundaries at each piece of electrical equipment, and the recommended coordination settings for each piece of adjustable electrical equipment in the distribution system.

7. Provide (2) 24” x 48” copies of the entire electrical distribution system riser diagram in both SKM format as well as in the original Autocad Building Electrical System Power One-Line Diagram Format showing SKM values for available short circuit current and available Arc Flash energy at each bus within the distribution system.

PART 2 - PRODUCTS

2.01 TESTING MATERIALS

A. Include all material, equipment and devices necessary for testing to demonstrate satisfactory performance and compliance with specifications.

PART 3 - TESTING

3.01 TESTING

A. Before an application for final acceptance of the work will be considered, all tests deemed necessary by the Architect to show proper execution of the work shall have been performed and completed in the presence of an Architect's representative. Scheduling of all testing procedures shall be arranged to suit the convenience of the Architect. The Owner shall be notified two working minimum days prior to any acceptance testing.

B. In particular, testing of the emergency power system shall be provided complete in accordance with all of the requirements specified in Section 5-13, "Installation Acceptance" of NFPA 110, "Standard for Emergency and Standby Power Systems."

C. The electrical work shall include the provision of any assistance (such as removal of panelboard trims and junction and pull box covers) deemed necessary by the Architect to demonstrate compliance with the requirements of the drawings and specifications.

D. Where electricity utilizing equipment, supplied separate from the electric work, is energized, controlled or otherwise made operative by electric work wiring systems, the testing to provide the proper functional performance of such wiring systems shall be conducted by the trade responsible for the equipment. The electrical work shall, however, include cooperation in such testing and the
making available of any necessary electrical testing equipment. Also, testing shall be included in the electric work to show the proper functioning of lighting fixtures regardless of who furnishes them.

E. Electrical Acceptance Tests and Inspections: Furnish the Architect and the Owner with certificates or reports of testing and inspection of electrical systems by an independent testing company. Certificates or reports shall indicate approval of authority having jurisdiction and conformance to specifications.

END OF DOCUMENT
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ATTACHMENTS: Tel/Data Design Layout Drawings
1. **MIT IS&T INFRASTRUCTURE COMMUNICATION SYSTEM GOALS**

Information Systems and Technology (IS&T) is MIT's central IT organization, tasked with supporting MIT's core mission: "...to advance knowledge and educate students in science, technology, and other areas of scholarship that will best serve the nation and the world in the 21st century."

The organization's role is to provide modern, efficient, and cost-effective IT services to the entire MIT community. IS&T provides the technical infrastructure, services, and support to enable the diverse work that takes place at MIT, from high speed networks and state-of-the-art data centers supporting faculty research collaboration, to academic software packages and teaching systems used by MIT's over 10,000 undergraduate and graduate students. Through partnerships with other academic and administrative units, IS&T strives to continuously improve the Institute, streamlining business processes and lowering administrative costs wherever possible.

MIT's IT environment is large and diverse. The main campus network (MITnet) provides wired and wireless network services to all campus buildings, and consists of over 4,000 network switches and 6,200 wireless access points, connected by more than 7,200 miles of single-mode fiber optic cable. In addition to MIT's local network infrastructure, the Institute operates a 2,500-mile fiber optic regional network, connecting MIT's campus in Boston to New York City and over ten other locations. MIT partners with multiple commercial Internet service providers to provide robust and highly available commodity internet connectivity; in addition, MIT's network connectivity enables dedicated high-speed connections to many science and research networks: Internet 2, the National Lambda Rail, the Energy Sciences Network (ESNet), and the Large Hadron Collider network. In 2016, over 80,000 unique devices connect to MITnet every day!

In addition to end-user computing, MITnet also supports a large data center environment. IS&T operates 6 data centers supporting a wide array of academic, administrative, and research applications: email, web publishing, learning management, academic records, financial data, and many others. These applications are supported by over 2000 virtual servers backed by more than 1 petabyte of disk storage. An additional 3 petabytes of near-line backup capacity provides disaster recovery service for all data center systems and more than 5000 MIT community desktops and laptops.

Email is the lifeblood of most modern enterprises, and MIT is no exception: IS&T's email system sees a total of 1.6M inbound emails per day! Of these, roughly two-thirds (1.1 million) are spam, with the remainder (500,000) being legitimate. The MIT community sends an additional
approximately 700,000 messages per day; roughly 450,000 of these are MIT-internal, which the remainder being sent outside of MIT.

Supporting all of this is MIT’s IT helpdesk. Available to any member of the MIT community, the help desk call center answers over 40,000 support calls per year, and replies to an additional 45,000 support inquiries via email. IS&T also provides optional desk side support to many departments, and employs MIT students to provide residential computing and networking support in MIT’s dormitories, fraternities, sororities, and independent living groups.

To learn more about the organization, please visit: http://ist.mit.edu.

2. PURPOSE

2.1 Overview

MIT Information Systems & Technology has developed this document to establish a uniform standard for IS&T infrastructure, services, and support systems criteria that is required for building IT infrastructure Tel/Data Rooms (TR)’s and pathway systems at MIT. The purpose of the IS&T Standards is to ensure that secure, appropriately sized, environmentally controlled, and sustainable TR’s and pathway systems are built consistently for structured cabling, network, and technology systems deployed and operated by IS&T at MIT. Each environment will have its own unique requirements based on these standards, local codes and regulations.

MIT IS&T will provide design guidance for these systems, and the designer shall coordinate the implementation with MIT IS&T.

2.2 Terminology

There are a number of names and acronyms used to describe Tel/Data Rooms, also referred to as Telecommunication Rooms, (TR) including: Main Distribution Frame (MDF), Building Distribution Frame (BDF), Intermediate Distribution Frame (IDF), Tele/Data Closet, Equipment Rooms (ER), etc. The purpose of this document is to focus on two types of telecommunication rooms, the BDF and IDF. IS&T reserves the use of the MDF or Data Center to spaces that support multiple services, campus buildings, or the entire Campus. Telecommunication rooms (TR) provide environmentally suitable and secure spaces for installing cables, network switching equipment, associated hardware, racks and wall mounted technology equipment. Abbreviations throughout this document and related standards include:

1. BDF: Building Distribution Frame.
2. EF: Entrance Facility.
3. ER: Equipment Room.
4. HC (FD): Horizontal Cross-Connect (Floor Distributor).
5. IDF: Intermediate Distribution Frame.
2.3 Application

Each new building or addition to an existing building should include consistent spaces designated for the location of networking and technology equipment, incorporated into project documents by architects and engineers in accordance with design criteria herein. Such spaces must be specifically considered in the Program Statement phase or similar planning or planning processes used to define the scope of a project. Consideration for structured cabling pathways should also be included in project planning and documentation processes. The sizing guidelines set forth in the latest version of the BICSI Telecommunications Distribution Methods Manual (TDMM), should be adhered to when sizing TR’s. If deviations are required from the guidelines set forth in the latest version of the BICSI TDM Manual, the minimum requirements stated in this document should be followed when reviewing the needed TR and pathway infrastructure requirements for projects. If there are discrepancies in the existing building environment or areas of planning that cannot be accommodated with the designs as described or shown in the BICSI TDM Manual, then the design team must review and coordinate all exceptions with IS&T.

Refer to individual thematic folders for more information on particular equipment, for example Classrooms and Lecture Halls.

3. DESIGN CRITERIA FOR BUILDING DISTRIBUTION FRAMES (BDF)

The BDF is the main Technology Room for each building and will support the termination of backbone and campus cabling and house centralized communications equipment supporting the entire building. In addition to the BDF, a separate Entrance Facility (EF) should be built for connections to the campus outside plant (OSP) optical fiber and data network backbone and should be able to support two physically separate points of entry, and the outside plant (OSP) copper cabling backbone. This means that a building shall have two separate Entrance Facilities connecting to the BDF to allow for redundancy of connection to the campus system. Splitting the feed after the Entrance Facility point is not acceptable.

1. Entrance Facility (EF): Built for connections to the campus outside plant (OSP) optical fiber and data network backbone, and the outside plant (OSP) copper cabling backbone. Access should be controlled through a secured door with an IS&T specific key core and card access.
The BDF may also support other building information systems such as security in Division 28, Building Management Systems (BMS) in Divisions 23 and 25, and other building signaling systems in coordination with IS&T. In most cases the BDF will also support the function of one or more Intermediate Distribution Frames (IDF) supporting the connection points between backbones and horizontal cabling infrastructure.

3.1 BDF Room and Location Physical Requirements

BDF Room Size:

1. The minimum space allocated to the BDF shall be 153 square feet with a minimum dimension of 17 feet in one direction. Any deviation from this standard must be reviewed and approved by IS&T.

2. Refer to the appendix for drawings of typical BDF room layouts.

BDF Room Location:

1. The BDF, including if also serving as an IDF, requires a centralized location no further than 295 feet in cable length from the furthest communication outlet. Vertical rise shall be included in the length calculation. Architects shall include at least one floor-to-floor height with overall linear separation when evaluating BDF locations. BDFs shall be located off of a main corridor with doors that open into the corridor. Ideally, BDFs will be stacked directly under IDFs to support the vertical distribution of services between rooms.

2. Do not locate BDFs in any place that may be subject to water infiltration, steam infiltration, humidity from nearby water or steam, heat (e.g., direct sunlight) or any other corrosive atmospheric or adverse environmental conditions.

3. Locate BDFs above any threat of flooding. Avoid locations that are below elevation of 'plus 26.0 feet' referenced to the Cambridge base. BDF should not be located below grade and may need to start as high as the 2nd or 3rd level. Avoid BDF locations that are below or adjacent to areas of potential water hazard (e.g., restrooms and kitchens).

4. Locate BDFs far enough away from sources of Electromagnetic Interference (EMI) to reduce interference with network and telecommunications cabling, including EMI from electrical power supply transformers, motors, generators, and induction heating devices. Because BDFs are frequently occupied by technicians and sensitive electronic equipment, the room location should not be adjacent to sources of constant, excessive, low or high frequency noise, such as air-handling equipment, pumps, generators, etc.

BDF Room Use:

1. Room occupancy class, including requirements for cooling, power, and expected availability shall comply with ANSI/TIA-942 Telecommunications Infrastructure Standard for Data Centers defined levels (tiers) for each space. Tier levels may vary for BDFs depending on room contents. Coordinate with IS&T as required.
2. The BDF shall be dedicated solely to technology and related facilities including voice, data, wireless, security, access control, building management system, and cellular distributed antenna systems indicated in project engineering narratives and contract documents.

3. Equipment that does not support the BDF (e.g., pipes, duct work, distribution of building power) shall not be located in or pass through the BDF. While strongly discouraged, in cases where alternatives are punitive to the project’s overall interests, electrical conduits and non-liquid plumbing piping only may pass through an BDF provided that they are located no lower than any other overhead obstruction in the room and that there are no pull boxes, valves or other devices that require access by staff other than IS&T. In the case where a conduit must pass through the BDF, written approval from IS&T is required before routing and final placement.

3.2 BDF Architectural Requirements

BDF Structural Requirements:

1. The floor rating under distributed loading must be greater than 4.8 kPa and the rating for concentrated loading must be greater than 8.8 kN in areas that will support network and telecommunications equipment such as batteries and UPS equipment. If access flooring is used in the BDF, it must be rated accordingly.

BDF Wall Requirements:

1. BDF walls shall extend from the finished floor to the structural ceiling (e.g., the slab).
2. BDFs should not have windows installed on any wall. Coordinate with IS&T where existing windows cannot be changed.
3. At least 8 feet of contiguous wall space shall be reserved for access control panels and security panels in the BDF.
4. Backboards: AC-grade fire rated plywood, 8 feet high with a minimum thickness of 3/4 inch around the perimeter of the room over drywall, painted on one side with MIT white. The bottom of the plywood shall be mounted 6 inches above finished floor.
5. Wall Base: Resilient base shall be 6 inches high typical.

BDF Connecting Sleeves and Slots:

1. Firestop Requirements: Comply with Division 07 “Firestopping”.

BDF Service Doors and Security:

1. Door Type: Hollow metal, minimum STC 35 with sound gaskets.
2. Minimum Size: 3 foot 6 inches wide and 80 inches tall.
3. Door sills and thresholds impede the movement of equipment, block ventilation, and are not recommended.
4. Doors that open outward provide additional usable space and reduce constraints on BDF layout.

5. BDF door hardware requires control against unauthorized access, typically a mechanical lock and key and IS&T card access. Doors shall include hinges with non-removable pins, single cylinder lockset with card access. Doors should remain open until manually closed. Automatic door closers shall not be used.

6. A security camera will be installed in each BDF. Comply with additional requirements in the security documents.

BDF Ceilings:

1. The minimum ceiling height is 8 feet 6 inches above the finished floor with ceiling protrusions (e.g., sprinkler heads) placed to assure a minimum clear height of 8 feet, clear of obstructions, to provide space over the equipment frames for cables and suspended ladder racks.

2. To permit maximum flexibility and accessibility of cabling pathways, ceilings are not allowed in BDFs.

3. Exposed ceilings with fireproofing or other non-smooth, potentially dust-collecting surfaces shall be reviewed with IS&T and may require enclosure.

4. Require exposed slabs above or concrete floors to be sealed and painted white to improve visibility and minimize dust.

BDF Floors:

1. Floor Finish: Static dissipative resilient flooring unless otherwise indicated, provide the following. Comply with additional requirements in Division 09 “Flooring”.
   a. Static Resistance: to ESD-S7.1 and ASTM F-150, Point to point and point to ground: $10^6$ to $10^9$ ohms.
   b. Static Generation: to ESD STM 97.2.
   c. Static Decay: Flooring in combination with ESD shoes and a person (5000 volts to zero): 0.5 seconds.

3.3 BDF Fire Suppression Requirements

Provide sprinkler heads in wire cages to prevent accidental operation. Coordinate the layout of fire protection systems with the equipment layout to avoid obstructing sprinklers, access to the alarm or other protective measures.

Comply with additional requirements in the local building code and Division 21 “Fire Suppression”.


3.4 BDF HVAC Requirements

Provide BDF with dedicated cooling equipment; e.g., a CRAC or fan coil unit that is dedicated to cooling the BDF and that is monitored by the Building Automation System (BAS). Comply with additional requirements in ANSI/TIA-942 and Divisions 23 “HVAC” and 25 “Integrated Automation”. Cooling shall not be from chilled water as this prohibits normal shutdown of the building chilled water system for repair, construction and maintenance. Cooling shall be local DX equipment rejecting heat to the ambient air.

The BAS should be configured to identify the room as being an IT room on the operator’s screen in the event of an alarm.

Technology equipment requires the HVAC system to function 24 hours per day, 365 days per year.

If a standby power source is available in the building, connect the HVAC system that serves the BDF to standby power.

The HVAC system that serves the BDF should be tuned to maintain a positive air pressure differential with respect to surrounding areas with a minimum of one air change per hour. Provide equipment to maintain the following acceptable ranges:

1. Temperature of 75 degrees F with no humidity control.

Estimated Heat Loads: ~ 5,000 to 7,500 BTU per equipment rack. Confirm heat loads with equipment to be deployed with the IS&T Project Manager as some equipment may generate more heat than others. Note: UPS and stand-alone air conditioning systems produce additional heat, if present.

3.5 BDF Electrical Requirements

Comply with additional requirements in Division 26 “Electrical”.

BDF Lighting:

1. Provide adequate and uniform lighting that provides a minimum equivalent of 50 foot-candles when measured 3 feet above the finished floor level.
2. Locate light fixtures a minimum of 8 feet 6 inches above finished floor level. Any variation should be coordinated with the IS&T Project Manager.
3. Locate light switches near the entrance to the BDF.
4. Coordinate lighting layout with the equipment rack layout, especially overhead ladder rack, to ensure that light is not obstructed. Preference is for lights over aisles rather than racks.
5. Power for the lighting should be separated from circuits that power technology equipment.
6. Provide non-heat generating LED lamps unless otherwise indicated.
BDF Equipment Power:

1. Provide individual branch circuits serving a single load from the feeder panel directly to a branch circuit receptacle (for cord- and plug-connected equipment), or equipment power terminal (for hardwired equipment).
2. Provide branch circuits for equipment power that are protected and wired for 120V, 20A. Confirm the need for 120V, 30A circuits with the IS&T Project Manager.
3. As a minimum, provide four 120V, 20A (NEMA 5-20R) dedicated circuits with one duplex receptacle per circuit per equipment rack.

BDF Convenience Power:

1. Provide separate duplex 120V, 20A convenience outlets (NEMA 5-20R) for tools, test sets, etc., located at least 18 inches above the finished floor, placed at approximately 6 foot intervals around perimeter walls and identified and marked “Convenience Power”.

BDF Dedicated Power Feed and Panel:

1. Provide BDFs with a power supply circuit that serves only the BDF and terminates in its own electrical panel within the BDF (see typical BDF drawings in Appendix B).
2. The feeders that supply the power for technology equipment in BDFs should be dedicated only to supplying that equipment and should be designed to facilitate future growth. More than one dedicated feeder may be required for large installations with a wide variety of technology equipment.
3. The dedicated power panels should be wired and capable of future generator support if the standby power support is not already installed for the building.

BDF Bonding and Grounding:

1. Provide a complete Grounding/Bonding system per EIA/TIA 607-B and current BICSI Grounding and Bonding standards.
2. Comply with additional requirements in Divisions 26 “Grounding and Bonding” and 27 “Grounding and Bonding for Communications Systems.”

BDF Conduit Sleeve Penetrations:

1. Provide horizontal and backbone conduit sleeves into the BDF for the distribution of the horizontal and backbone cable from the ladder rack. Provide vertical conduit sleeves from the BDF if stacked above to support the distribution of backbone cables. If the IDF’s are not stacked with the BDF, provide continuous conduit.
2. Conduit and conduit sleeves consist of a minimum of four 4 inch conduits/sleeves stubbed into the BDF extending 6 inches on both sides if sleeved. Additional conduits/sleeves may be required depending on the cable density.
3. All conduit and conduit sleeve counts shall be coordinated and approved by the IS&T Project Manager. Comply with additional requirements in Division 27 “Conduits and
Backboxes for Communications Systems”.

3.6 BDF Communications Requirements

Comply with additional requirements in Division 27 including “Communications Cable Management and Ladder Racks”, “Communications Cabinets, Racks, Frames and Enclosures”, and “Grounding and Bonding for Communications Systems”.

BDF Overhead Ladder Rack:

1. Provide overhead ladder rack within the BDFs to route cable to or from sleeves, risers, ducts, ladder racks to termination fields within equipment racks or mounted on walls. This overhead ladder system shall be contained within the confines of the BDF.
2. Overhead ladder rack encircling the TR will be minimum 18 inches wide; actual size should be calculated to accommodate the cabling within the room at its maximum density.
3. Overhead ladder rack crossing over the 19 inch equipment racks will be minimum 20 inches wide.

BDF Overhead Ladder Rack Materials and Applications:

1. BDF overhead ladder rack may be mounted horizontally or vertically on walls and over equipment racks.
2. Vertical ladder rack will be used to support riser cable from floor to ceiling as it passes between floors.
3. The overhead ladder rack system shall be mounted to walls, the top of equipment rack while leaving appropriate space for the proper tray fittings, or hung with threaded rods for bracing and support in compliance with seismic codes.

BDF Overhead Ladder Rack Bonding and Grounding:

1. In the BDFs, the overhead ladder rack system shall be bonded to the Telecommunications Grounding Busbar with 6AWG stranded copper wire per current BICSI Grounding/Bonding standards.

BDF Equipment Racks:

1. Provide 7 foot by 19 inch Equipment Racks in the BDF with vertical wire management.
2. All equipment racks should have two 10 inch vertical cable managers, one cable manager per side. This may change depending on cabling densities, but any deviation from this standard should be reviewed and approved by IS&T.

BDF Power Accessory Requirements:

1. Each equipment rack is to have a minimum of two vertically mounted Power Distribution
Units (PDU) at the rear of the rack.

2. Both PDUs will connect to the rack-mounted UPS systems; one UPS will be installed per dedicated 20amp circuit.

3. The power receptacles on the PDU shall be NEMA 5-20R compatible. The plug shall be NEMA 5-20P compatible.

4. The IS&T Project Manager will provide the PDU and UPS specification.

**BDF Equipment Rack Installation Requirements:**

1. Provide all racks. Provide mounting components and accessories to securely fix equipment racks to floor.

2. Provide appropriate seismic transverse and longitudinal bracing per any local codes and the current National Uniform Seismic Installation Guidelines (NUSIG).

3. Provide cable bend management fixtures to maintain the proper bend radius as cables drop into equipment racks.

4. Do not allow cables to be unsupported at distances greater than 4 feet, or sag more than 3 inches, as they run from conduit or cable ladder to equipment racks. Comply with BICSI and TIA 569-C for additional requirements.

5. Non-continuous pathway supports shall be UL listed.

**BDF Equipment Racks Bonding and Grounding:**

1. The equipment racks shall be bonded to the Telecommunications Ground Bus with 6AWG stranded copper wire per current BICSI Grounding/Bonding standards.

2. Comply with additional requirements in Divisions 26 “Grounding and Bonding” and 27 “Grounding and Bonding for Communications Systems”.

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### 4. DESIGN CRITERIA FOR INTERMEDIATE DISTRIBUTION FRAMES (IDF)

#### 4.1 IDF Room and Location Physical Requirements

**IDF Room Size:**

1. IDFs shall have a minimum clear dimension of 9 feet in one direction. The program, port density, and the desired technology requirements will drive the actual room size. Provide 36 inches of clearance from front of equipment to any obstruction.

2. As a general rule, use the following parameters to determine the minimum TR size:

   a. 9 by 11-1/2 feet - (3) Rack TR = 20,000 usable square feet coverage area.
   b. 9 by 14 feet - (4) Rack TR = 40,000 usable square feet coverage area.
3. Refer to the appendix for drawings of a typical IDF room layout in 3-rack, 4-rack or 5-rack versions.

IDF Room Location:

1. Provide at least one IDF room per floor. Floor plates over 10,000 square feet may require more than one TR.
2. Multiple rooms are required on a floor if the cable length between the IDF and the most distant telecommunications outlet, including slack, exceeds 295 feet including both vertical and horizontal dimensions.
3. All TRs should be located off of a main corridor with door(s) opening into the hallway.
4. Locate IDFs above any threat of flooding. Avoid locations that are below or adjacent to areas of potential water hazard (e.g., restrooms and kitchens). Comply with flooding prevention requirements for BDF above.

IDF Room Use:

1. The IDF shall be dedicated solely to Technology and related facilities including voice, data, wireless, security, access control, and cellular distributed antenna systems indicated in project engineering narratives and contract documents.
2. Equipment that does not support the IDF (e.g., pipes, duct work, distribution of building power) shall not be located in or pass through the IDF. While strongly discouraged, in cases where alternatives are punitive to the project’s overall interests, electrical conduits and non-liquid plumbing piping only may pass through an IDF provided that they are located no lower than any other overhead obstruction in the room and that there are no pull boxes, valves or other devices that require access by staff other than IS&T. In the case where a conduit must pass through the IDF, written approval from IS&T is required before routing and final placement.

4.2 IDF Architectural Requirements

IDF Structural Requirements:

1. Provide a minimum floor loading of 50 pounds per square foot.

IDF Wall Requirements:

1. IDF walls should extend from the finished floor to the structural ceiling (e.g., the slab).
2. The IDF should not have windows installed, nor is it desirable to locate IDFs on perimeter walls where windows comprise the majority surface of the wall.
3. At least 8 feet of contiguous wall space should be set aside for access control panels and security panels in the IDF.
4. Backboards: AC-grade fire rated plywood, 8 feet high with a minimum thickness of 3/4 inch around the perimeter of the room over drywall, painted MIT white. The bottom of the plywood shall be mounted 6 inches above finished floor.

5. Wall Base: Resilient base shall be 6 inches high typical.

IDF Connecting Sleeves and Slots:

1. Firestop Requirements: Comply with Division 07 “Firestopping”.

IDF Service Doors and Security:

1. Door Type: Hollow metal, minimum 1-hour fire rated, minimum STC 35 with sound gaskets.
2. Minimum Size: 3 foot 6 inches wide and 80 inches tall.
3. Door sills and thresholds impede the movement of equipment, block ventilation, and are not recommended.
4. Doors that open outward provide additional usable space and reduce constraints on IDF layout.
5. IDF door hardware requires control against unauthorized access, typically a mechanical lock and key and IS&T card access. Doors shall include hinges with non-removable pins, single cylinder lockset with card access. Doors should remain open until manually closed. Automatic closers shall not be used.
6. A security camera will be installed in each IDF. Comply with additional requirements in the security documents.

IDF Ceilings:

1. The minimum ceiling height is 8 feet 6 inches above the finished floor with ceiling protrusions (e.g., sprinkler heads) placed to assure a minimum clear height of 8 feet, clear of obstructions, to provide space over the equipment frames for cables and suspended ladder racks.
2. To permit maximum flexibility and accessibility of cabling pathways, ceilings are not allowed in IDFs.
3. Exposed ceilings with fireproofing or other non-smooth, potentially dust collecting surfaces shall be reviewed with IS&T and may require enclosure.

IDF Floors:

1. Floor Finish: Static dissipative resilient flooring unless otherwise indicated, provide the following. Comply with additional requirements in Division 09 “Flooring”.
   a. Static Resistance: to ESD-S7.1 and ASTM F-150, Point to point and point to ground: $10^6$ to $10^9$ ohms.
   b. Static Generation: to ESD STM 97.2.
c. Static Decay: Flooring in combination with ESD shoes and a person (5000 volts to zero): 0.5 seconds.

4.3 IDF Fire Suppression Requirements

Provide sprinkler heads in wire cages to prevent accidental operation. Coordinate the layout of fire protection systems with the equipment layout to avoid obstructing sprinklers, access to the alarm or other protective measures.

Comply with additional requirements in the local building code and Division 21 “Fire Suppression”.

4.4 IDF HVAC Requirements

Provide HVAC that will maintain continuous and dedicated environmental control (24 hours per day, 365 days per year). Cooling shall not be from chilled water as this prohibits normal shutdown of the building chilled water system for repair, construction and maintenance. Cooling shall be local DX equipment rejecting heat to the ambient air.

The HVAC system that serves the IDF should be tuned to maintain a positive air pressure differential with respect to surrounding areas with a minimum of one air change per hour. Provide equipment to maintain the following acceptable ranges:

1. Temperature of 75 degrees F with no humidity control.

Estimated Heat Loads: ~ 5,000 BTU per equipment rack. Confirm heat loads with equipment to be deployed as some equipment may generate more heat than others. UPS and stand-alone air conditioning systems produce additional heat, if present.

Comply with additional requirements in Division 23 “HVAC”.

4.5 IDF Electrical Requirements

Comply with additional requirements in Division 26 “Electrical”.

IDF Lighting:

1. Provide adequate and uniform lighting that provides a minimum equivalent of 50 foot-candles when measured 3 feet above the finished floor level.
2. Locate light fixtures a minimum of 8 feet 6 inches above finished floor level. Any variation should be coordinated with the IS&T Project Manager. Preference is for lights over aisles rather than racks.
3. Locate light switches near the entrance to the IDF.
4. Coordinate lighting layout with the equipment rack layout, especially overhead ladder rack, to ensure that light is not obstructed.
5. Power for the lighting should be separated from circuits that power technology equipment.
6. Provide non-heat generating LED lamps unless otherwise indicated.

IDF Equipment Power:

1. IDFs shall be equipped to provide adequate electrical power. As a minimum, provide four 120V, 20A dedicated circuits, with one duplex receptacle per circuit per equipment rack. Confirm the need for 120V, 30A circuits with the IS&T Project Manager.

IDF Convenience Power:

1. Provide separate duplex 120V, 20A convenience outlets (NEMA 5-20R) for tools, test sets, etc., located at least 18 inches above the finished floor, placed at approximately 6 foot intervals around perimeter walls and identified and marked “Convenience Power”.

IDF Dedicated Power Feed and Panel:

1. Provide IDFs with a dedicated power supply circuit that serves only the IDF and terminates in its own electrical panel within the IDF (see typical IDF drawings in Appendix B). The feeders that supply the power for technology equipment in IDFs should be dedicated only to supplying that equipment and should be designed to facilitate future growth.
2. The dedicated power panels should be wired and capable of future generator support if the generator support is not already installed for the building.

IDF Backup Power:

1. Because of the “mission-critical” nature of the IDF, backup power should be provided if possible.
2. Additionally, a rack-mounted UPS with a minimum of 30- minute battery capacity per each active rack circuit for each rack at full load shall be provided.

IDF Bonding and Grounding:

1. Provide a complete grounding/bonding system per EIA/TIA 607-B and current BICSI Grounding and Bonding standards.
2. Comply with additional requirements in Divisions 26 “Grounding and Bonding” and 27 “Grounding and Bonding for Communications Systems.”

IDF Conduit Sleeve Penetrations:

1. Provide horizontal and backbone conduit sleeves into the IDF for the distribution of the horizontal and backbone cable from the ladder rack. Provide vertical conduit sleeves from the IDF if stacked above to support the distribution of backbone cables. If the IDFs are not stacked with the BDF, provide continuous conduit.
2. Conduit and conduit sleeves consist of a minimum of four 4 inch conduits / sleeves stubbed into the IDF extending 6 inches on both sides if sleeved. Additional conduits/sleeves may be required depending on the cable density.

3. All conduit and conduit sleeve counts shall be coordinated and approved by the IS&T Project Manager. Comply with additional requirements in Division 27 “Conduits and Backboxes for Communications Systems”.

4.6 IDF Communications Requirements

Comply with additional requirements in Division 27 including “Communications Cable Management and Ladder Racks”, “Communications Cabinets, Racks, Frames and Enclosures”, and “Grounding and Bonding for Communications Systems”.

IDF Overhead Ladder Rack:

1. Provide overhead ladder rack within the IDF’s to route cable to or from sleeves, risers, ducts, ladder racks to termination fields within equipment racks or mounted on walls. This overhead ladder system shall be contained within the confines of the IDF.

IDF Overhead Ladder Rack Materials and Applications:

1. IDF overhead ladder rack may be mounted horizontally or vertically on walls and over equipment racks. Vertical overhead ladder rack will be used to support riser cable from floor to ceiling as it passes between floors. The overhead ladder rack system shall be mounted to walls, the top of equipment rack, or hung with threaded rods for bracing and support in compliance with seismic codes.

IDF Overhead Ladder Rack Bonding and Grounding:

1. In the IDF’s, the overhead ladder rack system shall be bonded to the Telecommunications Grounding Busbar with 6AWG stranded copper wire per current BICSI Grounding / Bonding standards.

IDF Equipment Racks:

1. Provide between three and five 7 foot by 19 inch Equipment Racks in the IDF with two 10 inch double-sided vertical wire managers depending on the usable square footage served. See square footage served information in section “Room Size”.

IDF Power Accessory Requirements:

1. Each equipment rack is to have a minimum of two vertically mounted Power Distribution Units (PDU) at the rear of the rack.

2. Both PDUs will connect to the rack-mounted UPS systems; one UPS will be installed per dedicated 20amp circuit.
3. The power receptacles on the PDU shall be NEMA 5-20R compatible. The plug shall be NEMA 5-20P compatible.
4. The IS&T Project Manager will provide the PDU and UPS specification.

IDF Equipment Rack Installation Requirements:

1. Provide all mounting components and accessories to securely fix equipment racks to floor. Provide appropriate seismic transverse and longitudinal bracing per any local codes and the current National Uniform Seismic Installation Guidelines (NUSIG).
2. Provide cable bend management fixtures to maintain the proper bend radius as the cables drop into the equipment racks.
3. Do not allow cables to be unsupported at distances greater than 4 feet, or sag more than 3 inches, as they run from conduit or cable ladder to equipment racks. Comply with BICSI and TIA 569-C for additional requirements.
4. Non-continuous pathway supports shall be UL listed.

IDF Equipment Racks Bonding and Grounding:

1. The equipment racks shall be bonded to the Telecommunications Ground Bus with 6AWG stranded copper wire per current BICSI Grounding / Bonding standards.
2. Comply with additional requirements in Divisions 26 “Grounding and Bonding” and 27 “Grounding and Bonding for Communications Systems”.

5. DESIGN CRITERIA FOR THE COMMUNICATION CABLE SYSTEM SUPPORT INFRASTRUCTURE

The horizontal communication cable system infrastructure includes the pathway and support hardware that concentrates supports and protects horizontal cable between its origination point in the IDF or BDF and the workstation outlet location. It also provides a permanent pathway that facilitates the addition or replacement of cable over time. Horizontal support hardware is further defined as continuous, (e.g., conduit, cable tray) and non-continuous (e.g., J-Hooks, Saddle Bags).

5.1 Communication Cable Trays

Distribution cable tray shall be installed above the accessible ceiling for the creation of main pathways for the management of high volumes of cable through corridors, and for access and egress to BDF and IDFs. Comply with additional requirements in Division 27 “Cable Trays for Communication Systems”.

Construction:
1. Cable tray shall be the wire basket type manufactured of ASTM A510 high strength steel wires or equal, and comply with NEMA VE1.
2. The cable tray shall be Underwriters Laboratory (UL) listed.
3. Any variation of this shall be approved by the IS&T Project Manager.

Dimensions:

1. The cable tray shall be a minimum of 18 inch wide, with a depth of 4 inches. Comply with NEC requirement for 40% fill ratio when determining size.
2. Narrower cable tray may be used for locations with lower volumes of cable.
3. All cable tray dimensions shall be approved by the IS&T Project Manager.

Support Requirements:

1. A trapeze-style support shall be used along the span of the cable tray. The trapeze shall be constructed of channel stock and minimum 5/8 inch galvanized or stainless steel threaded rods. The trapeze support elevation should allow a minimum of 12 inches between the top edge of the cable tray and the slab above. Appropriate threaded rod anchors shall be selected and installed per manufacturer’s instructions. Trapeze supports shall be selected based on project requirements and placed a minimum of every 10 feet and at cable tray intersections and terminations.
2. Seismic bracing for the cable tray as required by code, shall be installed along cable tray routes. Coordination of lateral and oblique bracing locations shall be coordinated with the other disciplines whose equipment and systems share the area above the suspended ceiling with coordination drawings or Building Information Model (BIM) clash detection.

Bonding and Grounding Requirements:

1. The cable tray shall be bonded to the Telecommunications Grounding Busbar in the IDF(s) per current BICSI Grounding/Bonding standards. All non-contiguous segments of the cable tray shall be bonded together using 6AWG stranded copper wire, with crimp-on lugs bolted to each segment of the cable tray to ensure electrical continuity throughout the length of the cable tray system.

Cable Tray Firestopping Requirements:

1. Cable trays that penetrate fire-rated walls shall be equipped with wall penetration sleeves at each location, and have appropriate firestopping materials installed after the placement of cable has been completed.

5.2 Communication Cable System Conduit

Provide Communications cable conduit in locations where access to cable tray is unavailable or where portions of the pathway span are inaccessible (i.e., embedded in walls or inaccessible
ceilings). Provide conduit for small quantities of cable where cable tray is impractical. Conduit materials may be used to house non-rated cables between end points to ensure NEC Code compliance.

Conduits serving individual workstation outlets shall be a minimum of 1 inch. The conduits shall be connected to double-gang, deep device boxes 2-1/8 inches deep, equipped with a single-gang mud ring at the outlet location. Individual workstation conduits are to be dedicated to only one outlet box each, and shall not be “daisy-chained” together.

The following conduit type shall be utilized as described below. Comply with additional requirements in the local building code and Divisions 26 “Electrical” and 27 “Communications.”

1. **Rigid Galvanized Steel (RGS):**
   a. Rigid galvanized steel conduit shall be used in areas exposed to the outside elements above ground and used for the containment of non-rated cable as specified in the NEC.
   b. RGS shall be installed using threaded couplers and fittings and should be left with pull strings for future use.

2. **Thinwall Electrical Metallic Tubing (EMT):**
   a. EMT shall be used for installations within the confines of an environmentally controlled building and should be left with pull strings for future use. EMT conduit is not acceptable for non-rated cable installations. EMT conduit may be used, however, to carry riser-rated cable and innerduct in vertical and horizontal cable applications. EMT conduit may be used as sleeves for wall penetrations, and for floor core riser penetrations.
   b. EMT conduit connectors and fittings shall be installed using “Set-Screw” type or airtight “Compression” type fittings.

3. **Flexible Conduit (“Flex”):**
   a. Flexible conduit shall not be used for communication cable installation when EMT conduit is available.
   b. Flex conduit may be used for connections into modular furniture or similar applications and should be left with a pull string for future use.
   c. When using Flex conduit, increase the diameter of the Flex by one trade size over what the requirement would be using smooth-wall conduit.

4. **Plastic Conduit / Polyvinyl Chloride:**
   a. Plastic and PVC conduit shall be used for underground duct construction between...
buildings and vaults.

b. Plastic and PVC conduit shall be used for underground duct construction between buildings and vaults.

5. PVC:

a. The PVC conduit shall be a minimum of Schedule 40 PVC. Plastic and should be left with mule tape or pulling rope for future use.

5.3 Conduit Installation Guidelines

Communication Cable System Conduit:

1. Support Requirements:

a. Conduits shall be installed with support systems such as channel stock/threaded rod trapeze supports. Individual conduits may be supported using threaded rods with clamps. Conduits may be affixed to walls where practical. Seismic bracing shall be installed as required by local building codes and NUSIG (National Uniform Seismic Installation Guidelines).

b. Accommodations for lateral and oblique bracing struts must be coordinated with the other disciplines that vie for critical ceiling space.

2. Bonding and Grounding:

a. Bonding of conduits to the Telecommunications Grounding System is required. At the termination of conduit runs within IDFAs, attachment of a ground wire between the Telecommunications Ground Bus to grounding rings installed on conduit box connectors should be accomplished to ensure electrical continuity of the conduit system.

3. Firestopping:

a. Partially filled and empty conduits that pass through fire-rated walls or through floors shall be firestopped in accordance with Local Fire Codes. Material shall be flexible firestopping putty or pillows.

5.4 Communication Cable System Pull Boxes

1. Pull Boxes: A pull box shall be installed in conjunction with conduit installations to provide access to cables at appropriate locations for distribution to tributary locations, and to facilitate cable installation.

2. Materials: For indoor use, use NEMA Type 1 pull boxes. For exterior applications or
areas exposed to heavy moisture, chemicals or weather elements, NEMA Type 3 or 4 pull boxes shall be installed. The pull box shall be equipped with hinged covers, or removable covers that are screwed or bolted on. The pull boxes shall have hardware for supporting and securing cabling and pulling eyes to facilitate cabling installation.

3. Placement: A pull box shall be installed after 100 feet of conduit has been placed, and/or after 180 degrees of directional change in the conduit pathway has been affected. The installation of a pull box shall not be used for directional change.

4. Support Requirements: Pull boxes shall be attached directly to the ceiling slab, or suspended by 4-point threaded rod supports anchored to the ceiling. Pull boxes require seismic bracing to comply with Local Building Codes. Seismic bracing shall be installed as required by local building codes and National Uniform Seismic Installation Guidelines (NUSIG). Accommodations for lateral and oblique bracing struts must be coordinated with the other disciplines that vie for critical ceiling space.

5.5 Horizontal Cable Support Hardware (Non-Continuous)

Horizontal Cable Support Hardware such as J-Hooks shall be used in locations where the communication cable cannot be supported by continuous systems such as cable trays or conduit. Note: Saddle Bags are also acceptable as per products listed in this Section.

Provide J-Hooks every 48 inches at a minimum, attached to threaded rod or ceiling hangers to provide support for cable bundles. The J-Hooks shall be metal stampings configured in a “J” form providing a broad cradle or saddle for supporting for of cable.

5.6 Jack Numbering Sequence

Faceplates shall have an applied P-Touch label with building number, room number and sequence jack number, for example W92-212-13.

Sequence numbering for jacks within a room shall be clockwise, starting as you enter the room, with lowest to highest number.

Patch panels shall have matching labels.

Green snap trim shall be used to indicate that the jack is connected to MITnet.
6. TEL/DATA DESIGN LAYOUT DRAWINGS

6.1 Room Diagrams

Comply with design layout drawings attached at the end of this document. Consult with IS&T prior to modifying design layout drawings.

APPENDIX A: IS&T PRODUCT LIST

The following materials are to be used for each of the components of the IT structured cabling systems at MIT. All products listed in this section shall be installed per the manufacturer’s product installation instructions. Basis-of-design products which have been used at MIT are listed; equal products by comparable manufacturer's will be considered during the submittal process, except where 'no substitutions' is indicated.

Installers shall provide all factory fittings and accessories required for a complete installation in accordance with the manufacturers instructions.

A. Structured Cabling System - No Substitutions

Commscope, 760092429, MGS600-262, GigaSPEED X10D® MGS600 Series Information Outlet, white.

Commscope, 760105940, 2091B GR 4/23 R1000, GigaSPEED X10D® 2091B ETL Verified Category 6A U/UTP Cable, white jacket, 4 pair count, 1000 ft (305 m) length, reel.

Commscope, 760105858, 1091B SL 4/23 R3000, GigaSPEED X10D® 1091B ETL Verified Category 6A U/UTP Cable, slate jacket, 4 pair count, 3000 ft (914 m) length, reel.


Commscope, 108168469, M12L-262, L Type Flush Mounted Faceplate, two port white.

Commscope, M106FR2-262, M106 Flush Mounted Modular Mounting Frame, two port, white.

Commscope, M106FR4-262, M106 Flush Mounted Modular Mounting Frame, four port, white.

Commscope, 108333063, M12LE-262, LE Type Flush Mounted Faceplate, two port, white.

Commscope, 108168543, M14L-262, L Type Flush Mounted Faceplate, four port, white.
Commscope, 108333162, M14LE-262, LE Type Flush Mounted Faceplate, four port, white.

**B. Racks And Cable Management Components - No Substitutions**
Chatsworth Products, 55053-703, Two-Post Standard Rack.

Chatsworth Products, 30163-703, CCS Combination Cabling Section.

Chatsworth Products, 30139-719, Universal Horizontal Cable Manager.

**C. Power Strips**
Chatsworth Products, 12848-756, Metered Power Strip, Vertical Mount.

**D. Cable Tray For Tel/Data Rooms (Tr)**
Type 1: Chatsworth Products, Cable Runway Pathway Dividers.

Type 2: Chatsworth Products, Universal Cable Runway

Connecting Components: To be determined.

**E. Cable Tray For Distribution Systems**
Chatsworth Products, Ontrac Wire Mesh Cable Tray System.

**F. Horizontal Cable Support Hardware**
Erico, CAT32HP, Caddy Cat HP, J-Hook.

Erico, CAT425, Adjustable Cable Supports.

**G. Indoor Ribbon Cable - No Substitutions**
Corning, 012EC8-14101-A3 NAFTA_AEN, Ribbon Interlocking Armored Cable, Plenum, 24 F, Single-mode (OS2).

Corning, 024EC8-14101-A3 NAFTA_AEN, Ribbon Interlocking Armored Cable, Plenum, 12 F, Single-mode (OS2).

Corning, 036EC8-14101-A3 NAFTA_AEN, Ribbon Interlocking Armored Cable, Plenum, 36 F, Single-mode (OS2).

Corning, 048EC8-14101-A3 NAFTA_AEN, Ribbon Interlocking Armored Cable, Plenum, 48 F, Single-mode (OS2).

Corning, 072EC8-14101-A3 NAFTA_AEN, Ribbon Interlocking Armored Cable, Plenum, 72 F, Single-mode (OS2).

Corning, 096EC8-14101-A3 NAFTA_AEN, Ribbon Interlocking Armored Cable, Plenum, 96 F, Single-mode (OS2).
Corning, 144EC8-14101-A3_NAFTA_AEN, Ribbon Interlocking Armored Cable, Plenum, 144 F, Single-mode (OS2).

**H. Indoor-Outdoor Ribbon Cable - No Substitutions**


Corning, 144ECF-14101-A1_NAFTA_AEN, FREEDM Ribbon Interlocking Armored, Gel-Filled Cable, Riser, 144 F, Single-mode (OS2).

**I. Outdoor Ribbon Cable - No Substitutions**

Corning, 012EC5-14100D53_NAFTA_AEN, SST-Ribbon Single-Tube, Gel-Free, Armored Cable, 12 F, Single-mode (OS2).

Corning, 024EC5-14100D53_NAFTA_AEN, SST-Ribbon Single-Tube, Gel-Free, Armored Cable, 24 F, Single-mode (OS2).

Corning, 036EC5-14100D53_NAFTA_AEN, SST-Ribbon Single-Tube, Gel-Free, Armored Cable, 36 F, Single-mode (OS2).

Corning, 048EC5-14100D53_NAFTA_AEN, SST-Ribbon Single-Tube, Gel-Free, Armored Cable, 48 F, Single-mode (OS2).

Corning, 072EC5-14100D53_NAFTA_AEN, SST-Ribbon Single-Tube, Gel-Free, Armored Cable, 72 F, Single-mode (OS2).

Corning, 096EC5-14100D53_NAFTA_AEN, SST-Ribbon Single-Tube, Gel-Free, Armored Cable, 96 F, Single-mode (OS2).

Corning, 144EC5-14100D53_NAFTA_AEN, SST-Ribbon Single-Tube, Gel-Free, Armored Cable, 144 F, Single-mode (OS2).
J. Rack-Mount Hardware – Option 1 - No Substitutions
Corning, CCH-01U_NAFTA_AEN, Closet Connector Housing (CCH), one rack unit, holds two CCH connector panels.

Corning, CCH-02U_NAFTA_AEN, Closet Connector Housing (CCH), two rack units, holds four CCH connector panels.

Corning, CCH-03U_NAFTA_AEN, Closet Connector Housing (CCH), three rack units, holds six CCH connector panels.

Corning, CCH-04U_NAFTA_AEN, Closet Connector Housing (CCH), four rack units, holds twelve CCH connector panels.

Corning, CCH-CS12-AE-POORJ_NAFTA_AEN, Closet Connector Housing (CCH) Pigtailed Splice Cassette, 12 F, Shuttered LC UPC duplex, Single-mode (OS2), ribbon fiber.

Corning, CCH-CS24-AE-POORJ_NAFTA_AEN, Closet Connector Housing (CCH) Pigtailed Splice Cassette, 24 F, LC UPC duplex shuttered, Single-mode (OS2), ribbon fiber.

K. Rack-Mount Hardware – Option 2 - No Substitutions
Corning, CCH-CP12-A9-P03RJ_NAFTA_AEN, Closet Connector Housing (CCH) Panel, ribbon pigtailed, LC Connectors, Duplex, UPC, 12 F, Single-mode (OS2).

Corning, CCH-CP24-A9-P03RJ_NAFTA_AEN, Closet Connector Housing (CCH) Panel, ribbon pigtailed, LC Connectors, Duplex, UPC, 24 F, Single-mode (OS2).


Corning, M67-076_NAFTA_AEN, Splice Tray, Mass Fusion Splices or Heat-shrink Fusion Splices, 0.4-inch; 6 mass fusion splices or 12 heat-shrink fusion splices.

Corning, PC1-SPLC-04R_NAFTA_AEN, Splice Tray Bracket for PCH-01U.

Corning, PC2-SPLC-6SR_NAFTA_AEN, Splice Tray Bracket for PCH-02U.

Corning, PC4-SPLC-12SR_NAFTA_AEN, Splice Tray Bracket for PCH-04U.

Corning, PCH-01U_NAFTA_AEN, Pretium Connector Housing (PCH), one rack unit, holds two CCH connector panels.

Corning, PCH-02U_NAFTA_AEN, Pretium Connector Housing (PCH), two rack units, holds four CCH connector panels.

Corning, PCH-04U_NAFTA_AEN, Pretium Connector Housing (PCH), four rack units, holds twelve CCH connector panels.
L. Rack-Mount Hardware - No Substitutions
Corning, M67-076_NAFTA_AEN, Splice Tray, Mass Fusion Splices or Heat-shrink Fusion Splices, 0.4-inch; 6 mass fusion splices or 12 heat-shrink fusion splices.

Corning, OSE-LD0-0T-L_NAFTA_AEN, Optical Splice Enclosure (OSE) Universal, low density, 432 single fiber / 864 mass fusion splice, standard cable entry, with “T” slot mounting kit and lockable.

Corning, OSE-ST-3_NAFTA_AEN, Optical Splice Enclosure (OSE) Splice Trays, Mass Fusion (Ribbon).

Corning, WSH-11SPT-F_NAFTA_AEN, Wall-Mountable Splice Housings (WSH), for up to eleven 0.4-inch category 4S, 4R, or 4A splice trays.

END OF DOCUMENT
Fan Coil Space Option: Above Ladder Rack, NOT over Eq. Racks

Overhead Light

Front Side of Racks

Tel/Data Room - 3 Rack TR : Ladder Rack View

DESIGN STANDARDS

Massachusetts Institute of Technology
Fan Coil Space Option: Above Ladder Racks; NOT over Eq. Racks

Overhead Light

Front Side of Racks

Overhead Light

1' - 6"
Fan Coil Space Option: Above Ladder Rack; NOT over Eq. Racks

Overhead Light

Front Side of Racks

Overhead Light

Tel/Data Room - 5 Rack TR : Ladder Rack View

DESIGN STANDARDS

Massachusetts Institute of Technology
Fan Coil Space Option: Above Ladder Rack; NOT over Eq. Racks

Overhead Light

1'-6"

20 amp (2) 20 amp (2) 20 amp (2) 20 amp (2) 20 amp (2) 20 amp (2) 20 amp (2) 20 amp (2) 20 amp (2)

Tel/Data Room - 5 Rack BDF : Ladder Rack View

DESIGN STANDARDS

Massachusetts Institute of Technology
MIT
Design Standards

DIVISION 28 — Fire Alarm

May 2018
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1. MIT FIRE ALARM SYSTEM GOALS

The goal of M.I.T.’s fire alarm system is first to insure the safety of students, faculty and staff. A secondary goal is to reduce the Institutes exposure to property loss and to interruption in carrying out its mission of education and research and a tertiary goal is to design a system capable of delivering intelligible mass notification messages. In order to meet these goals fire detection coverage is required in 100% of all facilities. In existing buildings, projects will bring all renovated areas into conformance with Institute standards and current best practice.

Designers should understand that M.I.T. requirements differ from normal industry practice. This is most apparent in the level and quality of testing that M.I.T. requires for all fire alarm systems whether new or modified. Particular attention must be paid to such differences and the contract documents must clearly explain the contractor’s responsibilities. This section will point out some of those differences but close cooperation with the M.I.T. project manager and Fire Protection Engineer will be necessary for a complete understanding of the Institutes requirements.

M.I.T. operates a Proprietary Supervising Central Station fire alarm system. This system type operates in a different manner than most other systems in that it monitors only M.I.T. alarms from contiguous and non-contiguous properties. The central station also monitors categories of alarms such as water flow, low air pressure and other categories as necessary based on the program.

2. DESIGN REVIEW CHECKLIST

The Design Consultant is responsible for filling out, signing, and submitting this checklist at each phase of design as a guide for review by M.I.T. Facilities.

2.1 Schematic Design (SD) Phase

1. Review of applicable codes, regulations, and standards.
2. System descriptions (Basis of Design).
3. Alternative design concepts.
4. Outline specifications.
5. Equipment cut sheets.

2.2 Design Development (DD) Phase

1. To be determined.
2.3 90% Construction Documents and Construction Documents (CD) Phase

1. List of design changes from the Design Development issue.
2. Updated equipment cut sheets.
3. Electrical loads coordinated with electrical drawings.
4. Coordination with fire suppression systems.
5. Variances approved by responsible authorities.
6. Review of specification sections.

2.4 Shop Drawing Phase

1. Ensure that the shop drawing submittals comply with all aspects of the contract documents; note in writing any deviations for discussion with M.I.T. or provide written certification that shop drawing submittals are compliant.

2.5 Record Drawing Phase

1. Review record drawings and final submittals for compliance. Provide a written report of compliance or deviations.
7. A draft, pencil-set of as-built documents and matrices be maintained on the job site and updated on a 48 hour basis.

3. FIRE ALARM SYSTEMS DESIGN CRITERIA

All fire alarm systems must conform to the latest edition of NFPA 72, National Fire Alarm and Signaling Code, as adopted by The Massachusetts State Building Code as well as to 527 CMR 24.00. The design requirements that appear in the following paragraphs are based on experience in operating M.I.T.’s fire alarm system for many years. These requirements are to be followed without deviation unless through discussion with the project manager and M.I.T. Fire Protection Engineer an alternate path is agreed on. M.I.T. is open to better ideas and alternate approaches but discussion must precede their adoption.

This Design Guideline is not part of the contract documents that will direct the contractors work and will be the basis for a legal agreement between M.I.T. and the general contractor. It is the responsibility of the fire alarm system designer to incorporate M.I.T.’s standards and direction into the contract documents in a manner that will provide clear direction to the contractor during both the bidding and execution phases of the project. Failure to do so will result in RFI’s and eventually in change orders since the contractor will be unaware of the areas where M.I.T.’s requirements differ from those of many other owners.
3.1 General Requirements

Voice notification (emergency voice / alarm communication (EVAC) shall be designed for all new fire alarm systems. Horns are only permitted for extensions or modifications to existing fire alarm systems.

3.2 Annunciator

An annunciator is to be located in the fire command center. An annunciator is also to be located at each entrance used by the fire department access to the building.

All annunciators must be configured with the same layout and functionality. This may require each annunciator to be a node depending on the manufacturer.

All annunciators are to have expanded displays with a minimum of 640 characters.

The annunciators must have indicators (alarm and trouble) and bypass switches for each initiating device type (smoke detector, heat detector, manual station, water flow, tamper, etc.) by floor.

Each annunciator is required to have a microphone to broadcast live voice messages.

3.3 Initiating Devices

General: Any detector installed in normally locked rooms shall be provided with a remote indicating light outside the room.

Heat-Sensing Fire Detectors: Heat detectors shall be of the fixed temperature type only, rate of rise detectors are not permitted. Any heat detectors mounted in normally locked rooms shall have a remote indicating light outside the room.

Smoke-Sensing Fire Detectors:

1. Smoke detectors are to be installed in all electrical and mechanical rooms, areas where electrical panels are present, and plumbing rooms that contain pumps and motors.
2. Smoke detectors may be required in certain laboratory and research areas. The designer shall confirm if additional smoke detectors are required in these areas with the M.I.T. fire protection engineer.

Smoke Detection for Air Duct Systems:

1. Duct smoke-sensing fire detectors shall be mounted so that they are accessible for service and have an accessible remote test and indicating station that can be reached from the floor or a ladder of no more than six feet in height. Air sampling type smoke detectors might be required when duct smoke detectors are not accessible. This allows the components that are likely to require service to be located in a location that accessible
2. Duct detectors shall be programmed to provide a distinct supervisory signal to the M.I.T. operations center.

3. Occasionally a duct will be laid out in the shop drawings in a manner that will require multiple duct detectors. The drawings or specifications should note that the additional detector is to be provided if necessary.

Projected Beam-Type Smoke Detectors: The use of beam detectors is discouraged, aspiration type systems should be considered first. That said, there may be cases where there is no other solution. This must be discussed with the M.I.T. fire protection engineer.

Air Sampling-Type Smoke Detectors: Aspirating detection systems shall be engineered and detailed drawings shall be provided.

Radiant Energy Sensing Fire Detectors:

1. Flame detectors should be provided in areas where combustion engines for generators, fire pumps or similar are located within a building.

Gas Detection for Carbon monoxide: Are required in all residential and child-care, day-care or similar occupancies where sleeping may occur. The installed locations should be based on the Technical Options in accordance with 527 CMR 31.05 where detectors are located in areas that contain fossil fuel burning appliances including boilers, generators, etc.

Sprinkler Waterflow Alarm-Initiating Devices:

1. Water flow detectors shall be vane type with retard. Potter Signal flow switches are preferred.
2. A main water flow switch shall be provided.
3. The main water flow switch should be set to activate between 45 and 60 seconds, and the floor or zone water flow switch should be set to activate between 30 and 40 seconds.

Manually Actuated Alarm-Initiating Devices: Pull stations shall be double action and mounted at 48 inches AFF.

Supervisory Signal, Initiating Devices, Generator & Transfer Switches:

1. The status (running or fault) of the generator is required to be displayed on the fire alarm control unit and all annunciators.
2. The position (normal or alternate) is required to be displayed on the fire alarm control unit and all annunciators.
3.4 Notification Appliances

Horn / strobes, speaker / strobes and strobes are required to be installed so that the entire strobe lens is between 80 and 96 inches above the finished floor per NFPA 72. The notification appliances shall be located at a uniform height throughout the building. The mounting height should consider the location of notification appliances in connecting buildings when determining the mounting height.

The designer should assume that the fire alarm system will be used for mass notification in the future. NFPA 72 prohibits the appliances to be labeled ‘Fire’ if the equipment is used for notification purposes other than fires. The label on the appliances is required to be labeled “Alert” or not labeled.

A UL 1971 listed red 24 VDC strobe (beacon) shall be provided and mounted outside of the building at the location of fire department entry.

In areas where multiple circuits are provided and serve the same area, the load on each circuit should be distributed within 20% of the average of all circuits on that floor. The intent is to distribute the load over the circuits and not load circuits to their maximum.

The drawings which locate speakers and strobes shall also indicate the speaker tap setting (1/4 Watt, 1/2 Watt etc.) as part of the drawing CAD symbol. These settings shall be based on the engineers experience and knowledge of the program use for the space. Alternatively, required sound pressure levels may be indicated (75 dB, 81 dB etc.) Since it is inevitable that some of the settings will require adjustment, the specifications should require that the contractor provide one readjustment of the settings and should ask for a unit price should more than one adjustment be required.

The designer must indicate those spaces which will have notification appliances and those that will not, at the Design Development phase.

Voice intelligibility is required in sleeping units, corridors, common offices areas, conference rooms, classrooms and similar spaces. Intelligibility may be required in other areas depending on the fire alarm and mass notification strategy. For example, campus lock down procedures may require individuals to remain in private offices and if walls are soundproofed, a speaker may be required in each individual office to provide intelligibility in the offices. Locations where intelligibility will be required should be reviewed with the M.I.T. Fire Protection Engineer at Schematic Design phase.

If a speaker is not provided in each individual office, the fire alarm raceway system should be designed to allow for future improvements.

The NFPA 72’Distinctive Evacuation Signal’ is required to use square wave with a fundamental frequency of 520 Hz ± 10 percent in all buildings regardless if the building has sleeping areas.
An electric bell is to be provided above all of the fire department connections to the sprinkler system. The water flow bell is to be powered from a 24 VDC power supply that is separate from the fire alarm system and capable of being activated if the fire alarm system is not operational.

### 3.5 Interfacing

**General:** The fire alarm system will likely be required to interface with a number of building systems. This interfacing is required to be coordinated through the design process. The strategy should be agreed in the design development phase and interface locations should be coordinated in the construction document phase.

**Mass Notification:**

1. The fire alarm system is required to be configured to receive one analog line level (0.707 VRMS or greater) audio input.
2. The fire alarm system is required to be provided with a ‘low priority mass notification input’ which will activate the strobes and broadcast the received audio signal through the fire alarm speakers. This signal will be configured to not override any active fire alarm messages and if a fire alarm occurs when a low priority message is active the fire alarm message is to be broadcast.
3. The fire alarm system is required to be provided with a ‘high priority mass notification input’ which will activate the strobes and broadcast the received audio signal through the fire alarm speakers. This signal will be configured to override any active fire alarm messages and if a fire alarm occurs when a high priority message is active the fire alarm message will not be broadcast.
4. The use of the fire alarm mass notification inputs will be determined in the future. The use will be determined through the risk analysis and documented in the emergency response plan.

**HVAC System Controls:**

1. The HVAC systems should not rely on logic from the building management system to shutdown air handling units unless permitted by the M.I.T. Fire Protection Engineer. Shutdowns are preferred to be completed at the motor starter or VFD.
2. Duct smoke detectors with sampling tubes require a minimum velocity to operate, this will likely require the smoke dampers to close if the air handling unit is not operational.
3. Complex smoke control systems are preferred to be controlled by a building management system that is listed to perform smoke control functions. This strategy shall be coordinated with the designer and the M.I.T. Fire Protection Engineer during detailed design.

**Access Control:**

1. Access controlled doors on all levels shall be released upon activation of the fire alarm
system. There are exceptions which must be discussed with the M.I.T. fire protection engineer.

2. The use of delayed egress doors may require smoke detectors located within the vicinity of the doors or complete smoke detection in the areas.

3.6 System Power

If a generator exists in the building to provide emergency or standby power, the fire alarm system should be connected to an emergency or standby power source. The NFPA 72 reduction in duration to 4 hours is not permitted because generators on campus are not provided with 24 hour fuel supply.

The secondary power supply calculations should be based on operating the fire alarm system for 24 hours in standby operation followed by 15 minutes for full building alarm including all increases for future expansion and all addresses are used on each SLC card. The batteries shall be sized to provide an additional 50 percent of the calculated load, i.e. calculations require 50 AH batteries, 75 AH batteries are required to be provided.

The calculations should assume that the signaling line circuit cards and amplifiers are fully loaded. This eliminates the need to update the power supply calculations when a detector or speaker is added to the circuit.

Door holders shall be 24 VDC directly powered from the fire alarm control panel, control modules shall not be used and 120V power is not acceptable. Provision shall be made to provide an 8 second delay before release of the doors.

3.7 Raceway and Conduit

Fire alarm conduit shall be 3/4 inch minimum, EMT conduit with fittings painted red. Conduit fill shall not exceed 40 percent. This conduit fill requirement is referred to in the code but some contractors believe (wrongly) that it does not apply because the fire alarm system is low voltage and is power limited. The conduit fill should include 20 percent spare space in all conduits and 40 percent in all risers for installation of cabling in the future.

Extension rings are not permitted. The contract documents will need to require extra deep or specialty back boxes to be provided.

Terminal cans shall be 14 GA steel painted red with a continuous piano hinge and marked “Fire Alarm Terminal Cabinet”. The cabinets shall include Space Age tool less terminal strips. The terminal cabinets are required to have a keyed lock that is keyed the same as the fire alarm system in the building. Note, these terminal cabinets are special order from Space Age Electronics.

If speakers are not installed in each individual office, an additional junction box should be located in the raceway system to allow for a speaker to be easily added to the office in the future.
No permanent MC cable is allowed. MC cable may be used during construction on a temporary basis.

In architecturally sensitive finished areas where conduit must be exposed specify surface mounted raceway, Wiremold 700 or equal.

In locations where surface mounted conduit is installed, skirts shall be provided around junction boxes for devices and appliances. The size of the skirts is to be coordinated with the fire alarm equipment manufacturer. The skirts are to be continuously welded at all seams, the welds sanded smooth and painted to match the installed surface.

### 3.11 Circuitting and Cabling

**General:**

1. M.I.T. has a specific color code for all fire alarm cabling. The color must be in accordance with the table that follows this section as an appendix. The designer must take care to be sure that the contractor is fully aware of M.I.T.’s requirements in this area and the wire color code must be included in the contract documents. M.I.T. has developed this legend to make future system maintenance and troubleshooting easier for the Repair and Maintenance personnel and to reduce system downtime, which is an important safety factor as well. While the wire is available from local suppliers it is not always a stock item and there could be lead time and minimum order issues. Be sure that there is language to get this requirement on the table early in the contractor’s submittal process.

2. As mentioned above, a color coded wiring legend is provided as an appendix. The specifications should require that the contractor follow that legend.

3. The minimum wire size of any conductor is 16 AWG.

4. All wiring is required to be stranded. All cabling is required to be 7 strands.

5. All fire alarm cabling is required to be installed in conduit to provide mechanical protection.

6. All calculations shall be completed using the lump sum method, distributed load calculations are not acceptable.

7. No splices, t-taps or inline terminal block connections are allowed. All wiring shall be point to point from device to device. The use of wire nuts is not permitted.

8. The cable shall terminate under saddle plates or be terminated with an insulated fork compression terminal where saddle plates are not provided.

9. End of line resistors, where used, shall be in the floor terminal cabinets at the riser. End of line resistors are permitted to be installed in the monitored device (i.e. water flow, tamper switch, four wire carbon monoxide detector, etc.) when only one device is being monitored by the fire alarm system.

10. M.I.T. will provide the cabling for the Active Multiplex Transmission System (XA loop).
The contractor will be responsible for determining the length, picking up, installing and returning the unused cabling to M.I.T. The contractor will work with the M.I.T. electricians on terminating the cabling.

Signaling Line Circuits:

1. All signaling line circuits are required to be designed as a Class X circuit. Isolation is required between floors. Field isolation modules are not preferred.
2. New installations are not permitted to exceed 70 percent of the total available addresses. This allows for additional equipment to be installed on the fire alarm system.

Notification appliance circuits:

1. The NAC calculations should include an additional 20% increase in circuit load and length for future expansion. This is a minimum requirement as buildings that are expected to undergo significant changes may require a larger increase for future expansion.
2. Class A circuits should use the entire circuit length with the load located at the end. Assuming the load is at the middle of the circuit is not acceptable.
3. A minimum of two notification appliance circuits are required per floor. The circuits should alternate so that a fault on one circuit would maintain notification on a floor. If a room contains two notification appliances, each appliance should be connected to a different circuit.
4. Class B notification appliance circuits are permitted for dedicated speakers in stairs.
5. In dormitories, the speakers in the corridor are to be connected to different circuits than the sleeping and dwelling units. This allows for the speakers to remain operational in the corridors in the event of tampering within the rooms.
6. In dormitories, the audible and visible notification circuits serving notification appliances within the housemaster’s apartment are required to be connected to a dedicated circuit. This requirement is intended to minimize disruption caused by testing.

3.12 Residential Fire Alarm

Each dormitory room or suite requires a single station addressable smoke sensor with sounder base. Standalone smoke alarms (directly powered with 120V power) are not permitted to be installed. System smoke detectors are used.

The designer shall indicate suites on the design drawings. All sounders shall operate when any detector within the suite is activated.

Sounder bases shall be programmed to sound the NFPA 72 ‘Distinctive Evacuation Signal’ (Temporal Three) tone.

A dedicated SLC loop is required for dormitory room or suite smoke sensors on each floor.
Tampering of any fire alarm equipment within the sleeping or dwelling unit should not impact the operation of the fire alarm equipment that is not located in the sleeping or dwelling unit. The floor devices (smoke sensors, manual pull stations, water flow devices) shall be independent of the SLC loop that monitors the dorm room / suite sensors.

The SLC loop shall be a dedicated channel from the fire alarm control unit and shall not be “isolated” or “split” from the SLC loop monitoring other floor devices. This requirement may differ from normal fire alarm practice and must be specifically called to the contractor’s attention.

Where there are two or more rooms that form a suite with a common hallway or study area, a smoke sensor shall be installed in the hallway/common area in addition to the bedrooms.

Tactile notification appliances (bed shakers) will be required in rooms occupied by hearing impaired students. A detail of the wiring for this system is attached at the end of this section.

A dedicated fire alarm annunciator that monitors the room-suite smoke sensors and is labeled “Dorm Room Smoke Sensors” is required in these locations:

1. In the front lobby adjacent to the building fire alarm annunciator.
2. In the building managers office.
3. Adjacent to the main Fire Alarm Control Panel.

### 3.13 Supervising Station

All new fire alarm systems are required to be provided with the following interfaces to report signals to the M.I.T. Supervising Station. Note some of these interfaces will be used at system acceptance and others may be used in the future.

1. Electrical contacts to Active Multiplex Transmission System.
2. Digital Alarm Communicator Transmitter (DACT).
3. RS-232 interface.

Active Multiplex Transmission System: The fire alarm system will need to provide electrical contacts to communicate with a Data Gathering Panel (DGP). The DGP must be a separate Simplex 4100ES with an XA Loop Interface card. The DGP will translate the signals received to the status of a XA loop address. Note existing systems may be interfaced through AutoCall XA loop interface circuit boards, these circuit boards are no longer being manufactured and there is a significant premium on these components. Existing AutoCall XA loop interface circuit boards may be reused if spare inputs are available. The central station needs to receive the following separate signals:

1. Fire alarm (pull station, heat, smoke).
2. Water flow.
3. Duct smoke activation.
4. Any trouble in the system.
5. Any unacknowledged new trouble. This signal is activated any time that a trouble is not acknowledged within 20 seconds, this signal clears once the trouble is acknowledged.
6. Fire pump motor or engine running for electric and diesel fire pumps.
7. Electric fire pump supervisory signals to include controller connected to alternate source (loss of primary power), phase loss and phase reversal. Due to address limitations on the existing active multiplex transmission system, these may be combined into one supervisory signal.
8. Diesel fire pump supervisory signals to include controller is off or manual and trouble on controller or engine. Due to address limitations on the existing active multiplex transmission system, these may be combined into one supervisory signal.
9. Supervisory signals which are to be individually reported, shall include but are not limited to:
   a. Valve tamper.
   b. Low and high air pressure.
   c. Low water pressure to the building if not fed by the campus fire protection loop.
   d. Low space temperature in dry sprinkler rooms.
   e. Loss of power to air compressors.
   f. CO, methane or other gas detection.
   g. Fire pump supervisory signals.
   h. Low battery alarm on gas monitoring systems.
   i. Panel trouble on gas monitoring systems.
   j. Highly toxic, toxic, pyrophoric gas detection.
   k. Flammable gas detection.
   l. Flammable liquid vapor and liquid leak detection.
   m. Low oxygen detection.
   n. High priority mass notification message active that has overridden an active notification message.

Digital Alarm Communicator Transmitter (DACT): The fire alarm system shall be programmed to transmit a unique address for each system component. The DACT shall be programmed to output signals in the Contact ID format. As part of the Contractor submission, a complete list of all signals is required to be provided to M.I.T. for programming of the supervising station equipment.

RS-232 Interface: The fire alarm system is required to have an RS-232 interface to communicate signals to a printer or to a centralized system associated with the supervising station.
4. DESIGN DOCUMENTATION

4.1 Designer Responsibilities

The designer is responsible for producing the following documentation:

1. Specifications.
2. Drawings including the following:
   a. Floor plans indicating all walls, device and appliance locations, control units, risers, terminal cabinets.
   b. Riser diagrams.
   c. Input / output Matrix of Operation.
   d. Annunciator layout of switches and buttons.
   e. Equipment mounting heights.

4.2 Contractor Responsibilities

Contractor Documentation is to include the following items. The designer needs to require the contractor to provide documentation in accordance with the “Documentation” chapter in the latest edition of NFPA 72. Note that this chapter was added to the 2013 edition of NFPA 72 and is not currently adopted in Massachusetts but should be used as a framework for the contract documents.

1. Product data including data sheets and installation instructions that clearly indicate which model is being provided.
2. Shop Drawings (Installation Documentation):
   a. Floor plans indicating conduit routing and contents.
   b. Riser diagrams.
   c. Control unit diagrams for the interior and exterior of the equipment.
   d. Typical wiring diagrams.
   e. Input / output Matrix of Operation.
   f. Calculations including power supplies, voltage drop, dB loss and conduit fill.

4.3 As-Built Documentation

The contractor will be required to update the product data for all equipment installed.

The contractor is to update the shop drawings to reflect the actual installed condition.
The Engineer of Record shall review all changes to the Input / output Matrix of Operation. The Input / output Matrix of Operation is to reflect the programing logic of the fire alarm system.

5. COORDINATION

The fire alarm system interfaces with a number of building systems. It is important that the fire alarm system is coordinated with the other systems during the design phase. The interfacing strategy must consider the project phasing and material selection. Once system components are purchased it is usually too late to make modifications without a significant cost impact to the project.

The following items should be considered when coordinating the fire alarm system:

1. Sprinkler systems including wet, dry, pre-action, etc. interfaces.
2. Fire pump monitoring.
3. Elevator recall.
4. HVAC equipment shutdown.
5. Activation of the post fire smoke purge system.
6. Emergency power for fire alarm equipment.
7. Monitoring of generator and transfer switch.
8. Smoke control system.
10. Kitchen suppression system.
11. Access control system.
12. Door hardware for door releasing.

The designer is responsible for determining the quantity of inputs and outputs for each system requiring coordination. For example, an elevator requires coordination for the recall levels between the elevator controller and the fire alarm system, and in the case of multiple elevator cars located in the same bank may require an interface with each controller.

The installation must be coordinated between various contractors. In many cases there is usually wiring that is provided by one contractor, which is terminated at each end by a different contractor. There is also a need for the configuration and programming to occur on each of these systems.

6. ACCEPTANCE TESTING
6.1 Initial Acceptance Testing

Both M.I.T. and the Massachusetts State Building Code require that the fire alarm system be installed and constructed in accordance with NFPA 72, National Fire Alarm and Signaling Code. While this is a requirement for all fire alarm work in Massachusetts many contractors do not adhere to all of the testing requirements in NFPA 72 and many local jurisdictions are not as strict in their adherence to the requirement as is the City of Cambridge and M.I.T. This difference between what contractors normally do and what is required by M.I.T. is the source of frequent disagreements and delays at the end of the project. As a result, the Certificate of Occupancy and move in dates are often at risk. The designer must make every effort to insure that such delays do not occur by making the requirements clear in the contract documents.

A summary of key issues follows this paragraph but the designer is expected to fully understand the testing requirements and to clearly explain them in the documents. The designer should understand that M.I.T. will commission an independent third party test of all new or modified fire alarm systems and that this test is also required by the City of Cambridge. The contractor is expected to allow time and budget in his schedule and bid to support this testing and the designer is expected to make this requirement clear.

An NFPA System Record of Completion is required for all projects. The form is available from NFPA (nfpa.org/72). The Contract Documents must make clear the requirement for this Record of Completion.

M.I.T. in conjunction with Simplex Grinnell has created a Fire Alarm Acceptance Testing Procedure, a copy of that procedure is available from M.I.T. The following paragraphs summarize the key requirements of that testing procedure. These must be incorporated into the contract documents in a manner that ensures that the contractor allows sufficient time and budget to successfully comply with their requirements.

1. General Instructions: The acceptance testing must be completed by the system installer, typically the electrical subcontractor, and by a representative of the fire alarm provider. This provider is often but not always Simplex Grinnell. The results of the system testing must be recorded on the NFPA 72 System Record of Completion and NFPA 72 System Record of Inspection and Testing forms. A copy of the forms may be obtained from NFPA (http://www.nfpa.org/72).

2. Off-Site Monitoring: Most M.I.T. building fire alarm systems will be connected to the M.I.T. Supervising Station. The contractor is required to make the Operations Center aware of any testing and its expected duration. The M.I.T. Supervising Station does not have the capability to log signals. Where acceptance testing can be extremely disruptive to staff in the Operations Center, the connection to report signals to the M.I.T. Supervising Station is not permitted to occur until after contractor and third party testing is completed.

3. Occupant Notification: In occupied buildings the contractor is required to notify
occupants of any testing that would impact them. The method of notification will vary by building and must be discussed with M.I.T. The contractor shall provide notification through the fire alarm system prior to beginning and when testing is completed at the end of the day. Individuals may enter the building after the announcement is made, therefore it is important that the contractor is responsible for providing signs at entrances when testing is occurring. It is not acceptable for the signs to remain when testing is not being completed.

4. Fire Alarm Power: A series of tests to confirm fire alarm normal and emergency power, grounding, circuit protection and other wiring is required. All fire alarm systems will have a battery backup and a connection to a circuit powered by an emergency generator, if a generator is present in the building. The testing for battery capacity and load is detailed and possibly unfamiliar to many contractors. The NFPA 72 forms contain detailed information about the battery testing, care must be taken to ensure that these requirements are fully spelled out in the contract documents. Other details covering testing of fire alarm power are contained in the above referenced document.

5. Fire Alarm Control Panel Testing: Some control panel testing must be performed prior to powering the panel for the first time. Details of the control panel testing are given in the M.I.T. simplex Grinnell document this also includes considerable detail on testing of fiber-optic cables which should also be communicated to the contractor. Additional panel testing will include notification appliance tones and indicator illuminations at the panel.

6. Testing of Electrically Supervised Circuits: A total of 10 percent of the devices on each circuit must be tested to be sure that a troubled condition is reported to the fire alarm control panel if the circuit is connected to ground or broken.

7. Functional Testing of Initiating Devices: Each initiating device must be verified for proper labeling using the input-output matrix. The fire alarm contractor shall confirm that room numbers are present prior to beginning testing to confirm that the description for each device is correct. In existing buildings, the contractor should bring these locations to the attention of M.I.T. and a sign will be provided. In major renovations and new buildings, temporary room numbers must be present for the fire alarm testing. The list of initiating devices will include but not be limited to:

b. Smoke detectors.
c. Duct smoke detectors.
d. Heat detectors.
e. Flame detectors.
f. Projected beam smoked detectors.
g. Aspirating smoke detection systems.
h. Carbon monoxide detectors.
Sprinkler system flow switches require a somewhat more complicated testing procedure which is outlined in the above referenced document.

1. **Functional Testing of Notification Appliances:** This portion of the testing is intended to ensure that notification appliances can be seen and heard as required. This includes voice activation or mass notification systems and contains requirements for the intelligibility of notices delivered over the systems. Require that the contractor prepare a drawing showing the ambient sound pressure level as well as the level achieved by the notification appliance in each space. If a space or a whole project is designated as one requiring voice intelligibility then the drawing must indicate the means by which acceptable intelligibility is determined.

2. **Other System Tests:** Functional testing of other systems is required. These systems include but are not limited to:
   a. Elevator recall.
   b. Auxiliary relays.
   c. Smoke door release.
   d. Override switches.
   e. Bypass switches.
   f. Fan control and fan override systems.
   g. Connection to the supervising station.

3. **Documentation:** Documentation required at the completion of testing includes:
   a. As built drawings of the system.
   b. A signed Record of Completion.
   c. A copy of the test log results.
   d. A complete copy of the points list.
   e. A final copy of the input / output matrix in editable (XLS) form.
   f. An engineer’s performance acceptance certificate. This certificate is not a formality with M.I.T.

The designer is required to review and approve the submitted documentation.

**6.2 Third Party Testing**

The company performing the third party testing of the fire alarm system is hired directly by M.I.T. The installing contractor of the fire alarm system will be responsible for supporting the third party testing with staff, materials and programming expertise. The third party testing contractor will not perform any work on the fire alarm. The contractor will need to be responsible for having a manufacturer’s representative available during the third party testing to review and make changes to the fire alarm system program as necessary.
The contract documents should include an estimated duration of the third party testing. M.I.T. can provide historical durations for third party testing for similar projects. This duration is dependent on the quality of the design documents and the installation. The duration is important since it is one aspect that is not included initially in the project schedule and can delay occupancy of the building.

The third party testing will include integrated end to end testing. The intent of the integrated testing is to confirm that the interconnections are complete and the anticipated functionality is verified. For example, the integrated testing for a fire alarm and stair pressurization system would confirm that the stair pressurization fans activate when a smoke detector activates, it is not the intent of the integrated testing to confirm that the pressure is sufficient and the door opening forces are within code requirements. Representatives for each of the interconnected systems need to be available for this integrated testing. The contract documents must reflect this requirement.

## 7. PRACTICES AND PROCEDURES

### 7.1 General Comments to the Fire Alarm System Designer

The designer must require that the contractor follow NFPA 241: Standard for Safeguarding Construction, Alteration and Demolition Operations and FM Global Property Loss Prevention Data Sheet 1-0, ‘Safeguards During Construction, Alteration, and Demolition’ during construction. Requirements will differ for each project and must be discussed with M.I.T.

The fire alarm designer must require that the contractor maintain fire alarm equivalency during demolition and renovations. This will generally require that the contractor submit an impairment plan for M.I.T.’s approval. The designer must discuss this need with M.I.T. prior to completion of the contract documents.

The fire alarm system designer must prepare a narrative & sequence of operations as required by the Massachusetts State Building Code for all fire alarm systems. This is to be presented in preliminary form at the Detailed Design stage of the project.

The designer must require that the contractor follow the M.I.T. Shutdown Notification Procedure whenever any fire alarm system is to be impaired. The M.I.T. project manager should be contacted for additional details on this procedure.

Narratives, drawings and other documentation will be required at a number of stages in the design process.

A fire alarm input / output matrix will be required for all fire alarm installations. A draft of this matrix will be required at the Design Development stage. This must be submitted in editable form such as Microsoft Excel, and must be made available to the contractor in that same form as
part of the contract documents. In most projects the matrix will require interface with at least the designer of the building automation system but in more complex projects the electrical, lighting and access control designers may be impacted. The fire alarm system designer is responsible for coordinating with the other designers as necessary and for doing so at an early stage in the design.

The designer must require that the input / output matrices be updated by the contractor along with as-built drawing and approved by the design professional before final approval and payment to the contractor. The designer must require that a draft, pencil-set of as-built documents and matrices be maintained on the job site and updated on a 48 hour basis.

The fire alarm design professional is required to periodically perform reviews of the work that include verification of as-built conditions and compliance with approved contract documents. The contract documents should specify the required content and format of the final close-out documents. These reviews are referred to as Construction Control in the Massachusetts State Building Code, 780 CMR: State Board of Building Regulations and Standards. These are reviews and spot-checks only.

Contract documents must be clear that the fire alarm contractor must participate in or be responsible for all necessary testing. First the designer must require that the contractor is responsible for ensuring that an NFPA 72 fire alarm system acceptance test has been completed and documented. In addition to the contractor testing, a third party test will be conducted by a contractor hired by M.I.T., the designer will witness a test, and Cambridge Fire Department will complete their test. The contractor must then take part in integrated system testing to the extent required by any other testing protocols. Discussion with M.I.T. will be required to determine what, if any, these protocols will be. Only after the NFPA 72 acceptance test is completed and the test report reviewed and accepted by both the designer and M.I.T., should any integrated testing or third party testing be scheduled. This must be made clear in the contract documents. The contractor must be required to submit a written statement indicating that the system has been installed in accordance with the approved documents and tested in accordance with the manufacturer’s published instructions and the appropriate NFPA requirements. The Contractor is required to support the testing required by Cambridge Fire Department.

### 7.2 Areas Where M.I.T. Requirements May Differ from Common Practice

These differences must be understood by the designer and must be clearly spelled out in the contract documents. Failure of the contractor to understand these differences and a consequent bid and schedule based on common practice will result in delays, RFI’s and potential change orders.

1. The contractor must provide adequate time in his schedule and budget in his bid to accomplish the level of initial acceptance testing that is expected. This testing, while not exceeding the requirements in NFPA 72, is expected to strictly conform to the requirements of that document. That expectation likely differs from that which most owners have.
2. The contractor must maintain fire alarm and notification functionality during demolition and renovations. This usually requires submission of an impairment plan for M.I.T.’s approval. The designer must discuss this need with M.I.T. prior to completion of the contract documents.

3. The contractor must coordinate testing of fire alarm, emergency power, HVAC, FCS, elevators and any other systems connected to the fire alarm system. Projects for other owners may not require this work. The contract documents need to require support from the contractors that are familiar with the systems that are interconnected with the fire alarm system.

4. The building must have full coverage of audible notification appliances. Visible notification appliances are to be provided in all public, common and high noise areas of the building. These must also provide clear voice intelligibility in the identified areas. These requirements are particularly important in a college environment where emergency notification may be required and in a lab environment where noise from testing machines or lab experiments may create difficulties in hearing an alarm or announcement. M.I.T.’s requirements in this area are strictly enforced and may cause the addition of notification devices if coverage is not seen to be sufficient. Additionally, a record of the contractors testing of the achieved sound pressure levels is required.

5. Stranded wire that is properly color coded is required for all fire alarm work. While the Code allows the use of solid wire, M.I.T. does not. This requirement is based on M.I.T.’s experience in maintaining and repairing its own fire alarm systems. Stranded wire is more reliable and the color coding makes service considerably easier. Most owners contract out the maintenance and are indifferent to wire type or color coding.

6. Contractors sometimes install systems requiring special staging or ladders longer than standard stepladder for routine maintenance or testing. This is not acceptable at M.I.T. Accessibility and maintainability must be prime criteria in locating fire detection devices, the specification must address this issue. Air sampling smoke detection may be required in high ceiling areas.

7. M.I.T. has a close relationship with the Cambridge Fire Department. That relationship is often beneficial in explaining the special conditions that often exist in campus buildings. Design professionals should not meet with the fire department without M.I.T. approval or without a representative from M.I.T. in attendance.

8. M.I.T.’s residential fire alarm requirements have been explained elsewhere. These differ from common practice and must be clearly explained.

9. Items such as circuit loading and battery capacity differ from common practice. These requirements flow from the need to maintain extra capacity which will facilitate the many changes that M.I.T. buildings undergo.

### 7.3 Areas Where M.I.T. Requirements or Practice Differ from Code

Fire alarm systems must conform to the requirements of NFPA 72, the National Fire Alarm and Signaling Code and to Massachusetts 527 CMR 24.00.

1. Testing is required in NFPA 72. The M.I.T. requirements do not differ from what is required in any way. The principal difference here is that both M.I.T. and the Cambridge Fire Department (CFD) expect that the requirements will be met. Many owners do not enforce compliance with NFPA 72 and some contractors are surprised when M.I.T.
CFD do. This should have no cost impact.

2. The Code devotes 2-1/2 pages to discussion of the audible characteristics of notification appliances. It requires the documentation of required sound pressure levels for each space and, if required by the AHJ, the documentation of actual sound pressure levels achieved. M.I.T. has adopted this latter requirement though CFD has not generally asked for such documentation. This requirement would have a modest cost impact.

3. The Code requires that voice intelligibility standards be met when the system will be used for Emergency Notification. Such a notification system is under consideration by Security and Emergency Management Office (SEMO) at this time. The fire alarm systems are not presently designed to support Emergency Notification but some decisions have been made to allow more cost effective implementation in the future. These decisions include the following:

a. Change wording on horn or speaker strobes from “fire” to “alert”, this has no cost impact.

b. Require some additional junction boxes in the notification circuit wiring to facilitate the addition of more speakers in the future. Modest cost impact.

4. Code allows either solid or stranded wire for fire alarm systems. M.I.T. limits the contractor to stranded wire that must match the M.I.T. color coding chart. No cost impact.

END OF DOCUMENT
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1. **311000 - SITE CLEARING**

1.1 **Project Includes**

Site clearing includes the following as applicable to the project:

1. Protection of previously installed erosion control devices and/or stormwater BMPs.
2. Protection of existing trees, vegetation, landscaping, and site improvements not scheduled for clearing which might be damaged by construction activities.
3. Trimming of existing trees and vegetation as recommended by arborist for protection during construction activities.
4. Clearing and grubbing stumps and vegetation, removal and disposal of debris, rubbish, designated trees, and site improvements.
5. Topsoil stripping and stockpiling.
6. Temporary erosion control, siltation control, and dust control.
7. Temporary protection of adjacent property, structures, benchmarks, and monuments.
8. Temporary removal and relocation of site lighting, site furnishings, fencing, play structures and other site improvements scheduled for reuse.
9. Watering of trees and vegetation during construction activities.

1.2 **Operations**

Prevent damage to existing improvements indicated to remain, including improvements on and off site. Protect existing trees and vegetation indicated to remain. Do not stockpile materials, and disallow traffic within drip line of existing trees to remain. Provide and maintain temporary guards to encircle trees or groups of trees to remain; obtain approval of protective measures before beginning work.

Water vegetation as required to maintain health. Do not tear or rip tree roots during excavation with machinery; certified arborist shall root prune utilizing an air spade prior to excavating or trenching as directed by Owner. Cover temporarily exposed roots with wet burlap and backfill as soon as possible.

If construction operations damage vegetation, repair or replace vegetation or pay damages as acceptable to the MIT Project Manager. Remove heavy growths of grass before stripping. Stockpile satisfactory topsoil containing no large stones, foreign matter and weeds on site for reuse.
Completely remove all improvements including stumps and debris except for those indicated to remain. Remove below grade improvements at least 12 inches below finish grade and to the extent necessary so as not to interfere with new construction. Remove abandoned mechanical and electrical work as required. Consult with Owner for permission before leaving any abandoned utilities in place.

Prevent erosion and siltation of bare soils. Protect streets, sidewalks, catch basins and piping from sedimentation. Control windblown dust. Cover or seed stockpiles remaining longer than 14 days. Any soils required for removal will be tested and stockpiled at end of day, and off-site disposal will be coordinated thru Owner and MIT EHS at MIT approved sites. Remove waste materials and unsuitable soil from site and dispose of in a legal manner with MIT approval.

2. **312000 - EARTH MOVING**

2.1 **Project Includes**

Earthwork operations.

2.2 **Quality Assurance**

Compaction:

1. Under structures, building slabs, steps, pavements, and walkways, 95 percent maximum density, ASTM D1557.
2. Under lawns or unpaved areas, 90 percent maximum density, ASTM D1557.

Grading Tolerances Outside Building Lines:

1. Lawns, unpaved areas, and walks, plus or minus 1 inch.
2. Pavements, plus or minus 1/2 inch.

Grading Tolerance for Fill Under Building Slabs:

1. Plus or minus 1/2 inch measured with 10-foot straightedge.

2.3 **Products**

1. Earth moving materials may include:

   a. Subbase Material: Graded gravel or crushed stone.
   b. Bedding Course: Graded crushed gravel and sand.
   c. Borrow Soil: Off-site soil for fill or backfill.
   d. Drainage Fill: Washed gravel or crushed stone.
e. Common Fill: Mineral soil free from unsuitable materials.
f. Structural Fill: Graded gravel.
g. Impervious Fill: Gravel and sand mixture.

2. Applications may include:
   a. Excavation, filling, compacting and grading operations both inside and outside building limits as required for below-grade improvements and to achieve grades and elevations indicated. Provide trenching and backfill for mechanical and electrical work and utilities.
   b. Subbase materials, drainage fill, common fill, and structural fill materials for slabs, pavements, and improvements.
   c. Suitable fill from off-site if on-site quantities are insufficient or unacceptable, and legal disposal of excess fill off-site.
   d. Imported fill materials will be tested and approved by MIT according to Section 312322 prior to shipment to MIT.

3. Rock excavation without blasting unless blasting is specifically authorized.

2.4 Installation

Excavation is unclassified and includes excavation to subgrade regardless of materials encountered. Repair excavations beyond elevations and dimensions indicated as follows:

1. At Structure: Concrete or compacted structural fill.
2. Elsewhere: Backfill and compact as directed.

Maintain stability of excavations; coordinate shoring and bracing as required by authorities having jurisdiction. Prevent surface and subsurface water from accumulating in excavations. Stockpile satisfactory materials for reuse, allow for proper drainage and do not stockpile materials within drip line of trees to remain or RPZ, whichever is larger.

Compact materials at the optimum moisture content as determined by ASTM D 1557 by aeration or wetting to the following percentages of maximum dry density:

1. Structure, Pavement, Walkways: Subgrade and each fill layer to 95 percent of maximum dry density to suitable depth.
2. Unpaved Areas: Top 6 inches of subgrade and each fill layer to 90 percent maximum dry density.

Place acceptable materials in layers not more than 8 inches loose depth for materials compacted by heavy equipment and not more than 4 inches loose depth for materials compacted by hand equipment to subgrades indicated as follows:

1. Structural Fill: Use under foundations, slabs on grade in layers as indicated.
2. Drainage Fill: Use under designated building slabs, at foundation drainage and elsewhere as indicated.
3. Common Fill: Use under unpaved areas.
4. Subbase Material: Use under pavement, walks, steps, piping and conduit.

Grade to within 1/2 inch above or below required subgrade and within a tolerance of 1/2 inch in 10 feet.

Protect newly graded areas from traffic and erosion. Recompact and regrade settled, disturbed and damaged areas as necessary to restore quality, appearance, and condition of work.

Control erosion to prevent runoff into sewers or damage to sloped or surfaced areas.

Control dust to prevent hazards to adjacent properties and vehicles. Immediately repair or remedy damage caused by dust including air filters in equipment and vehicles. Clean soiled surfaces.

Dispose of waste and unsuitable materials off-site in a legal manner.

3. **312500 - EROSION AND SEDIMENTATION CONTROLS**

### 3.1 Project Includes

Implementing an erosion and sediment control program to minimize erosion and siltation during the construction phase of all campus sites subject to land disturbance.

1. Projects that meet the City of Cambridge requirements for the Land Disturbance regulations are required to develop and follow a site specific Stormwater Pollution Prevention Plan (SWPPP) and shall follow the erosion and sedimentation controls as outlined in this plan.

These erosion and sediment control provisions are the minimum requirements for an erosion control program. The Contractor shall provide additional erosion and sediment control materials and methods as required to affect the erosion and siltation control principles described herein.

1. Erosion control measures shall be established at the beginning of construction and maintained during the entire period of construction. On-site areas which are subject to severe erosion, and off-site areas which are especially vulnerable to damage from erosion and/or sedimentation, are to be identified and receive special attention.
2. All land-disturbing activities are to be planned and conducted to minimize the size of the area to be exposed at any one time, and the length of time of exposure.
3. Surface water runoff originating upgrade of exposed areas should be controlled to reduce erosion and sediment loss during the period of exposure.
4. When the increase in the peak rates and velocity of storm water runoff resulting from a land-disturbing activity is sufficient to cause accelerated erosion of the receiving stream
bed, provide measures to control both the velocity and rate of release so as to minimize accelerated erosion and increased sedimentation of the stream.

5. All land-disturbing activities are to be planned and conducted so as to minimize off-site sedimentation damage.

6. The Contractor is responsible for cleaning out and disposing of all sediment once the storage capacity of the sediment facility is reduced by one-half. Sediment disposal will be conducted to meet regulatory requirements.

7. Inspect, repair, and maintain erosion and sedimentation control measures during construction until permanent vegetation has been established. Condition of erosion control device shall be checked twice each month or more frequently as required. Damaged and/or deteriorated items shall be replaced.

8. Remove erosion and sedimentation controls and restore and stabilize areas disturbed during removal.

3.2 Submittals

Proposed methods, materials to be employed, and schedule for effecting erosion and siltation control and preventing erosion damage shall be submitted for approval. Submittals shall include:

1. Proposed methods for effecting erosion and siltation control including 1" = 40' scale plans indicating location of erosion control devices and siltation basins.
2. List of proposed materials, including manufacturer's product data.
3. Schedule of erosion control program indicating specific dates from implementing programs in each major area of work.

3.3 Quality Assurance

The objective is to minimize to the maximum extent practicable, sediments or pollutants exiting the site, entering the public right-of-way or being deposited into any Water Resource or stormwater drainage system.

1. In order to meet these objectives, the Contractor shall:
   a. Implement measures intended to keep soil on site or out of water resources, stormwater drainage systems or the public right-of-way as the first step in any development.
   b. Remove any soil that enters the public right-of-way.
   c. Protect stormwater inlets that are functioning during the course of the development by approved sediment control measures so that sediment-laden water cannot enter the inlets without first being properly treated.
   d. Apply permanent or temporary soil stabilization to denuded development site areas in conformance with the City of Cambridge Wastewater and Stormwater Management Guidelines.
   e. Plant replacement vegetative cover in accordance with the City of Cambridge Wastewater and Stormwater Management Guidelines.
   f. Secure or protect soil stockpiles throughout the project with temporary or permanent soil stabilization measures, protect all stockpiles on the site and those transported
from the site. All handling of soils shall be done in accordance with the City of Cambridge Wastewater and Stormwater Guidelines and all applicable federal, state and local laws, rules and regulations. Soil stockpiles will be covered at the end of the day. Stockpiles remaining greater than 14 days must be seeded.

g. Post signage on the site of the permitted land disturbing activity that identifies the DPW 24-hour Hotline Number (617-349-4800).

h. Sequence activities to minimize simultaneous areas of land disturbance.

i. Maximize groundwater recharge as approved by DPW.

j. Properly manage on-site construction and waste materials.

k. Site Dewatering: Water pumped from the site shall be reviewed by MIT EHS for possible permit implications and shall be treated by temporary sedimentation basins, grit chambers, sand filters, upflow chambers, hydro-cyclones, swirl concentrators or other appropriate controls. Water shall not be discharged in a manner that causes erosion or flooding of the site or receiving channels or a wetland.

When MIT or the Architect determines that special site conditions may prevent compliance with the objectives outlined above, MIT or Architect may require additional erosion, sediment and pollutant control measures as set forth in the City of Cambridge Wastewater and Stormwater Management Guidelines.

1. Special site conditions may include, but are not limited to, the following:
   a. Slopes before development that are greater than 10 percent (1 Vertical: 10 Horizontal).
   b. Land disturbance of a natural vegetative buffer within 50 feet of a wetland and/or waterbody.
   c. The development site is located entirely or partially within a Flood Plain Overlay District.

2. Required additional control measures may include but are not limited to:
   a. Requiring that a Massachusetts registered professional engineer (P.E.), other professional certified by the State of Massachusetts with experience or qualifications in preparing erosion and sediment control plans, a registered CPESC or Massachusetts registered Landscape Architect prepare or implement the Erosion and Sediment Control Plan.
   b. Limiting the quantity of denuded soil at any given time
   c. Requiring a bond, letter of credit or other guarantee.

Comply with governing codes and regulations. Provide products of acceptable manufacturers which have been in satisfactory use in similar service for three years.

Use experienced installers.

Deliver, handle, and store materials in accordance with manufacturer’s instructions.
3.4 Products

Silt fence shall be a wire-bound woodroll snow fence covered with filter fabric. Fence shall be 4 ft. high minimum, and shall have 3/8 in. by 1-1/2 in. wide pickets, approximately 2 in. apart, bound together with at least 13 gage minimum, galvanized steel wire.

Hay bales for construction of erosion control devices shall be new, firm, wire- or nylon-bound livestock feed-grade and free of weed seed.

Erosion Control Blankets shall be specifically designed and engineered using 100% biodegradable materials for ecologically sensitive areas like wetlands, stream bank stabilization, forest lands.

1. Utilize woven nettings of type and material to ensure consistent quality and performance while limiting the potential for wildlife entanglement.

Temporary Seed shall conform to MHD Specifications Section M6.03.0, "Seed for Slopes and Shoulders".

Filter baskets shall be Fossil Filter, manufactured by Kristar Enterprises, Inc. KriStar Enterprises, Inc. Cumming, Georgia or approved equal. Baskets shall be installed at all catch basins in lieu of Hay Bale Catch Basin Filters.

3.5 Installation

Install materials and systems in accordance with manufacturer's instructions and approved submittals. Install materials and systems in proper relation with adjacent construction. Coordinate with work of other sections.

3.6 Maintenance and Removal of Erosion Control Devices

Wetland areas, water courses, and drainage swales adjacent to construction activities shall be monitored twice each month, within 24 hours after rainfall, or daily if there is an active Stormwater Pollution Prevention Plan (SWPPP) in place for the site, for evidence of silt intrusion and other adverse environmental impacts, which shall be corrected immediately upon discovery.

Culverts and drainage ditches shall be kept clean and clear of obstructions during construction period.

Maintenance of Erosion Control Devices unless required otherwise by the SWPPP:

1. Sediment behind the erosion control device shall be checked twice each month and after each heavy rain. Silt shall be removed if greater than 6 in. deep.
2. Condition of erosion control device shall be checked twice each month or more frequently as required. Damaged and/or deteriorated items shall be replaced. Erosion control devices shall be maintained in place and in effective condition.
3. Hay bales shall be inspected frequently and maintained or replaced as required to maintain both their effectiveness and essentially their original condition. Underside of bales shall be kept in close contact with the earth below at all times, as required to prevent water from washing beneath bales.

4. Sediment shall be removed from the retention ponds at the completion of the Project and periodically during construction. Sediment deposits shall be removed when sediment has accumulated to a depth of 12 in. or as directed.

5. Sediment deposits shall be disposed of off-site, in a location and manner which will not cause sediment nuisance elsewhere.

Removal of Erosion Control Devices

1. Erosion control devices shall be maintained until all disturbed earth has been paved or vegetated, at which time they shall be removed. After removal, areas disturbed by these devices shall be regraded and seeded.

2. Erosion control netting shall be kept securely anchored until start of permanent turf construction.

3. Erosion protection material shall be kept securely anchored until acceptance of completed slope or entire Project, whichever is later.

4. 313100 - SOIL TREATMENT

4.1 Integrated Pest Management (IPM)

Comply with MIT integrated pest management requirements, included in the EH&S Thematic Folder.

5. APPENDICES

5.1 Construction Specifications

Refer to the following documents, to be used in their entirety for applicable projects.

Division 01 specifications are attached to Division 01 of the MIT Design Standards.

   Section 015640 - MIT Temporary Tree and Soil Protection

Division 31 specifications are attached to Division 31 of the MIT Design Standards.

   Section 312317 - MIT Specialized Root Zone and Soil Excavation
   Section 312322 - MIT Imported Fill Criteria and Management

Division 32 specifications are attached to Division 32 of the MIT Design Standards.

   Section 321313 - MIT Concrete Paving
SECTION 312317
MIT SPECIALIZED ROOT ZONE AND SOIL EXCAVATION

PART 1 GENERAL

1.1 GENERAL PROVISIONS

A. Attention is directed to the CONTRACT AND GENERAL CONDITIONS and all Sections within DIVISION 01 - GENERAL REQUIREMENTS which are hereby made a part of this Section of the Specifications.

B. Examine all Drawings and all Sections of the Specifications for requirements and provisions affecting the Work of this Section.

1.2 DESCRIPTION OF WORK

A. Provide all work equipment, labor and supervision necessary to perform specialized root zone and soil excavation with a compressed air-powered tool also referred to as an air spade, within the limits indicated on the Drawings and as specified herein. Work shall include, but not be limited to, the following:

1. Remove and break up soils around existing trees to conduct visual inspection and correction of specific plant health concerns.
2. Remove and break up soils around existing trees to conduct diagnosis of plant diseases.
3. Remove and break up soils around existing trees to facilitate application of blended soils or amended soils to promote root growth.
4. Remove and break up soils around existing trees to facilitate root pruning.
5. Remove and break up soils around existing trees to locate tree roots.
6. Remove and break up soils around existing trees to accommodate proposed site construction.
7. Root Collar (Crown) Excavation (RCX) to expose the lower trunk and buttress roots of the designated trees and shrubs.
8. Soil replacement for the prevention or mitigation of soil compaction, poor drainage, soil structural issues or new landscape construction.
9. Root pruning.
10. Removal of all rubbish, debris, and other materials to be disposed of as a result of the work of this section.

1.3 DEFINITIONS

A. Arborist: An individual engaged in the profession of arboriculture who, through experience, education and related training, possesses the competence to provide for, or supervise the management of, trees and other woody ornamentals.

B. Dripline: an imaginary line defined by the branch spread.

C. Critical Root Zone (CRZ): The minimum volume of roots necessary for maintenance of tree health and stability, typically determined by measuring the tree diameter 4.5 ft. above grade and multiplying by 12 in., a minimum radius of 10’ from the trunk, or at the tree's dripline, whichever is farthest from the trunk, or as otherwise indicated on the Drawings, or established in the field. CRZ will be determined/established on a case by case basis by the Arborist and approval by the Landscape Architect.
D. Finish Grade: Elevation of finished surfaces.

E. Hand-Digging: Careful soil excavation using ‘hand-tools’ to expose roots for inspection or to determine where mechanical excavation can be done without causing significant root damage or loss.

F. Subgrade: Surface or elevation of subgrade soil remaining after completing excavation, or top surface of a fill or backfill immediately beneath planting soil.

G. Topsoil: Soil that is present at the top layer of the existing soil profile at the Project site.

H. Loam: Soil that contains a combination of particles typically almost equal in parts sand, silt and clay and including organic matter.

I. Mulch: A material placed on the soil surface composed of 100% fine-shredded pine bark or wood chips generated by sending tree parts through a wood chipping machine of uniform size and free from rot, leaves, twigs, debris, stones, or any material harmful to plant growth. No chunks 3 in. or more in size, and thicker than 1/4 in. shall be left on site.

J. Leaf Compost: Well-composted, stable, and weed-free organic matter, pH of 5.5 to 8; moisture content 35 to 55 percent by weight; 100 percent passing through a 1-inch (25-mm) sieve; soluble-salt content of 2 to 5 dS/m; not exceeding 0.5 percent inert contaminants and free of substances toxic to plantings.

K. Tree Resource Evaluation: A document or site plan describing the tree resources on the site, with information provided from an inventory or survey including: tree species, size (DBH), location, condition and liklihood of failure.

1.4 SUBMITTALS

A. Prepare and submit a “Specialized Root Zone and Soil Excavation Plan”, indicating the extent of soils to be air spaded. Show all areas of proposed staging, vehicle or equipment access, trenching, excavating, or other disturbance to soils. Include

1. Proposed plan will be reviewed and approval by the Owner and Landscape Architect. No work of this Section shall commence prior to approval.

B. Prepare and submit a “Tree Resource Evaluation”, as defined herein.

C. Proposed methods, materials, and schedule for effecting soils and root zones, in accordance with ANSI A300 (All Parts), shall be submitted by Certified Arborist for approval.

D. Submit schedule of existing trees to be air-spaded.

E. Submit a description of each type of proposed specialized root zone and soil excavation operation and reason for and location of each type described. Specialized root zone and soil excavation operations shall include, but not be limited to:

1. Soil aeration and decompaction.
2. Radial trenching.
3. Vertical mulching.
4. Root collar excavation.
5. Root pruning.
6. Bare rooting.
7. Soil replacement.
8. Transplanting.
9. Root training.
11. Excavation or trenching required for construction or utility work in CRZ.

F. Conduct a Tree Root Zone Investigation and evaluate the crown/foliage rating of each tree. Submit a health assessment for each tree to undergo specialized soil excavation operations, prepared by a Certified Arborist, indicating that each tree is healthy enough to withstand the proposed air spade operation and anticipated soil and/or root system disturbance.

1. Submit digital photos documenting tree conditions and illustrating the findings of the Tree Root Zone Investigation. Refer to Paragraph 3.05.

1.5 PROPERTY PROTECTION

A. Prevent damage to and movement, settlement or collapse of adjacent services, utilities, structures and trees. Assume liability for such damage, movement, settlement, or collapse. Promptly repair damage at no cost to the Owner.

1.6 TREE DAMAGE PENALTIES

A. Refer also to Section 015640 - MIT TEMPORARY TREE AND SOIL PROTECTION.

B. Certain specimen trees within the construction areas and in other key locations will be identified by the Owner and the Architect, and marked with red tags. Loss of any of these trees will result in fines assessed at $10,000 per tree. Damage to all other trees on the property will be assessed at the rate of $200 per inch caliper of the tree.

1. If at any time during the operation, damage to the trunk or root bark is noticed, the operator shall move the tool further from the root or trunk, or stop the operation. Bark damage is not acceptable and will result in fines.

C. A fine of $1,000 will be levied against the Contractor for incursion inside tree protection areas.

D. Damages to trees, shrubs, and other vegetation will be assessed by the Architect and Owner in accordance with the fine structure prescribed in Paragraphs A. and B. above.

E. Trees or roots visibly damaged will cause the Owner to withhold from the Contractor an assessed amount conforming to the requirements stipulated above for a period of two years. After that period the impact of the damage to any tree will be assessed accordingly.

F. If any trees or shrubs designated to be saved are damaged and replacement is required, a number and diameter of trees or shrubs of the same species and variety, as specified by the Owner and Architect, shall be furnished and planted by the Contractor. The total inch diameter of the replacement trees or shrubs shall equal the diameter of the tree or shrub to be replaced.

1.7 EXISTING SERVICES

A. Existing structures and utilities shall be suitably protected from damage.

1.8 QUALITY ASSURANCE
A. Work of this section shall be completed by a professional Certified Arborist with a minimum five years experience, who has successfully the Massachusetts Certified Arborist (MCA) program/examination sponsored by the Massachusetts Arborists Association, 8-D Pleasant Street, South Natick, MA 01760; (508) 653-3320; FAX: (508) 653-4112; E-mail: MaarbAssn@aol.com.

B. Arborist shall have the following minimum qualifications:

1. Certification by:
   a. TCIA -- Tree Care Industry Association, Inc. accreditated company
   b. ISA – International Society of Arborists
2. Meet state requirements for insurance.
3. Licenses for application and use of pesticides if pesticide application will be required.

C. Equipment utilized to complete the work of this Section shall be operated by experienced technicians, trained and certified by equipment manufacturer to safely and properly operate the compressed air-powered tool in accordance with manufacturer’s Operator’s Manual and the “AirSpade Technical Applications Bulletin (2016)”.

D. Air spade operations shall not be performed in heavy rain or when soil is deemed too wet or too dry by Certified Arborist.

E. Tree trunks shall be suitably protected from damage by air spade operations during all activities specified.

1.9 SITE MONITORING

A. While use of an air spade can significantly reduce trauma to the tree, it is important to monitor the trees health and care before, during and after the procedure. Supplemental watering is typically necessary and should be provided with direction and continued monitoring of a Certified Arborist.

B. Site monitoring shall be the responsibility of a Certified Arborist. Any damage to existing trees shall be immediately reported to the Architect. If any tree has been damaged, work shall be halted and reasons for damage assessed. No work shall commence until Contractor has submitted a plan for prevention of further tree damage and plan has been approved in writing by Landscape Architect.

1.10 PRECONSTRUCTION CONFERENCE

A. Pre-Construction Conference: Prior to implementing specialized root zone and soil excavation measures, conduct meeting with Landscape Architect, Certified Arborist, air spade manufacturer’s representative and Owner to verify and review the following:

1. Project requirements for tree and soil protection measures as set out in Contract Documents.
2. Air spade manufacturer's product data including application, operation and safety instructions.
3. Limits where specialized root zone and soil excavation measures shall be implemented.
4. Areas of proposed staging, vehicle or equipment access, trenching, excavating, or other disturbance to soils.
5. Health care needs of individual trees, including specific site conditions, that may affect the project goals or construction implementation strategy.
6. Tree health care implementation strategy before, during and after construction.
C. If air is drained from the hose and air tool, the tip of the tool shall be in contact or beneath the soil surface to avoid excessive noise.

PART 2 - PRODUCTS

2.1 EQUIPMENT

A. Specialized root zone and soil excavation operations shall be performed using a compressed air-powered tool also referred to as an air spade. High pressure air will come from a compressor that is matched to the design flow of the tool, producing a focused jet air stream capable of penetrating and fracturing existing soil for a fast, efficient method of excavating.

1. The compressor shall be in good working condition and exhibit no signs of excessive discharge of oil in the air stream.
2. Tool shall be equipped with a “dead-man trigger”.

PART 3 - EXECUTION

3.1 GENERAL

A. The site where air spading is to be performed shall have access restricted. Only personnel that are involved in the operation shall be permitted within 25 feet of the operation. A temporary screen barrier shall be set up to prevent flying rocks and debris from leaving the immediate work area during the operation.

B. Personnel using the air tool or working in close proximity to the operation shall wear appropriate personal protective equipment which includes at a minimum:

   1. Hard hat with plastic face shield
   2. Goggle type eye protection
   3. Ear plugs
   4. Ear muffs
   5. Long sleeved shirt and long pants
   6. Work boots and socks

C. If the area has active fire ant activity, personnel shall take precautions including sealing of cuffs and the use of insect repellents to avoid fire ant attack.

D. Air hoses used in the operation shall have safety pins and whip guards installed at each hose junction.

E. The air flow heating valve (if present on the compressor) shall be turned off when working near trees so as not to damage bark.

3.2 SOIL PREPARATION

A. Trees proposed to undergo specialized root zone and soil excavation operations shall be adequately watered before start of operations. Amount and frequency of watering shall be determined by Certified Arborist. No operations shall commence prior to preparation approval in writing by Certified Arborist.

B. Soil shall be moist to the point of field capacity prior to and during the operation. If dust is generated during the operation, it shall be stopped and the soil should be wetted. If turf,
large rock or mulch is present in the area to be included in the excavation, it shall be removed prior to the start of the operation.

3.3 AIR TILLING

A. Contractor shall utilize the air spade tool to aerate and de-compact to the specified depth (typically 6-8 in.) of the topsoil layer. If modification to soil content and aeration is necessary to a greater depth, then this application can be combined with others such as radial trenching or vertical mulching. (Refer to Paragraphs 3.06 and 3.07).

1. Place plywood sheets over adjacent trenches to prevent refilling.
2. Position the AirSpade at an angle of 30° to 45° (depending on target depth) and about 1 inch from the surface.
3. Move the nozzle from side to side to define the desired trench width
4. Do not dwell on the same spot.
5. Width, depth and length of trench, and soil augmentation to be determined based on tree needs and project goals.
6. The adjustable dirt shield should be positioned close to the ground to deflect airborne material away from the operator.
7. Refer to manufacture’s updated safety and operational guidelines.

3.4 SOIL AUGMENTATION

A. Soil augmentation: Fertilizers, composts or other soil components shall be applied evenly and at rates determined by soil test results in accordance with Section 329115 - MIT PLANTING SOILS. Soil amendments shall be blended into existing soil using an air spade.

3.5 TREE ROOT ZONE INVESTIGATION

A. At a minimum, Tree Root Zone Investigation shall include the following:

1. Establishing the objective of the inspection, such as detecting cut or damaged roots, particularly where trees are located near to recent excavation works on building sites or where trenches for underground utilities have been dug, root disease or decay, drilling for decay, collecting samples for submission to a Lab.
2. The location of tree roots may also need to be determined, for example during an assessment to trees in relation to building subsidence or when planning construction works near to a tree.
3. Defining the area to be excavated – mark the soil surface of the area to be inspected and define the depth of inspection/soil removal.
4. After inspection, define how the space is treated i.e. fill it in with the same soil, new soil or leave open; mulch, sod, or seed on surface.
5. Define aftercare e.g. soil moisture sensors, irrigation level or frequency.

B. The assessment should also provide any recommendations for tree protection, health care before, during, and after the completion of site work, and any additional issues or constraints that should guide project goals and/or implementation strategies based on tree and field conditions.

C. Utilize air spade or hand dig to carry out subterranean investigations to ascertain the condition of structural roots to assess tree stability. Air spade shall be used to investigate suspected tree root decay or damage.

3.6 VERTICAL MULCHING
A. Vertical mulching with air spade shall be used to de-compact and augment soil deep into the tree root zone.

B. Spray paint target marks on the ground to indicate hole locations.

C. Bore holes shall be to specified depth (typically 18 to 36 in. deep) depending on individual site needs and determined health of trees. When resistance is met, slowly withdraw the air spade and then reinsert, allowing loosened soil at the bottom of the hole to exit upwards.

D. Fill vertical holes with mature leaf compost or other augmentation material as recommended by Arborist.

E. To avoid undesirable concentrations of augmented nutrients ("hotspots"), use amendments that are compatible or blended with existing soils. Refer to Section 329115 - MIT PLANTING SOILS. For more extensive results, it is possible to perform vertical mulching over the course of several growing seasons.

3.7 RADIAL TRENCHING

A. Radial trenching with air spade shall be used to de-compact and augment soil into the tree root zone.

B. Spray paint lines on the ground to indicate trench locations.

C. Create trenches to a specific depth (typically 10 to 12 in. deep) depending on individual site needs and determined health of trees.

D. To avoid undesirable concentrations of augmented nutrients ("hotspots"), use amendments that are compatible or blended with existing soils. Refer to Section 329115 - MIT PLANTING SOILS.

3.8 ROOT COLLAR EXCAVATION

A. When grade is set too high against tree root flare or root collar it shall be corrected through root collar excavation with an air spade. Air spade must be kept moving back and forth. Do not dwell on same spot.

B. Fine roots should be cut and removed if they interfere with the excavation. The excavation shall be concluded when the upper portion of a majority of buttress roots are exposed. Once uncovered, Certified Arborist shall identify roots that need to be removed. Roots less than 1/4 in. diameter may be lowered into the soil using an air spade. If the excavation depth exceeds one foot, consult with the Certified Arborist and Landscape Architect. If signs or symptoms of decay or disease are noticed, notify the Certified Arborist and Landscape Architect. If a stem girdling roots that is less than 1/3 the diameter of the trunk is discovered during the operation, or if several small stem girdling roots are discovered, they should be removed. If stem girdling roots greater than 1/3 the diameter of the trunk or many smaller stem girdling roots are discovered, the Certified Arborist and Landscape Architect shall be notified.

C. Replace topsoil or augmented soil to cover roots to proper elevation. Refer to Section 329115 - MIT PLANTING SOILS.

D. After the excess soil is removed, the excavated area shall be filled with mulch or wood chips as directed by the Arborist. The mulch or wood chips shall not be in contact with the tree trunk and shall not hide the buttress roots from inspection. Mulch or wood chip depth
should be between 2 and 4 inches, based on the coarseness of the material and approved by the Certified Arborist and Landscape Architect.

3.9 ROOT PRUNING AND TRAINING

A. Trees subjected to soil cuts within the root zone shall be root pruned by a Certified Arborist utilizing an air spade, removing as little of the trees root system as possible.

B. Once existing roots have been safely exposed, a certified arborist shall determine the best places to make clean cuts using a hand pruner. Smaller roots shall be lowered down into soil horizon to help train them to follow a future path of growth.

C. When the tree’s excavated root zone will remain exposed for several days or more, protect and cover roots (for example with soil, mulch, or burlap cloth,) and provide supplemental water as required.

3.10 BARE ROOTING AND TRANSPLANTING

A. When bare rooting is required to relocate or replace soil around existing trees, utilize an air spade to minimize damage to the tree’s root system. Bare rooting operations shall expose existing tree roots as necessary to allow them to be pruned and turned down to accommodate new adjacent paving systems.

B. Using an air spade, remove almost all of the soil from the tree root system, or leave excess soil to transplant with the tree. Once the root zone is excavated, the Arborist can prune the root mass to the desired length. It is critical to keep bare roots protected from the sun and hydrated, and to minimize the time between excavation and transplanting.

3.11 SOIL REPLACEMENT

A. Refer to Section 329115 - MIT PLANTING SOILS.

3.12 DISPOSAL OF MATERIALS

A. Soil moved during the air spading operations shall be collected and moved off-site or disposed of on-site if it not visually apparent.

B. Material resulting from the specialized root zone and soil excavation work and not scheduled to be salvaged and which is unsuitable for reuse on the project, shall become the property of the Contractor and shall be legally disposed of off-site.

C. Debris, rubbish, and other material shall be disposed of promptly and shall not be left until final cleanup of site.

END OF SECTION
PART 1 - GENERAL

1.1 GENERAL PROVISIONS

A. Attention is directed to the CONTRACT AND GENERAL CONDITIONS and all Sections within DIVISION 01 - GENERAL REQUIREMENTS which are hereby made a part of this Section of the Specifications.

B. Examine all Drawings and all Sections of the Specifications for requirements and provisions affecting the Work of this Section.

1.2 DESCRIPTION OF WORK

A. This specification section applies to all Fill materials from off-site locations that are imported to complete the work of the Project. This applies to all Fills including, but not limited to, Fill required to complete earthwork, foundations, backfilling for structures and utilities, and preparation of subgrades for the structures, surface treatments, walkways and roadways, and landscaping.

B. MIT wants to be able to evaluate representative analytical test results for all imported fill soils. This includes test results to be submitted by the Contractor as part of their submittal process and following the review of that submittal, testing to be conducted the Engineer once the submitted fill has been stockpiled on site. Results of this testing will determine whether the stockpiled materials can be placed and used on the project.

C. Work to be done under this Section includes, but is not limited to, providing all labor, materials, equipment, and incidentals to conduct and complete the Work specified herein and shown on the Drawings, including but not limited to the following:

1. Furnish materials from approved off-site source(s) as required, including performing testing and providing data on the engineering properties and chemical characteristics representative of the materials and soils proposed for use.

2. Working with MIT, Architect, and Engineer to make sure the activities to meet the requirements of this Section are performed in the correct sequence.

1.3 EXISTING INFORMATION AND PROJECT CONDITIONS

A. Prior to submitting a bid, the Contractor shall review and understand the available subsurface information.

B. If, during the course of construction operations, conditions differing substantially from those indicated in the attached logs are encountered, promptly notify the Owner in writing, and do not disturb such conditions until directed. The Architect and/or Engineer will investigate such conditions, and, if it is determined that the conditions do differ substantially from those that reasonably would have been anticipated from examination of the report and site, and that such conditions will necessitate a change in the Work, the Architect and/or Engineer will recommend any required changes and adjustments. Verbal or written communications with field personnel will not constitute acknowledgment of a differing subsurface condition.

C. Prospective bidders shall visit the site and observe existing conditions prior to submitting a bid.
1.4 DEFINITIONS AND REFERENCE STANDARDS

A. Owner: Massachusetts Institute of Technology (MIT).

B. Architect: Authorized representatives of the Owner, Owner’s Representative

C. Engineer: Authorized representatives of the Owner, Owner’s Representative, or Architect.

D. Contractor: Entity responsible for completing the Work of this Section.

E. ASTM: Specifications of the American Society for Testing and Materials

F. AASHTO: American Association of State Highway and Transportation Officials

G. ACI: American Concrete Institute


I. OSHA: Occupational Health and Safety Administration

J. DEP – Massachusetts Department of Environmental Protection

K. MCP – Massachusetts Contingency Plan 310 CMR 40.0000; latest revisions

L. EPA – Environmental Protection Agency

M. Imported Fill shall include all soil or rock materials imported to the site including but not limited to Common Fill, Gravel, Structural Fill, Borrow, Granular Fill, Topsoil, Loam, Planting Soils, Planting Soil Components, Compost, Playground Sand, Impervious Fill, Sand/Sand Bedding, Drainage Fill, Crushed Stone, Dense Graded Crushed Stone, and any other materials called for in the Contract Documents.

1.5 QUALITY CONTROL

A. Comply with all rules, regulations, laws and ordinances of the Commonwealth of Massachusetts, City of Cambridge, and all other authorities having jurisdiction. All labor, materials, equipment, and services necessary to make the work comply with such requirements shall be provided without additional cost to the Owner.

B. The Contractor shall adhere to the applicable requirements of the Standard Specifications, OSHA Standards, and to all other applicable ordinances, codes, statutory rules, and regulations of federal, state, and local authorities having jurisdiction over the Work of this Section and other applicable Sections.

C. The Contractor is required to conduct various field and laboratory testing at various times to prepare submittals and confirm compliance with the requirements of this Section. The Contractor shall cooperate with the Engineer in all respects to facilitate observations or review of that work.

D. All Fill materials submitted by the Contractor to be imported to the site will be reviewed by the Engineer or Owner prior to use on the site and may be re-tested by the Owner and/or Engineer if they appear different in composition, gradation, or other physical properties from the testing provided in the submittal from the Contractor. The Contractor will bear the cost incurred by the Owner of any and all tests which are deemed necessary to confirm the material delivered to the site are suitable for use. Test results and recommendations will be made available to the Contractor on a timely basis.
E. The presence of the Engineer shall not relieve the Contractor of its responsibility to perform the Work in accordance with the Contract Documents, nor shall it be construed to relieve the Contractor from full responsibility for the means and methods of construction, protection of site improvements against damage, and for safety on the construction site.

F. Beyond those required by this section, the Contractor may conduct additional field and laboratory testing or screening tests for its own information at no additional cost to the Owner.

1.6 SUBMITTALS

A. General

1. Unless otherwise specified, the Contractor shall forward submittals to the Architect a minimum of fifteen (15) working days prior to any planned work related to the Contractor’s submittals.

2. The time period(s) for submittals are the minimum required to review, comment, and respond to the Contractor. The Architect and/or Engineer may require resubmission(s) for various reasons. The Contractor is responsible for scheduling specified submittals and resubmittals so as to prevent delays in the work.

3. The Contractor’s submittals shall be reviewed and accepted by the Engineer prior to conducting any work.

4. Acceptance of the Contractor's submittals by the Engineer does not relieve the Contractor of the responsibility for the adequacy, safety, and performance of the Work.

B. Submit the following:

1. Location and details of anticipated on-site or imported off-site material stockpiles.

2. Contractor shall not import any material to the site unless accepted in advance by the Engineer.

3. Imported Fill Materials: For each type of imported fill material to be utilized, the Contractor shall deliver to the Engineer’s office for review:
   a. two representative 50-lb bag samples from each borrow source or supplier from the actual material proposed for use on the project;
   b. laboratory analytical testing results representative of the bag samples submitted to the Engineer – see below for testing requirements;
   c. With each submitted sample the Contractor must provide the following documentation:
      1) Location of borrow source site, including name of the owner or facility name with contact phone number, street address, city, and state.
      2) Present and past usage of the source site and material.
      3) All existing report(s) associated with an assessment of the source site as relates to the presence of oil or hazardous materials.

4. Quality Testing of Off-Site Imported Fill Materials:
   a. Chemical testing is not required for material from customarily utilized commercial borrow sources and hard, intact, naturally-occurring mineral materials provided as building materials (eg: Crushed Stone, Dense Graded Crushed Stone).
   b. All other materials, including but not limited to: Common Fill, Gravel, Structural Fill, Borrow, Granular Fill, Topsoil, Impervious Fill, Sand Bedding, Drainage, Landscaping Soils and amendments, and any other material proposed for use by the Contractor – will be required to have representative analytical test results as part of their submittal in advance of bringing the material on-site and its proposed use.
   c. A summary of required testing is provided below in Table 2: Analytical Testing Provided by the Contractor.
   d. The data shall be for samples obtained, transported, and tested in a manner acceptable to the Engineer shall be taken from and be representative of the actual
volume of materials proposed for use on the project, and the testing shall be within the 30-days prior to making the submittal. The cost of any required sampling, testing, any retesting, and reporting shall be borne by the Contractor. The Engineer will review the data and determine its acceptability for use on site.

e. Samples of each material shall be submitted to a DEP-certified laboratory. All sampling of soils for chemical testing shall be performed by a person experienced in sample collection and either:
   1) A Professional Engineer or Licensed Site Professional registered in the Commonwealth of Massachusetts
   2) An authorized representative of the one of the persons listed above.

5. Sequence of Submittals, Testing, and Approval for Use of Imported Fill: As outlined below:
   a. The Contractor must provide representative analytical testing in accordance with this specification for all imported fills proposed for use.
   b. The Engineer will review these results in comparison to Table 1 - MIT’s Imported Fill Criteria, and will also evaluate whether the imported fill will may be exposed at ground surface.
   c. If the proposed material conforms to the Imported Fill Criteria and complies with other specified criteria – the Contractor will be notified in writing that they are allowed to import and stockpile – but not yet use – the material at the site. Otherwise, materials will be rejected for use.
   d. When the Contractor delivers and stockpiles materials at the site, the Contractor must provide a Bill-of-Lading for the material complete with date and time of loading from the supplying facility, date and time of deliver to site, name of transporter, and weight of material delivered to the site.
   e. The Engineer will review the materials stockpiled on-site for consistency with the physical properties and analytical testing submitted by the Contractor.
      1) If the materials appear consistent with the Contractors submittal, the Contractor will be informed in writing that they are authorized to proceed with the use of the imported materials.
      2) If the materials appear to differ from the information submitted by the Contractor, the Engineer will obtain samples from the stockpile and complete analytical or physical testing as deemed necessary by the Engineer to confirm if the materials delivered to the site meet the criteria in this Section.
   f. If re-testing is completed, the Engineer will review these results in comparison to Table 1 - MIT’s Imported Fill Criteria, specification requirements, and the analytical testing submitted by the Contractor for that material.
   g. If the representative analytical test results of the on-site stockpiled material are inconsistent with the Contractor-submitted test results for that material and/or do not conform to Table 1 - MIT’s Imported Fill Criteria or any other criteria of the specifications, the materials will be rejected and the Contractor must remove them from the site at no cost to the Owner.
   h. If the representative analytical test results of the on-site stockpiled material are consistent with the Contractor-submitted test results, other criteria of the specifications, and conform to Table 1 - MIT’s Imported Fill Criteria, the material will be approved for on-site use.

6. Samples to be submitted and tested for the following parameters:
   a. Total Petroleum Hydrocarbons (EPA Method 9071/418.1) every 250 cy.
   b. Extractable and Volatile Petroleum Hydrocarbons every 250 cy.
   c. Volatile Organic Compounds (EPA Method 8260) every 250 cy.
   d. PCB and Pesticides (EPA Method 8080) every 250 cy.
   e. Thirteen Priority Pollutant Metals (EPA Method 6000-7000 series) every 250 cy.
   f. Acid-Base Neutrals (EPA Method 8270) every 250 cy.
g. TCLP (for a particular parameter) if the measured concentration for that particular parameter exceeds twenty times the RCRA Hazardous Waste TCLP Regulatory criteria.

7. Submit additional material samples and representative analytical test results throughout the course of the Work, in the same frequency as listed above, to evaluate and document the consistency of the source or process, at no additional cost to the Owner. If the properties of the material and/or representative analytical test results are inconsistent with the previously submitted test results for that material, inconsistent with the physical properties of the previously submitted materials, and/or do not conform to Table 1 - MIT’s Imported Fill Criteria, they will be rejected.

8. Soil Volumes - The Contractor shall estimate and submit to the Engineer the i) total excavation volume of soil from the Work outlined on the Drawings and ii) total off-site volume of materials needed for Imported Fill to backfill excavations, provide raise in grade, backfill trenches, complete landscaping, and make the work complete based on the details shown on the Drawings.

Table 1: MIT IMPORTED FILL CRITERIA

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Depth 0-2' Planting Medium Criteria (mg/kg)</th>
<th>Depth 2' below grade Planting Medium OR Subgrade Materials Criteria (mg/kg)</th>
<th>MCP RCS-1 Criteria (mg/kg)</th>
</tr>
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<tbody>
<tr>
<td>volatile organic compounds (VOCs)</td>
<td>ND</td>
<td>ND</td>
<td>NA</td>
</tr>
<tr>
<td>organochlorine pesticides - standard method 8081</td>
<td>ND</td>
<td>ND</td>
<td>NA</td>
</tr>
<tr>
<td>Polycyclic Aromatic Hydrocarbons (PAHs)</td>
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<td></td>
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<tr>
<td>Acenaphthene</td>
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<td>0.5</td>
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<td>Acenaphthylene</td>
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<td>Anthracene</td>
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<tr>
<td>Benzo(a)anthracene</td>
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<td>7</td>
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<tr>
<td>Benzo(a)pyrene</td>
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<td>2</td>
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<tr>
<td>Benzo(b)fluoranthene</td>
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<td>7</td>
</tr>
<tr>
<td>Benzo(g,h,i)perylene</td>
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<td>200</td>
<td>1000</td>
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<tr>
<td>Benzo(k)fluoranthene</td>
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<tr>
<td>Chrysene</td>
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<td>70</td>
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<td>Dibenzo(a,h)anthracene</td>
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<td>0.5</td>
<td>0.7</td>
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<td>Fluoranthene</td>
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<td>Fluorene</td>
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<tr>
<td>Indeno(1,2,3-cd)pyrene</td>
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<td>Methylnaphthalene, 2-</td>
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<td>4</td>
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<tr>
<td>Phenanthrene</td>
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<td>10</td>
</tr>
<tr>
<td>Pyrene</td>
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<td>1000</td>
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<td>Extractable Petroleum Hydrocarbons (EPH)</td>
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<td>total EPH</td>
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<tr>
<td>Polychlorinated Biphenyls (PCBs)</td>
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## Total Metals

<table>
<thead>
<tr>
<th></th>
<th>Chemical Testing Required by Contractor</th>
<th>Chemical Testing Not Required by Contractor</th>
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<tbody>
<tr>
<td>Arsenic</td>
<td>20</td>
<td>20</td>
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<tr>
<td>Barium</td>
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<tr>
<td>Cadmium</td>
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<td>Chromium (Total)</td>
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<td>Chromium(IV)</td>
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<td>Lead</td>
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<td>Mercury</td>
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<td>Selenium</td>
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<tr>
<td>Silver</td>
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Notes:
(1) Represents values for the MA DEP Natural Soils Criteria, with the exception of pesticides and VOCs.

Table 2: ANALYTICAL TESTING PROVIDED BY THE CONTRACTOR

<table>
<thead>
<tr>
<th>Material Description</th>
<th>Chemical Testing Required by Contractor</th>
<th>Chemical Testing Not Required by Contractor</th>
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<tbody>
<tr>
<td>Common Fill</td>
<td>X</td>
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<tr>
<td>Gravel Structural Fill</td>
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<tr>
<td>Borrow</td>
<td>X</td>
<td></td>
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<tr>
<td>Granular Fill</td>
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<td></td>
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<tr>
<td>Topsoil, Loam, Planting Soils, and Planting Soil Components</td>
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<tr>
<td>Compost</td>
<td>X</td>
<td></td>
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<tr>
<td>Playground Sand</td>
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<tr>
<td>Impervious Fill</td>
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<td></td>
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<tr>
<td>Sand/Sand Bedding</td>
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<td></td>
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<tr>
<td>Drainage Fill</td>
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<td></td>
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<tr>
<td>Crushed Stone</td>
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</tr>
<tr>
<td>Dense Graded Crushed Stone</td>
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<td></td>
</tr>
<tr>
<td>Gravel Borrow from Commercial Source</td>
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</table>

PART 2 - NOT APPLICABLE

PART 3 - NOT APPLICABLE

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

A. No separate measurement or payment will be made for excavation, on-site handling, temporary storage, reuse, segregation, screening, off-site stockpiling, returning the soil to the site for reuse, representative analytical testing, reporting, preparing submittals, backfilling, soil management, stockpiling, equipment, or other associated items or activities considered incidental to the conduct of the Work.
B. As part of their bid, the Contractor shall estimate the total excavation volume of soil from the Work outlined on the Drawings and estimate the total off-site volume of materials needed for Imported Fill to backfill excavations, provide raise in grade, backfill trenches, complete landscaping, and make the work complete based on the details shown on the Drawings.

C. The costs provided by the Contractor for all items listed in Section 4.2 shall include all costs for submittals (including required analytical testing), transporting, handling, stockpiling, off-site disposal (if required), coordinating with the Engineer, preparing and providing required documentation (from supplying facilities), and other incidental work to excavated soils, import soils, and manage materials on the site.

D. The Contractor shall improve, or remove and replace Work not in conformance with the specified requirements, or which becomes disturbed or unsuitable. All costs related to laboratory testing of nonconforming Work or materials shall be back-charged to the Contractor.

E. Measurement of the material types imported to the site will be per ton measured by scale at the supplying facility to the nearest 0.1 ton. Quantities of each material type will be measured and paid separately. The Contractor shall provide unit prices for all material classifications listed in Section 4.2.

4.2 PAYMENT

A. Except for the Items listed below, all work shall be conducted as part of the Base Contract Price and paid for as part of the Contract Lump Sum. Work of this Section that will not be measured and will be paid for as part of the Base Contract Price, will include all labor, equipment, and incidentals required to complete all excavation; excavation support; over-excavation and replacement of unsuitable soils and materials; material processing, handling and re-handling; segregation; screening; submittals, stockpiling; loading for off-site removal; subgrade preparation; analytical testing, recordkeeping, backfilling; acquisition of permits; dewatering; transportation fees and taxes; permits; police details; surveying; or other associated items or work necessary to the conduct the Work of this Section.

B. No separate measurement and payment will be made for removal and disposal of debris encountered in the fill soils, asphalt pavement, or other demolition debris generated during the construction. Removal and disposal of these materials shall be part of the Base Contract Price.
### Table 4.1: Estimated Overall Quantities:

<table>
<thead>
<tr>
<th>Material Type</th>
<th>Estimated Volume/Weight (tons)</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Estimated Excavation Volume(^1) (A)</td>
<td></td>
<td>Base bid</td>
</tr>
<tr>
<td>Total Estimated Excavated Materials to be Reused(^2) (B)</td>
<td></td>
<td>Base bid</td>
</tr>
<tr>
<td>Total Estimated to be Imported for Backfill(^3) (C)</td>
<td></td>
<td>See Table II below</td>
</tr>
<tr>
<td>Total Estimated Backfill(^4) (D=B+C)</td>
<td></td>
<td>Base bid</td>
</tr>
<tr>
<td>Total Estimated Materials requiring Off-site Disposal(^5) (E = A-D)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 4.2: Soil Import Unit Costs \(^6\),

<table>
<thead>
<tr>
<th>Material Type</th>
<th>Unit Price (per ton)</th>
<th>Unit Price (per ton)</th>
<th>Estimated Volume/Weight (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meeting Criteria of Table 1 – MIT Imported Fill Criteria</td>
<td>0-2 ft bgs</td>
<td>&gt; 2 ft bgs and/or below structure</td>
<td></td>
</tr>
<tr>
<td>Common Fill</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gravel Structural Fill</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Borrow</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Granular Fill</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topsoil, Loam, Planting Soils, and Planting Soil Components</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compost</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Playground Sand</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impervious Fill</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand/Sand Bedding</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drainage Fill</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crushed Stone</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dense Grade Crushed Stone</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gravel Borrow from Commercial Source</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other project specific imported materials</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Include unit costs for other Imported Fill materials required for the Work of the Project not specifically listed above.
Notes and Assumptions:
1. Quantity A: Total quantity of material Contractor estimates to be removed within the limit of the work, including but not limited to: surface asphalt, sidewalks, curbs, soil, buried rubble, foundation walls, and utility structures.
2. Quantity B: Quantity of the soil the Contractor estimates can be reused with the excavation assuming that all excavated materials are geotechnically and environmentally suitable.
3. Quantity C: Total quantity Contractor estimates for importing material from off-site borrow source, including but not limited to: select backfill, bedding material, and subbase material. Note that on-site excavated material may be reused as bedding material or subbase material if the on-site material meets the gradation requirements or can be processed to meet specified gradation requirements.
4. Quantity D: Total quantity Contractor estimates will be needed as backfill (includes imported and on-site material to be reused).
5. Quantity E: Total quantity Contractor estimates will require off-site disposal.
6. Unit Prices: Contractor shall provide a unit price for each material type listed in the table.
7. Unit prices for imported soil materials should include the total unit price for testing, transportation, and stockpiling. Unit prices will be applied to actual import quantities which may vary from quantities based on Contractor-provided bid and percentages provided in Table II.
8. When converting from cubic yards to tons, Contractor shall assume that 1 cy equals approximately 1.7 tons.

END OF SECTION
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9.1 CONSTRUCTION SPECIFICATIONS..................................................................................... 29
1. **321313 - CONCRETE PAVING**

1.1 **Project Includes**

Plain cast-in-place concrete for exposed, plain concrete paving for MIT campus. For Cambridge City ROW, meet the Cambridge DPW Specification.

1.2 **Quality Assurance**

Unless otherwise specified, work and materials for construction of Portland cement concrete paving shall conform to ACI 325.9R.

Manufacturer Qualifications: Manufacturer of ready-mixed concrete products who complies with ASTM C 94/C 94M requirements for production facilities and equipment.

Manufacturer certified according to NRMCA's "Certification of Ready Mixed Concrete Production Facilities."

Testing: Independent testing laboratory.
Mock-Ups: Provide mock-up as required to demonstrate quality of workmanship.

To ensure compliance with American with Disabilities Act (ADA) and the requirements of the Massachusetts Architectural Access Board (MAAB), and the standards described in MIT Standards – Earthwork and Site Improvements Special Requirements shall govern.

Comply with governing codes and regulations. Provide products of acceptable manufacturers which have been in satisfactory use in similar service for three years. Use experienced installers. Deliver, handle, and store materials in accordance with manufacturer's instructions.

Construction Tolerances: Contractor shall assume that sidewalk grades will be verified and checked with a 2-foot long electronic ‘smart level’. Comply with tolerances in ACI 117 (ACI 117M) and as follows:

1. Elevation: 3/4 inch (19 mm).
2. Thickness: Plus 3/8 inch (10 mm), minus 1/4 inch (6 mm).
3. Surface: 1/8 inch in 10 feet for grade and alignment of top of forms; 1/4 inch in 10 feet for vertical face on longitudinal axis. On sloped pavement or ramps, compliance with CMR 521 for MAAB shall be required.
4. Alignment of Tie-Bar End Relative to Line Perpendicular to Paving Edge: 1/2 inch per 12 inches (13 mm per 300 mm) of tie bar.
5. Lateral Alignment and Spacing of Dowels: 1 inch (25 mm).
7. Alignment of Dowel-Bar End Relative to Line Perpendicular to Paving Edge: 1/4 inch per 12 inches (6 mm per 300 mm) of dowel.
8. Joint Spacing: 3 inches (75 mm).
9. Contraction Joint Depth: Plus 1/4 inch (6 mm), no minus.
10. Joint Width: Plus 1/8 inch (3 mm), no minus.

The requirements specified hereinabove shall supersede the grades indicated on the Drawings. If these requirements cannot be met with the grades indicated on the Drawings, the Architect or Civil Engineer shall be notified immediately for direction.

In service pavements located at Lowell Court and along the face of Building 4 shall serve as visual finish paving examples representing actual design and execution conditions for concrete mix materials, reinforcement, formwork, placing sequence, form removal, curing, and finishing. Refer also to MIT Design Standard Specification Section 321313 - MIT CONCRETE PAVING, Paragraph 1.4 – Preconstruction Mock-Up Panels.

1.3 Products

Steel Reinforcing:

2. Reinfocing Bars: Deformed steel bars, ASTM A615, Grade 60.
3. Fabricated Bar Mats: Steel bar or rod mats, ASTM A184, using ASTM A615, Grade 60 steel bars.
4. Joint Dowel Bars: Plain steel bars, ASTM A615, Grade 60.

Portland Cement Concrete: Portland cement concrete for pavements and slabs shall be air-entrained type with a maximum water-cement ratio of 0.45 conforming to ACI 325.9R. Minimum compressive strengths at 28 days shall be as follows:

1. Flexural strength with third point loading - 650 psi; compressive strength - 4000 psi.
2. Concrete shall be air-entrained type, conforming to ASTM C94. Air content by volume shall be 6% +/- 1.5%, and shall be tested in accordance with ASTM C231.
3. Concrete slump shall be no less than 2 inch nor greater than 4 inch, determined in accordance with ASTM C143.
4. Cement shall be Portland cement, conforming to ASTM C150, Type I or II. Only one color of cement, all of the same manufacturer, shall be used for the work. Type III cement shall be used only with the prior approval of the Architect.
5. Fine and coarse aggregates shall conform to ASTM C33.
6. Concrete shall contain a water reducing agent to minimize cement and water content of the concrete mix at the specified slump. Water reducing agent shall conform to ASTM C494.
7. No calcium chloride or admixtures containing calcium chloride shall be added to the concrete. No admixtures other than those specified shall be used in the concrete without the specific written permission of the Architect in each case.

Admixtures:
1. Provide admixtures certified by manufacturer to be compatible with other admixtures and to contain not more than 0.1 percent water-soluble chloride ions by mass of cementitious materials
   a. Water-Reducing Admixture: ASTM C 494/C 494M, Type A.
   b. Retarding Admixture: ASTM C 494/C 494M, Type B.
   c. Water-Reducing and Retarding Admixture: ASTM C 494/C 494M, Type D.
   d. High-Range, Water-Reducing Admixture: ASTM C 494/C 494M, Type F.
   e. High-Range, Water-Reducing and Retarding Admixture: ASTM C 494/C 494M, Type G.
   f. Plasticizing and Retarding Admixture: ASTM C 1017/C 1017M, Type II.

Form Materials:

1. Plywood, metal, metal-framed plywood, or other approved panel-type materials to provide full-depth, continuous, straight, smooth exposed surfaces. Use flexible or curved forms for curves with a radius 100 feet (30.5 m) or less.

Joints:

1. Expansion joints shall be doweled. Expansion joint filler shall be preformed, non-bituminous type joint filler conforming to ASTM D1752, Type II. Expansion joint shall receive joint backer rod and shall be sealed with joint sealant.

2. Control joints indicated to be sawn shall be made by using a diamond blade concrete power saw. Joint shall be made after concrete is finished and when the surface is stiff enough to support the weight of workmen without damage to the slab. Saw blade shall cut into slab at least 1 inch, but in no case less than 25% of slab depth.

3. Transverse construction joints shall be placed whenever placing of concrete is suspended for more than 30 minutes (cold joint) or at abutting pours.

4. Unless otherwise indicated, decorative saw cut joints shall be sawn into the concrete slab at intervals and patterns indicated on the Drawings. Joint shall be made after concrete is finished and when the surface is stiff enough to support the weight of workmen without damage to the slab, but before slab has achieved its final set. Saw cut joints shall be straight and accurate to line.
   a. Saw cut joints shall be sawn flush to vertical surfaces.
   b. Depth of decorative saw cut joint shall be 3/4 inch.

Curing Compound: Liquid-Membrane Forming and Sealing Curing Compound: ASTM C309, Type I, Class A.

Joint Sealant:

1. Sealant for sealing of control joints and expansion joints in concrete walks shall be a two component polyurethane based sealant conforming to ASTM C 920, Type M, Grade P, Class 25, Use T, M, & O and to Fed. Spec. TT- S-00227E, Class A, Type 1, with a
Shore A hardness of 30+5, or better. Sealant shall be Tremco THC-900, manufactured by Tremco, Cleveland, OH 44104, or approved equal.

a. Color of sealant shall be selected by the Architect from the manufacturer's full color range.
b. Primer shall be that recommended by the sealant manufacturer for the use intended.

1.4 Installation


1. Paving mix, equipment, methods of mixing and placing, and precautions to be observed as to weather, condition of base etc., shall meet the requirements of ACI 325.9R. Pavement shall be constructed in accordance with the Drawings.

2. The Architect shall be notified of concrete placement sufficiently in advance of start of operation to allow his representative to complete preliminary inspection of the work, including subgrade, forms, and reinforcing steel, if used.

3. Normal concrete placement procedures shall be followed. Concrete shall arrive at the jobsite so that no additional water will be required to produce the desired slump. When conditions develop that require addition of water to produce the desired slump, permission of the Architect must be obtained. The concrete shall be transported from the mixer to its place of deposit by a method that will prevent segregation or loss of material. Concrete shall be placed in accordance with ACI 304.

4. Work shall not be performed during rainy weather or when temperature is less than 40o F. (4.4o C).

5. Adjacent work, etc., shall be protected from stain and damage during entire operation. Damaged and stained areas shall be replaced or repaired to equal their original conditions.

6. Existing concrete, earth, and other water-permeable material against which new concrete is to be placed shall thoroughly damp when concrete is placed. There shall be no free water on surface.

7. Concrete which has set or partially set before placing shall not be employed. Retempering of concrete will not be permitted.

8. Concrete shall be thoroughly spaded and tamped to secure a solid and homogeneous mass, thoroughly worked around reinforcement and into corners of forms.
When joining fresh concrete which has attained full set, latter shall be cleaned of any foreign matter, and mortar scum and laitance shall be removed by chipping and washing. Clean, roughened base surface shall be saturated with water, but shall have no free water on the surface. A coat of 1:1 cement-sand grout approximately 1/8 inch thick, shall be well scrubbed into thoroughly dampened concrete base. New concrete shall be placed immediately, before grout has dried or set.

Unless otherwise indicated on the Drawings, horizontal surfaces of concrete surfaces which will be exposed shall be given a light broomed finish, with direction of grooves in concrete surface perpendicular to length of concrete pavement. Broomed surface shall be uniform, with no smooth, unduly rough or porous spots, or other irregularities. Coarse aggregate shall not be dislodged by brooming operation.

Details of handling and protecting of concrete during freezing weather shall be subject to the approval and direction of the Architect. Procedures shall be in accordance with provisions of ACI 306R.

During periods of excessively hot weather (95 degrees F., or above), ingredients in the concrete shall be cooled insofar as possible and cold mixing water shall be used to maintain the temperature of the concrete at permissible levels all in accordance with the provisions of ACI 305. Any concrete with a temperature above 95 degrees F., when ready for placement will not be acceptable, and will be rejected.

Concrete surfaces shall be cured by completely covering with curing paper or application of a curing compound.

Testing Services: Testing of composite samples of fresh concrete obtained according to ASTM C 172 shall be performed according to the following requirements:

1. Testing Frequency: Obtain at least 1 composite sample for each 5000 sq. ft. or fraction thereof of each concrete mix placed each day.
   a. When frequency of testing will provide fewer than five compressive-strength tests for each concrete mixture, testing shall be conducted from at least five randomly selected batches or from each batch if fewer than five are used.
2. Slump: ASTM C 143/C 143M; one test at point of placement for each composite sample, but not less than one test for each day's pour of each concrete mix. Perform additional tests when concrete consistency appears to change.
3. Air Content: ASTM C 231, pressure method; one test for each composite sample, but not less than one test for each day's pour of each concrete mix.
4. Concrete Temperature: ASTM C 1064; one test hourly when air temperature is 40 deg F (4.4 deg C) and below and when 80 deg F (27 deg C) and above, and one test for each composite sample.
5. Compression Test Specimens: ASTM C 31/C 31M; cast and laboratory cure one set of three standard cylinder specimens for each composite sample.
6. Compressive-Strength Tests: ASTM C 39/C 39M; test 1 specimen at 7 days and 2 specimens at 28 days.
   a. A compressive-strength test shall be the average compressive strength from 2 specimens obtained from same composite sample and tested at 28 days.
Concrete surfaces shall be protected from traffic or damage until surfaces have hardened sufficiently. If necessary 1/2 in. thick plywood sheets shall be used to protect the exposed surface.

2. **321314 – EXPOSED AGGREGATE CONCRETE PAVING**

2.1 **Project Includes**

Exposed aggregate cast-in-place concrete for exposed aggregate finish concrete paving. In addition to Design Standards described above for 321313, Concrete Paving, the following additional Standards apply to the construction of exposed aggregate concrete paving work.

2.2 **Quality Assurance**

OCP maintains aggregate samples and historic mix submittal information to assist the Contractor in determining an acceptable exposed aggregate concrete mix and installation process.

2.3 **Products**

Concrete: Concrete for exposed-aggregate pavement shall contain a minimum of 560 pounds of ASTM C150, Type II Portland cement per cubic yard of concrete, and a water-cement ratio no greater than 0.45 by weight. Minimum compressive strength shall be 4,000 psi at 28 days.

1. Maximum slump shall not exceed 4 inches and average air entrainment shall be 7-1/2 percent.
3. Ready mixed concrete, if used, shall meet ASTM C 94.
4. An over-sanded base mix may be used, and if so, the water-cement ratio specified above shall govern the mix design, and the cement content shall be raised accordingly. Aggregate source and cement type and brand shall not be altered once construction begins.

Special Aggregate: Special aggregate to be exposed shall be hard, sound, durable, and free of all deleterious materials and staining qualities.

Aggregate shall match aggregate displayed in the in-service installation located at Lowell Court and identified on the In-Situ Mockup for Concrete Paving Map included in the MIT Design Standards, Earthwork and Site Improvements Special Requirements document. Aggregate shall be of one sieve size or no more than two. Shape of aggregate shall resemble spheres and cubes. Flat, slivery stones which may become dislodged easily shall not be used.

Meeting or Patching Existing Pavement: For pavements meeting adjacent existing pavement, or patching existing pavement, aggregate shall match that exposed in existing pavement.
Surface Retarder: Spray applied, film forming, water based top surface retarder, calibrated for specific sized aggregate and finish requirements.

Sealer: Sealer shall be a clear oligomeric siloxane or silane/siloxane water-based high-performance water repellent providing a long lasting, breathable barrier which exhibits superior resistance to water, airborne dust and dirt, salt, acid rain, efflorescence, alkali, freeze/thaw damage and spalling. Sealer shall be subject to the approval of the Architect.

Application: After the slab is cured and completely dry, and all sawn joints have been completed, the water repellent sealer shall be uniformly applied to the surface at the application rate and methods recommended by the sealer manufacturer.

Concrete Placement:

Concrete shall be consolidated by suitable means to eliminate voids and pockets.

Monolithic Exposed-Aggregate Finish: Expose coarse aggregate in pavement surfaces as follows:

1. Immediately after float finishing, spray-apply chemical surface retarder to pavement according to manufacturer's written instructions. (Surface retarder may be used, only after approval by the Architect and shall be of the same brand used to prepare the approved sample panel. The retarder shall be applied uniformly over the concrete surface and in accordance with the manufacturer's instructions.)
2. If recommended by surface retarder manufacturer, cover pavement surface with plastic sheeting, sealing laps with tape, and remove when ready to continue finishing operations.
3. When the concrete is hard enough to retain the aggregate and the mortar is still soft enough to be removed by brushing, the surface retarder shall be removed by brushing and flushing with water. The exposing operation of washing and brushing with a stiff-bristle broom and pressure washer shall continue until the surface matches the approved sample panel. The final washing operation shall cease when the flush water runs clear, there is no noticeable cement film on the aggregate, and cement film is removed from aggregate surfaces to depth required.

Curing shall be by use of moisture retaining curing cover.

1. Moisture-Retaining Cover: Curing paper shall be nonstaining, fiber reinforced laminated kraft bituminous product conforming to ASTM C 171. Four mil polyethylene sheeting may be substituted for curing paper.

As soon as the washing operation ceases, the curing operation shall begin. The concrete shall be kept in continuously moist condition by covering with curing paper for 5 days in warm weather (70 deg. F or higher) or 7 days in cooler weather (50-70 deg. F). The temperature of the concrete shall not be allowed to fall below 50 deg. F. during the curing period.

Cover concrete surfaces with moisture-retaining cover for curing concrete, placed in widest practicable width, with sides and ends lapped at least 12 in. and sealed by waterproof tape or
adhesive. Immediately repair any holes or tears during curing period using cover material and waterproof tape.

2.4 Installation

Monolithic Exposed-Aggregate Finish: Expose coarse aggregate in pavement surfaces to match in-service installation located at Lowell Court and identified on the In-Situ Mockup for Concrete Paving Map included in the MIT Design Standards, Earthwork and Site Improvements Special Requirements document, and as follows:

1. Immediately after float finishing, spray-apply chemical surface retarder to pavement according to manufacturer's written instructions. (Surface retarder may be used, only after approval by the Architect and shall be of the same brand used to prepare the approved sample panel. The retarder shall be applied uniformly over the concrete surface and in accordance with the manufacturer's instructions.)

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Cover concrete surfaces with moisture-retaining cover for curing concrete, placed in widest practicable width, with sides and ends lapped at least 12 in. and sealed by waterproof tape or adhesive. Immediately repair any holes or tears during curing period using cover material and waterproof tape.

3. 321400 - UNIT PAVING

3.1 Project Includes

Concrete unit paving.
3.2 Quality Assurance

Comply with governing codes and regulations. Provide products of acceptable manufacturers which have been in satisfactory use in similar service for three years. Use experienced installers. Deliver, handle, and store materials in accordance with manufacturer's instructions. Mock-Ups: Provide mock-up as required to demonstrate quality of workmanship.

3.3 Products

Contact the MIT Office of Camplus Planning for a copy of the Standards Catalogue for additional information.

Pavers shall be Hanover Prest-Brick, hydraulically precast concrete pavers, manufactured by Hanover Architectural Products, Inc., 5000 Hanover Road, Hanover, PA 17331; Tel. 717-637-0500; Fax: 717-637-7145; Web; www.hanoverpavers.com, or approved equal.

1. Pavers shall have an average minimum compressive strength of 8000 psi, with no individual unit less than 7,200 psi, in accordance with ASTM C 93.
2. Water absorption shall be 5% or less.
3. Color and finish shall be selected by the Architect from the manufacturer's full range of standard colors and finishes
4. Traffic types may include:
   Driveways and entrances
   Exterior commercial walkways
   Low traffic walkways and patios

Setting Bed Materials:

4. Asphalt cement/fine aggregate bituminous setting bed with neoprene-modified asphalt adhesive.
5. Clean, sharp, natural sand conforming to ASTM C 33, except that the fineness modulus shall be 2.25 \( \pm \) 0.10.
6. Stone dust of decomposed granite or trap rock conforming to the gradation requirements of AASHTO M 43, No. 10, or "stone dust" minus 1/4 in. screenings.
8. Setting Beds may include:
   a. Mortar over concrete slab.
   b. Bituminous setting bed over concrete base slab.
   c. Bituminous setting bed over bituminous concrete base.
   d. Sand or stone dust over compacted aggregate base.
   e. Sand over perforated concrete base slab.
Joints may include:

1. Hand-tight joints with stone dust filler.
2. Hand-tight joints with sand filler.
3. Hand-tight joints with polymeric sand filler.
4. Latex-Modified Portland cement grout.

Edge Restraints:

1. Steel Edge Restraints: Painted commercial steel edging with loops pressed from or welded to face to receive stakes at 36 inches (900 mm) o.c., and steel stakes 15 inches (380 mm) long for each loop.
2. Extruded-aluminum edging with loops pressed from face to receive stakes at 12 inches (300 mm) o.c., and aluminum stakes 12 inches (300 mm) long for each loop.
3. Plastic Edge Restraints: Manufacturer's standard triangular PVC extrusions designed to serve as edge restraints for unit pavers; rigid type for straight edges and flexible type for curved edges, with pipe connectors and 3/8-inch (9.5-mm) diameter by 12-inch- (300-mm-) long steel spikes.

3.4 Installation

Install materials in accordance with manufacturer's instructions and approved submittals. Install materials in proper relation with adjacent construction and with uniform appearance. Coordinate with work of other sections.

Do not use unit pavers with chips, cracks, voids, discolorations, and other defects that might be visible or cause staining in finished work.

Mix pavers from several pallets or cubes, as they are placed, to produce uniform blend of colors and textures.

Cut unit pavers with motor-driven masonry saw equipment to provide clean, sharp, unchipped edges. Cut units to provide pattern indicated and to fit adjoining work neatly. Use full units without cutting where possible. Hammer cutting is not acceptable.

Tolerances:

1. Where slopes to drains are critical: Do not exceed 1/32-inch (0.8-mm) unit-to-unit offset from flush (lippage) nor 1/8 inch in 10 feet (3 mm in 3 m) from level, or indicated slope, for finished surface of paving.
2. Where normal control of paving is acceptable: Do not exceed 1/16-inch (1.6-mm) unit-to-unit offset from flush (lippage) nor 1/8 inch in 24 inches (3 mm in 600 mm) and 1/4 inch in 10 feet (6 mm in 3 m) from level, or indicated slope, for finished surface of paving.
Expansion and Control Joints: Provide for sealant-filled joints at locations and of widths indicated. Provide joint filler as backing for sealant-filled joints where indicated. Install joint filler before setting pavers. Install edge restraints before placing unit pavers.

Aggregate material for base beneath concrete pavers shall be applied in lifts less than or equal to 6 in. thick, compacted measure. Each lift shall be separately compacted at optimum moisture content to not less than 95% of maximum density as determined by ASTM D 1557.

Setting on Mortar Bed:

1. Apply latex-modified bond coat and mortar setting bed in accordance with manufacturer’s printed instructions.
2. Mix and place only that amount of mortar bed that can be covered with pavers before initial set. Cut back, bevel edge, remove, and discard setting-bed material that has reached initial set before placing pavers.
3. Tamp or beat pavers with a wooden block or rubber mallet to obtain full contact with setting bed and to bring finished surfaces within indicated tolerances. Set each paver in a single operation before initial set of mortar; do not return to areas already set and disturb pavers for purposes of realigning finished surfaces or adjusting joints.
4. Provide 3/8 inch (10 mm) nominal joint width with variations not exceeding plus or minus 1/16 inch (1.6 mm).
5. All joints, except expansion joints, shall be completely filled with mortar, then raked out to a depth of not less than 3/4 in. Raked joints shall be brushed clean and pointed with mortar grout to a flat cut joint.

Setting on Bituminous Bed:

1. Bituminous setting bed shall be installed over the fully cured concrete or bituminous concrete base.
2. Place bituminous material and power roll to produce a smooth, firm, and even nominal 3/4 inch (19 mm) thick setting bed. Adjust thickness as necessary to allow accurate setting of unit pavers to finished grades indicated.
3. Apply neoprene-modified asphalt adhesive to cold setting bed by squeegeeing or troweling. After the modified asphalt adhesive dry to the touch, carefully place the concrete pavers by hand with hand tight joints and uniform top surface.
4. Spread dry sand and fill joints. Follow manufacturer’s printed instructions if using polymeric sand joint filler.

Setting on Sand or Stone Dust Bed:

1. If installing over perforated concrete base then first fill vertical weep holes with drain stone and cover with filter fabric.
2. Spread sand or stone dust over concrete base slab or compacted aggregate base as a setting bed for pavers. Place leveling course and screed to a thickness of 1 to 1-1/2
inches (25 to 38 mm), taking care that moisture content remains constant and density is loose and constant until pavers are set, leveled and compacted to required slope and grade. Bed shall not be compacted until pavers are installed.

3. Set pavers with a minimum joint width of 1/16 inch (1.6 mm) and a maximum of 1/8 inch (3 mm), being careful not to disturb leveling base. If pavers have spacer bars, place pavers hand tight against spacer bars. Use string lines to keep straight lines. Fill gaps between units that exceed 3/8 inch (10 mm) with pieces cut to fit from full-size unit pavers.

4. Spread dry sand and vibrate pavers into leveling course. Add sand until joints are completely filled, then remove excess sand.

5. Follow manufacturer’s printed instructions if using polymeric sand joint filler.

Restore damaged pavers. Clean and protect work from damage

4. **321600 - CURBS AND GUTTERS**

4.1 **Project Includes**

Curbs and gutters.

4.2 **Quality Assurance**

- Comply with governing codes and regulations.
- Provide products of acceptable manufacturers which have been in satisfactory use in similar service for three years.
- Use experienced installers.
- Deliver, handle, and store materials in accordance with manufacturer's instructions.

Construction Tolerance:
- 1/8 inch in 10 feet for grade and alignment
- 1/4 inch 10 feet for vertical or sloped face on longitudinal axis.
- Mock-Ups: Provide mock-up as required to demonstrate quality of workmanship.

4.3 **Products**

Precast Concrete Curbs and Gutters:

1. Application: Roadway curbs and gutters.
2. Concrete: Portland cement; normal weight aggregates; potable water.
3. Design Mix: 5000 psi, 28-day minimum compressive strength.
5. Precast units shall be moist cured by steam or water for a sufficient length of time for the concrete to obtain the required compressive strength. Curing compounds will not be permitted.
6. Penetrating sealer shall be Consolideck SX, manufactured by Prosoco Industries, Kansas City, MO 66177; Sil-Act, manufactured by Advanced Chemical Technologies; or equal selected from the "Qualified Product List" as maintained by the MHD Research and Materials Section.
7. Reinforcing Bars: Deformed steel bars.

Granite Curbs and Gutters: conforming to MHD Specifications Section M9.04.0 and ASTM C 615, Class I Engineering Grade, suitable for curbstone use.
1. Vertical Granite Curb: Sawed top and smooth quarry split face.
2. Sloped Granite Curb: Smooth quarry split face.

4.4 Installation

Provide acceptable materials and install curbing in strict compliance with Commonwealth of Massachusetts Highway Department; Standard Specifications for Highways and Bridges, Section 501.
Set curbs on compacted gravel base with joints between curb pieces from 1/8 inch to 3/4 inch wide. Provide concrete haunch if indicated on the Drawings. Point joints with mortar and tool concave; remove surplus mortar and clean curbs.

5. 321800 – PLAYGROUND SAFETY SURFACING

5.1 Project Includes

Playground safety surfacing.

5.2 Quality Assurance

Comply with governing codes and regulations. Provide products of acceptable manufacturers which have been in satisfactory use in similar service for three years. Use experienced installers. Deliver, handle, and store materials in accordance with manufacturer's instructions.
Poured In Place Surfacing - Performance Requirements: Provide a 2 layer rubber-polyurethane playground surfacing system which has been designed, manufactured and installed to meet the following criteria:
1. Shock Attenuation (ASTM F1292):
   b. Head Injury Criteria: Less than 1000.
3. Tensile Strength (ASTM D412): 60 psi (413 kPa).
4. Tear Resistance (ASTM D624): 140%.
5. Water Permeability: 0.4 gal/yd²/second.

Certified test data indicating that safety surface meets or exceeds the following:
3. Current ASTM F-1292 requirements.

5.3 Products

Playground Safety Surfacing Systems:

1. Manufacturers: Surface America, Williamsville, NY 14231, Telephone: (800) 999-0555, (716) 632-8413; Fax: (716) 632-8324; E-mail: info@surfaceamerica.com; website: http://www.surfaceamerica.com, or approved equal.
3. Types may include:
   a. Playground Safety Surfacing ace, base mat type.
   b. Playground Safety Surfacing face, full pour type.

4. Colors: as selected by Architect and Owner.

5.4 Installation

Install materials and systems in accordance with manufacturer's instructions and approved submittals. Install materials and systems in proper relation with adjacent construction. Coordinate with work of other sections. Restore damaged surfaces and protect work.

6. 323300 - SITE FURNISHINGS

6.1 Project Includes

Benches, tables, bollards and bike racks.

6.2 Quality Assurance

Comply with governing codes and regulations. Provide products of acceptable manufacturers which have been in satisfactory use in similar service for three years. Use experienced installers. Deliver, handle, and store materials in accordance with manufacturer's instructions. Where appropriate, and when approved by the Architect, manufacturer's catalogue cuts may be substituted for shop drawings. Certificate of wood treatment shall be submitted upon delivery of treated wood items. Submit assembly instruction drawings showing layout(s), connections, bolting and anchoring details as per manufacturer's standards. A report of site furnishing parts consisting of recycled materials. Product specification data, providing test information for deflection and creep in accordance with ASTM D 648 and ASTM
D 2990 for site furnishings which use plastic lumber as a component, shall be submitted. The data shall provide a comparison of deflection and creep measurements to other comparable materials.

Furnish evidence indicating that source of Ipe wood used for table and bench construction is a plantation farm or other designated source practicing sustain yield concept in forestry, and regulated by governing authorities regarding the growing, harvesting, and replanting of tropical hardwood trees.

6.3 Products

Contact the MIT Office of Camplus Planning for a copy of the Standards Catalogue for additional information.

Manufacturers: Provide furnishings from preferred manufacturers included in MIT Design Standards and as follows.

Bench without Backrest:
1. Bench shall be EP 1991 Bench without Backrest, manufactured by Equiparc, 1001, rue James-Brodie, Saint-Jean-sur-Richelieu, QC Canada J2X 0C1, or approved equal.
2. General
   a. Dimensions:
      2. Length: 59 in.
      3. Depth: 22-1/4 in.
   b. Weight: 130 lbs.
3. Materials
   1. Bench frame made from hot dipped galvanized and powder coated steel.
   2. Ipe wood slats.
   3. Stainless Steel Fasteners.

Bench with Backrest:
1. Bench shall be EP 1990 Bench with Backrest, manufactured by Equiparc, 1001, rue James-Brodie, Saint-Jean-sur-Richelieu, QC Canada J2X 0C1, or approved equal.
2. General
   a. Dimensions:
      1. Height: 34 in.
      2. Length: 59 in.
      3. Depth: 23 in.
   b. Weight: 150 lbs.
3. Materials
   a. Bench frame made from hot dipped galvanized and powder coated steel.
   b. Ipe wood slats.
   c. Stainless Steel Fasteners.

Table:
1. Table shall be EP 2990 Table, manufactured by Equiparc, 1001, rue James-Brodie, Saint-Jean-sur-Richelieu, QC Canada J2X 0C1, or approved equal.

2. General
   a. Dimensions:
      1. Height: 30 in.
      2. Length: 71 in.
      3. Weight: 510 lbs.
   b. Materials
      a. Table frame made from hot dipped galvanized and powder coated steel.
      b. Ipe wood slats.
      c. Stainless Steel Fasteners.

Fixed Bollards:
1. Bollards shall be CBR-6-E-SS-F, Round Bollard, 6" Schedule 40 Stainless Steel Pipe, manufactured by Creative Pipe, Inc. PO Box 2458 Rancho Mirage, California 92270-1087 Toll Free (800) 644-8467 Phone (760) 340-5555 Fax (760) 340-5883 Web Site www.creativepipe.com, or approved equal.

2. General
   a. Dimensions:
      1. Length: 60 in.; 36 in. above grade/24 in. below grade.
   b. Mounting:
      1. Embedded.
   c. Finish:
      1. 304 Stainless Steel with #4 Satin Finish.
   d. Top:
      1. Flat.

Fixed Bollards (Vassar Street Specific):
1. Bollards shall be WHARF – WHA 452 S Stainless Steel Bollard, manufactured by Fornitubes, Unit 4, Medway Distribution Centre, Courteney Road, Gillingham, Kent, ME8 0RT; Te: 01144-208-378-3200; Email: sales@fornitubes.com, or approved equal.

2. General
   a. Dimensions:
      1. 850mm (a/g) x 300mm (b/g) x 90mm triangular (g/l); weight: 10kg.
   b. Mounting:
      1. Base plated.
   c. Finish:
      1. G304 Stainless Steel Satin Polished.

Removable Bollards:
1. Bollards shall be CBR-6-RF-SS-F, Round Bollard, 6" Schedule 40 Stainless Steel Pipe, manufactured by Creative Pipe, Inc. PO Box 2458 Rancho Mirage, California 92270-1087 Toll Free (800) 644-8467 Phone (760) 340-5555 Fax (760) 340-5883 Web Site www.creativepipe.com, or approved equal.

2. General
   a. Dimensions:
      1. 36 in. above grade.
b. Mounting:
   1. Removable flange.

c. Finish:
   1. 304 Stainless Steel with #4 Brushed Finish.

d. Top:
   1. Flat.

Bike Racks:
1. Bicycle rack shall be Dero Swerve Rack, manufactured by Dero Bike Rack Company, Minneapolis, MN 55406; Tel. 1-800-891-9298; Fax: 1-612-331-2731; www.dero.com, or approved equal.

2. General
   a. Material and Finish:
      1. 1.9 in. O.D. Schedule 40 steel pipe.
         2. Hot dipped galvanized after fabrication.
   b. Mounting:
      1. In Ground Mount.
   c. Capacity:
      1. 2 bikes.
   d. Spacing – City spacing requires racks be installed 36-inches on center. Contact the Office of Campus Planning to discuss spacing options.

6.4 Installation

Install site furnishings in accordance with manufacturer's instructions and approved submittals. Install materials and systems in proper relation with adjacent construction. Coordinate with work of other sections. Restore damaged surfaces and protect work.

7. 328000 - IRRIGATION

7.1 Project Includes

Irrigation systems for exterior lawn and planting areas.

Contact the MIT Office of Campus Planning for a copy of the Standards Catalogue for additional information.

7.2 Quality Assurance

Comply with governing codes and regulations. Provide products of acceptable manufacturers which have been in satisfactory use in similar service for three years. Use experienced installers. Deliver, handle, and store materials in accordance with manufacturer's instructions. Water Coverage for Turf Areas: 100 percent.
Water Coverage for Planting Areas: 100 percent.
Testing: Hydrostatic test at 100 psi.
All applicable ANSI, AWWA, and ASTM Standards and Specifications, and all applicable building codes and other public agencies having jurisdiction upon the work.

Contractor shall be responsible for constructing the system in complete accordance with all local codes, ordinances and laws. Any modification made to conform with said codes, laws and ordinances shall be completed at the Contractor's expense with no additional compensation allowed.

Protection of Existing Plants and Site Conditions: The Contractor shall take necessary precautions to protect site conditions to remain. Should damages be incurred, this Contractor shall repair the damage to its original condition at his own expense. Any disruption, destruction, or disturbance of any existing plant, tree, shrub, or turf, or any structure shall be completely restored to the satisfaction of the Owner, solely at the Contractor's expense.

Permits and Fees: Obtain all permits and pay required fees to any governmental agency having jurisdiction over the work. Inspection required by local ordinances during the course of construction shall be arranged as required. On completion of the work, satisfactory evidence shall be furnished to Architect to show that all work has been installed in accordance with the ordinances and code requirements.

On-Site Observation: At any time during the installation of the irrigation system by the Contractor, the Owner may visit the site to observe work underway. Upon request, the Contractor shall be required to uncover specified work as directed by the Owner without compensation. Should the material, workmanship or method of installation not meet the standards specified herein, the Contractor shall replace the work at his own expense.

Workmanship: All work shall be installed by skilled personnel, proficient in the trades required, in a neat, orderly, and responsible manner with recognized standards of workmanship. The Contractor shall have had considerable experience and demonstrated ability in the installation of sprinkler irrigation systems of this type.

Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

 Interruption of Existing Water Service: Do not interrupt water service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary water service according to requirements indicated:
1. Notify Owner no fewer than two days in advance of proposed interruption of water service.
2. Do not proceed with interruption of water service without Owner's written permission

7.3 Products

Irrigation Systems:

1. Manufacturers: Provide components from preferred manufacturers included in MIT Design Standards.
   a. All rotor heads used for installation shall be Hunter I-20, Hunter I-25, or Hunter
MP rotator.

b. All spray heads installed shall be Hunter ProSpray PRS30 or Rainbird 1800 SAM PRS heads for use with variable arc or fixed pattern nozzles.

c. All spray heads installed shall be Hunter ProSpray PRS40 heads for use with Hunter MP rotator heads.

d. All exterior electric valves installed shall be Rainbird PEB or PESB Series valves or Hunter ICV valves.

e. All drip irrigation tubing installed shall be Netafim Techline .9 GPH piping.

f. All Valve boxes installed shall be Carson or Amtek.

g. All automated irrigation controllers installed should be Rainbird ESP-SAT Series controllers for intended use with Maxicom.

h. All Quick coupler valves installed should be 1” Rainbird 5RC valves for use with a 55K Quick coupler key. For use on systems using non-potable water, locking rubber cover shall have molded-in warnings of "DO NOT DRINK" in English and Spanish.

i. All PVC piping should be SDR 21 (class 200) or thicker walled.

j. All new irrigation systems should contain a master valve and flow sensor.

k. All Hunter I-25 heads to be installed on Spears schedule 80 swing joints.

2. Applications may include:

   a. Irrigation for site plantings.

   b. Irrigation for lawns.

3. Piping may include:

   a. Copper.

   b. PVC plastic.

   c. Polyethylene


5. Backflow Preventers: Cast bronze.


7. Quick coupling valves shall be 1 in. heavy duty brass construction one-piece body design, with locking rubber cover. Furnish to the Owner the following additional items: three hollow coupler keys and three swivel hose ell adapters.

   a. For use on systems using non-potable water, locking rubber cover shall have molded-in warnings of "DO NOT DRINK" in English and Spanish.

8. Control and ground wiring shall be minimum Type "UF", #12 wire, 600 volt, solid copper, single conductor wire with PVC insulation and shall bear UL approval for direct underground burial feeder cable.

9. Rain sensor shall be a micro-electronic solid-state type, capable of interrupting the power from the irrigation controller to the valves when rainfall exceeds a preselected quantity.
10. Automatic Control Systems, UL listed and tested, may include:
   
   a. Interior locations.
   b. Exterior locations.

**7.4 Installation**

Coordinate all installation with landscape planting work, especially plant locations, fine grading, and soil preparation for planting areas. Protect existing landscaping from damage. Repair and repave cut paving to match paving in original condition.

Excavation required for the installation of the irrigation system shall conform to ASTM F 690. Install materials and systems in accordance with manufacturer's instructions and approved submittals. Install materials and systems in proper relation with adjacent construction. Coordinate with work of other sections.

Coverage Test: After completion of the system, test the operation of entire system and adjust sprinklers as directed by the Owner. Demonstrate to the Owner that all irrigated areas are being adequately covered. Furnish and install materials required to correct inadequacies of coverage due to deviations from the Drawings or where the system has been willfully installed when it is obviously inadequate or inappropriate without bringing it to the attention of the Owner.

Instruct Owner's personnel in proper operation and maintenance procedures.

At the end of the first irrigation season, the system shall be fully drained by use of compressed air (600 CFM or larger; do not exceed 50 psi) and shutdown for the season.

Prior to the start of the second irrigation season, the system shall be restarted, checked, and repaired. This start up procedure shall include but not be limited to:

1. Testing of all system components, (valves, heads, controllers, quick coupling valves, piping, etc.) for proper working order.

2. Adjustments, repair, or replacement of all system components that are not in proper working order.

**8. 329000 - PLANTING**

**8.1 Project Includes**

Trees, shrubs, ground covers, perennials, seed lawns and sod lawns.

**8.2 Quality Assurance**

Comply with governing codes and regulations. Provide products of acceptable manufacturers which have been in satisfactory use in similar service for three years. Use experienced installers. Deliver, handle, and store materials in accordance with manufacturer's instructions.

Balled and Burlapped Plants and Trees: Graded to American Standard for Nursery Stock, ANSI Z60.1.

Fall digging hazards shall conform to American National Standards Institute, Inc. (ANSI) species and guidelines

Testing: Laboratory testing for suitable soil amendments and fertilizer.
Storage: Unless specific authorization is obtained from the Architect, plants shall not remain on the site of work longer than three days prior to being planted. Plants shall be guaranteed for a period of two years after the date of Acceptance by the Owner.

8.3 Products

Plants:

1. Except as otherwise specified, size and grade of plant materials shall conform to ANSI Z60.1, latest edition. In no case shall ball size be less than 11 in. in diameter for each inch of caliper.
   a. Shade Trees: Single-stem trees with straight trunk, well-balanced crown, and intact leader, of height and caliper indicated, complying with ANSI Z60.1 for type of trees required. Minimum 6 ft. height above root flare for branches.
   b. Small Trees: Branched or pruned naturally according to species and type, with relationship of caliper, height, and branching according to ANSI Z60.1.
   c. Multistem Trees: Branched or pruned naturally according to species and type, with relationship of caliper, height, and branching according to ANSI Z60.1.
   d. Deciduous Shrubs: Form and Size: Deciduous shrubs with not less than the minimum number of canes required by and measured according to ANSI Z60.1 for type, shape, and height of shrub.
   e. Coniferous Evergreens: Form and Size: Normal-quality, well-balanced, coniferous evergreens, of type, height, spread, and shape required, complying with ANSI Z60.1.
   f. Broadleaf Evergreens: Form and Size: Normal-quality, well-balanced, broadleaf evergreens, of type, height, spread, and shape required, complying with ANSI Z60.1.

2. All trees and shrubs shall be labeled. Labels shall be durable and legible, stating the correct plant name and size in weather-resistant ink or embossed process. Labels shall be securely attached to all plants prior to delivery to the site, being careful not to restrict growth.

3. Container grown plants shall be well rooted and established in the container in which they are growing. They shall have grown in the container for a sufficient length of time for the root system to hold the planting medium when taken from the container, but not long enough to become root bound. Container grown plants exceeding the sizes indicated in ANSI Z60.1 shall have containers which are not less than 75% of the ball sizes for comparable B&B plant material. Each container plant shall be inspected and root pruned as needed.

4. Ground Cover and Perennials: Provide ground cover and perennials of species indicated, established and well rooted in pots or similar containers, and complying with ANSI Z60.1.

Planting Soil and Amendments:

1. Planting soil and amendments shall be as specified in Specification Section 329115 - MIT PLANTING SOILS and meet MIT Imported Soil Specification for sourcing and testing in Section 312322 - MIT Imported Fill Criteria and Management.
Planting Accessories:

1. Accessories
   a. Shredded pine bark mulch
   b. Wood Stakes: Straight, sound, rough sawn lumber 2 in. x 2 in., if square, or 2-1/2 in. diameter, if round; stained dark green. Wire for staking shall be 12 gauge steel.
   c. Strapping: Arbortie, manufactured by DeepRoot Green Infrastructure, LLC, 530 Washington Street, San Francisco, CA 94111 Tel: 800 458 7668 or 415 781 9700; Fax: 800 277 7668 or 415 781 0191, or approved equal.
   d. Wrapping: Arbor Tape, supplied by American Arborist Supplies, 882 S Matlack Street, Unit A, West Chester, PA 19382: Phone: 800-441-8381/610-430-1214; Fax: 610-430-8560; E-mail Address: info@arborist.com, or approved equal.
   e. Edging: extruded aluminum, 6063 alloy, T-6 hardness, maintenance strip edging for straight-line and gentle curve applications in corrugated L-shaped profile.
   f. Antidessicant shall be an emulsion specifically manufactured for plant protection which provides a protective film over plant surfaces which is permeable enough to permit transpiration.
   g. Root barrier shall be linear type root barrier or root box, capable of blocking tree roots from interfering with adjacent pavement without sacrificing secondary lateral root growth for stability, similar to "Deep Root" tree barrier, manufactured by Deeproot Partners, L.P., Burlingame, CA 94010; "Shawtown Root Barrier Panels” manufactured by NDA Inc., Lindsey, CA 93247; or approved equal.
   h. Tree watering system shall be 20 gallon Treegator, a slow release watering system for new trees., capable of delivering a high volume of water directly to the root system of a newly planted tree with no run-off or evaporation, manufactured by Spectrum Products, Inc., Youngville, North Carolina, 27596; supplied by PlanetGreenSpot.com PO Box 674 Pasadena, MD 21123, Tel. 888.574.6348.
   i. Tree watering stake shall be Deep Drip Tree Watering Stake, manufactured by Green King, LLC – World Headquarters, 162 W. Boxelder Place – Suite #2, Chandler, AZ 85225; Tel: (480) 422-0251 http://www.deepdrip.com/contact/ - #; Fax: (480) 503-2329http://www.deepdrip.com/contact/ - #; Email: info@deepdrip.com, or approved equal.

Lawns:

1. Part Shade Lawn Seed mix shall be as follows.

<table>
<thead>
<tr>
<th>Name of Seed</th>
<th>% by Weight in Mixture</th>
<th>Minimum % Purity</th>
<th>Minimum % Germination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jasper Creeping Red Fescue</td>
<td>25%</td>
<td>95</td>
<td>87</td>
</tr>
<tr>
<td>Victory</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chewings Fescue</td>
<td>25%</td>
<td>95</td>
<td>87</td>
</tr>
<tr>
<td>Spartan Hard Fescue</td>
<td>25%</td>
<td>95</td>
<td>87</td>
</tr>
<tr>
<td>America</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Kentucky Bluegrass 15%  90  87
Jefferson
Kentucky Bluegrass 10%  90  87

2. Full Sun and High Traffic Lawn Seed mix shall be as follows.

   a. Characteristics: A general purpose sports field mixture that features Rebel Turf-Type Tall Fescues, Perennial ryegrass and Kentucky bluegrass. It shall be a very durable mix that offers heat and drought tolerance. This mix shall be appropriate for high use sites that have limited watering capabilities. All chosen varieties shall be from the MD/VA recommended list as specified by the latest edition of The University of Maryland’s Turfgrass Technical Update #TT-77 (formally Agronomy Mimeo 77).

<table>
<thead>
<tr>
<th>Name of Seed</th>
<th>% by Weight in Mixture</th>
<th>Minimum % Purity</th>
<th>Minimum % Germination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Houndog 6 or, Coronado Gold;</td>
<td>80</td>
<td>95</td>
<td>90</td>
</tr>
<tr>
<td>Olympic Gold., or</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Endeavor Tall Fescue</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Keystone 2, or</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palmer III, or Brightstar II</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perennial Ryegrass</td>
<td>10</td>
<td>98</td>
<td>90</td>
</tr>
<tr>
<td>Geronimo, or Gold Rush</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kentucky Bluegrass</td>
<td>10</td>
<td>98</td>
<td>90</td>
</tr>
</tbody>
</table>

3. Sod shall be as follows.

   a. Certified Turfgrass Sod: Superior sod grown from certified, high quality seed of known origin or from plantings of certified grass seedlings or stolons. It shall be inspected by the certification agency of the state in which it is grown to assure satisfactory genetic identity and purity, overall high quality and freedom from noxious weeds as well as excessive quantities of other crop and weedy plants at time of harvest. All seed or original plant material in mixture must be certified. Turfgrass sod shall meet the published state standards for certification.

   1. Full Sun Mix – Sod - Premium Kentucky Bluegrass Blend supplied by Tuckahoe Farms - #305 Hubbard Rd, Berwick, ME 03901, or other sod farm capable of meeting the sod farm growing medium specified in Section 329115, PLANTING SOILS.

   2. Alternate: Part Shade Mix - Fine Fescue/Bluegrass supplied by Tuckahoe Farms - #305 Hubbard Rd, Berwick, ME 03901 or other sod farm capable of meeting the sod farm growing medium specified in Section 329115, PLANTING SOILS.

4. Sod Characteristics:
a. Thickness of Cut: Sod shall be machine cut at a uniform soil thickness of 5/8 in., plus or minus 1/4 in., at the time of cutting. Measurement for thickness shall exclude top growth and thatch.

b. Strip Size: Individual pieces of sod shall be cut to the supplier's standard width and length. Maximum allowable deviation from standard widths and lengths shall be plus or minus 1/2 in. on width, and plus or minus 5% on length. Broken strips and torn and uneven ends will not be acceptable.

c. Strength of Sod Strips: Standard size sections of sod shall be strong enough to support their own weight and retain their size and shape if suspended vertically when grasped in the upper 10% of the section.

d. Moisture Content: Sod shall not be harvested or transplanted when moisture content (excessively dry or wet) may adversely affect its survival.

e. Time Limitations: Sod shall be harvested, delivered, and transplanted within a 36 hour period unless a suitable preservation method is approved prior to delivery. Sod not transplanted within this period shall be inspected and approved by the Architect prior to its installation.

f. Thatch: Sod shall be relatively free of thatch. A maximum of 1/2 in. ( uncompressed) thatch will be permitted.

Lawn Accessories:

1. Hydroseeding Mulch: Wood fiber mulch shall be composed of 100% Thermally Refined wood fiber with the highest quality cellulose, delivering up to 15% greater yield, contain a green color additive, be weed free, and non-polluting, containing no germination or growth - inhibiting factors, similar to Conwed Fibers EnviroBlend with TriFlo, manufactured by Conwed Fibers, Profile Products LLC, 750 Lake Cook Rd, Suite 440, Buffalo Grove, IL 60089; Phone: 800-508-8681 Fax: 847-215-0577; SoilCover Wood, manufactured by Profile Products LLC • 750 Lake Cook Road • Suite 440 • Buffalo Grove, IL 60089; Technical Assistance: 800-508-8681; www.profileproducts.com, or approved equal.

2. Soil stabilization fiber shall be Stalok Fiber, polypropylene fiber filaments suitable for mixing with planting soil to provide structural reinforcement properties, manufactured by Stabilizer, Phoenix, AZ 85018, or approved equal.

8.4 Installation

Install materials in accordance with approved submittals. Install landscape work in proper relation with adjacent construction and with uniform appearance. Coordinate with work of other sections.

Preparation

1. Decompaction of planting areas and percolation testing shall be conducted in accordance with MIT Master Specification Section 329115 - MIT PLANTING SOILS.

Planting Soil
1. Prepare and place planting soil for plants and lawn areas in accordance with MIT Master Specification Section 329115 - MIT PLANTING SOILS.
   a. Final surface of planting soil immediately before seeding and sodding shall be within $\pm \frac{1}{2}$ in. of required elevation, with no ruts, mounds, ridges, or other faults, and no pockets or low spots in which water can collect. Stones, roots, and other debris greater than 1 in. in any dimension, which are visible at the surface, shall be removed and the resulting holes filled with topsoil, leaving a uniform planar surface.

Excavate as required for trees and shrubs. If the planting pit for any tree is dug too deep, soil shall be added to bring it to correct level, and the soil shall be thoroughly tamped. Walls of plant pits shall be dug so that they are sloped as shown on the Drawings, and scarified.

For seeded lawns, apply seed at rate recommended by seed supplier. Seed shall be applied in two applications; first shall be by mechanical spreader; second shall be by hydroseeding method. Sod shall be placed and all sodding operations completed within 72 hours following stripping from sod source bed. For lawns with sod, place sod tightly, with grain in same direction. Edges of the sodded areas shall be smooth, and all sodded areas shall conform to the design cross sections and grade. At edges adjacent to curbs, paved areas, etc., top surface of earth in sod shall be 1/2 in. below adjacent hard surface.

Plants shall be set as indicated on Drawings. Plants shall be set so that the root flare is at, or slightly above, finished grade. Plants located in poorly drained soils shall be set 2 to 4 inches above finished grade, gradually sloping between the top of the root ball and the surrounding finished grade.

Install plant material and backfill with planting soil mix. Stake and guy trees. Wrap trees and mulch tree pits and plant beds as required. Water thoroughly. Allow for soil settlement.

Planting Maintenance:

Provide maintenance and watering until turnover to MIT for maintenance and watering. Replace damaged materials and dead or unhealthy plants prior to turnover to MIT; determination as acceptable to the MIT Project Manager.

1. Maintenance shall consist of pruning, watering, cultivating, weeding, mulching, fertilizing, removal of dead material, repairing and replacing of tree stakes, tightening and repairing of guys, adjusting and replacing of damaged tree wrap material, resetting plants to proper grades and upright position, and furnishing and applying such sprays as are necessary to keep plantings free of insects and disease, and in a healthy growing condition.

2. One-Year Warranty Period: Provide replacement of plants that fail to thrive for a period of one year after turnover to MIT; determination as acceptable to the MIT Project Manager.

Lawn Maintenance:

Provide maintenance and watering until turnover to MIT for maintenance and watering. Replace damaged materials and dead or unhealthy lawns prior to turnover to MIT; determination as acceptable to the MIT Project Manager.
1. Maintenance of seeded areas shall begin upon completion of seeding and shall continue until acceptance of the building, or until mowing as specified below is completed, or until average height of grass is 1-1/2 in., whichever occurs later.
   a. Watering:
      1. Week No. 1: Provide all watering necessary to keep seed bed moist at all times. Perform watering daily or as necessary to maintain moist soil to a depth of 4 in.
      2. Week No. 2 and until acceptance of the building, or until mowing as specified below is completed, or until average height of grass is 1-1/2 in., whichever occurs later: Water as necessary to maintain adequate moisture in the upper 4 in. of soil to promote seed germination.
   b. Mowing
      1. Not more than 40% of the grass leaf shall be removed during the first or subsequent mowings.
      2. Bluegrass and other cool season grasses shall be maintained between 1-1/2 in. and 2-1/2 in.
      3. All clippings shall be removed.
   c. One-Year Warranty
      1. Provide replacement of lawns that fail to thrive for a period of one year after turnover to MIT; determination as acceptable to the MIT Project Manager.

2. Maintenance of sodded areas shall begin upon completion of sodding and shall continue for 45 days thereafter, unless sodding is not completed until after September 15, in which case maintenance shall continue until the June 15 following. Replace damaged materials and dead or unhealthy sod prior to turnover to MIT; determination as acceptable to the MIT Project Manager.
   a. Watering
      1. Week No. 1: Provide all watering necessary for rooting of sod. Soil on sod pads shall be kept moist at all times. Perform watering daily or as necessary to maintain moist soil to a depth of 4 in. Watering shall be done during the heat of the day to prevent wilting.
      2. Week No. 2 and Subsequent Weeks: Water as necessary to maintain adequate moisture in the upper 4 in. of soil to promote deep root growth.
   b. Mowing
      1. Mowing shall not be attempted until the sod is firmly rooted and securely in place. Not more than 40% of the grass leaf shall be removed during the first or subsequent mowings.
      2. Bluegrass and other cool season grasses shall be maintained between 1-1/2 in. and 2-1/2 in.
      3. All clippings shall be removed.
      4. After 2 mowings, the Contractor shall top dress the sod with an application of fertilizer at the rate of 1 pound of actual nitrogen per 1000 square feet.
   c. One-Year Warranty
      1. Provide replacement of sod that fail to thrive for a period of one year after turnover to MIT; determination as acceptable to the MIT Project Manager.
9. APPENDICES

9.1 Construction Specifications

Refer to the following documents, to be used in their entirety for applicable projects.

Division 01 specifications are attached to Division 01 of the MIT Design Standards.

Section 015640 - MIT Temporary Tree and Soil Protection

Division 31 specifications are attached to Division 31 of the MIT Design Standards.

Section 312317 - MIT Specialized Root Zone and Soil Excavation
Section 312322 - MIT Imported Fill Criteria and Management

Division 32 specifications are attached to Division 32 of the MIT Design Standards.

Section 321313 - MIT Concrete Paving
Section 329115 - MIT Planting Soils

END OF DOCUMENT
PART 1 GENERAL

1.1 GENERAL PROVISIONS

A. Attention is directed to the CONTRACT AND GENERAL CONDITIONS and all Sections within DIVISION 01 - GENERAL REQUIREMENTS which are hereby made a part of this Section of the Specifications.

B. Examine all Drawings and all Sections of the Specifications for requirements and provisions affecting the Work of this Section.

1.2 DESCRIPTION OF WORK

A. Provide all equipment and materials and do all work necessary to construct the Portland cement concrete paving work, complete, as indicated on the Drawings and as specified.

1.3 QUALITY ASSURANCE

A. Manufacturer Qualifications: Manufacturer of ready-mixed concrete products who complies with ASTM C 94/C 94M requirements for production facilities and equipment.

1. Manufacturer certified according to NRMCA's "Certification of Ready Mixed Concrete Production Facilities."

B. Testing Agency Qualifications: An independent agency qualified according to ASTM C 1077 and ASTM E 329 for testing indicated, as documented according to ASTM E 548.

1. Personnel conducting field tests shall be qualified as ACI Concrete Field Testing Technician, Grade 1, according to ACI CP-01 or an equivalent certification program.

C. ACI Publications: Unless otherwise specified, work and materials for construction of the Portland cement concrete paving shall conform to ACI 325.9R.

D. Work, materials, and color of the handicap ramp paving shall conform to applicable sections of Americans with Disabilities Act (ADA) Accessibility Guidelines for Buildings and Facilities.

E. Paving work, base course etc., shall be done only after excavation and construction work which might injure them have been completed. Damage caused during construction shall be repaired before acceptance.

F. Existing paving areas shall, if damaged or removed during course of this project, be repaired or replaced under this section of the specification. Workmanship and materials for such repair and replacement, except as otherwise noted, shall match as closely as possible those employed in existing work.

G. Pavement, base, or subbase shall not be placed on a muddy or frozen subgrade.
1.4 PRECONSTRUCTION MOCK-UP PANELS

A. General

1. Schedule mock-up casting for acceptance 30 days prior to casting of concrete surfaces represented by the mockups.
2. Locate mock-up panels in original location or non-public areas accepted by the Architect.
3. Continue to cast mock-ups until acceptable mock-ups area produced. Accepted mock-ups shall be the standard for color, texture, and workmanship for the work.
4. Mock-up sequence of forming, placing, form removal, curing, and finishing shall be reviewed and accepted by the Architect.
5. Mock-up formwork shall be inspected and accepted by the Architect before placing of concrete.
6. Use the same concrete mixes and placement procedures, accepted in mock-ups, in the final work, unless otherwise directed by the Architect.
7. Protect accepted mock-ups from damage until completion and acceptance of the work represented by the mock-up.
8. Remove mock-up panels from site at completion of project, as directed by the Architect.

B. Construct mock-up panels or areas as indicated to demonstrate the ability to cast concrete for concrete paving to achieve shape, color, and textured finish required. Mock-ups shall include or meet the following requirements:

1. Provide full scale mock-up panels and areas.
2. Provide mock-ups simulating actual design and execution conditions for concrete mix materials, reinforcement, formwork, placing sequence, form removal, curing, finishing, and methods and materials of stain removal and correction of defective work.
3. On mock-ups where directed by the Architect, provide minimum of three variation of mix color to be used in the repair of defective work, in order to determine acceptable color and texture match.
4. Demonstrate in the construction of the mock-up formwork the sealer material, form release agent, and curing materials and methods to be used.

C. Sample panel, 5 ft. x 5 ft. minimum, shall be constructed prior to start of handicap ramp paving, exhibiting detectable warning surface and required color contrast with adjacent paving in accordance with ADA Guidelines.

D. Source of Materials. Utilize the same source, stock, or brand of concrete materials for each class or mix of concrete which is to be exposed. Do not interchange materials or mixes until an additional mock-up shows that uniformity in finish texture and color, as compared to original mock-up will be maintained. If necessary, obtain and stockpile materials in sufficient quantity to ensure continuity and uniformity.

1.5 SUBMITTALS

A. Description of Methods and Sequence of Placement. For each type of specially-finished concrete provide description of methods and sequence of placement. Submit manufacturer's product data for the following:

1. Form release agent.
2. Preformed joint filler.
3. Sealants.

C. Submit samples of the following:
   1. Preformed joint filler.
   2. Color chart for selection of sealant color.

D. Design Mixtures: For each concrete pavement mixture. Include alternate mixture designs when characteristics of materials, Project conditions, weather, test results, or other circumstances warrant adjustments.

1.6 TESTING AND INSPECTION

A. The Owner reserves the right to inspect and test paving and associated work in accordance with Division 01.

PART 2 PRODUCTS

2.1 AGGREGATE BASE COURSE

A. Material for base course shall be a graded, granular, non-frost susceptible, free-draining material, combining crusher-run coarse aggregates of crushed stone and fine aggregates of natural sand or stone screenings uniformly premixed with a predetermined quantity of water, free from loam and clay, or other plastic materials, and which can be readily compacted to form a stable foundation.

1. Material shall conform to MHD Specifications Section M2.01.7.

2.2 STEEL REINFORCEMENT

A. Steel reinforcing bars shall conform to the following requirements:

   1. Reinforcing Bars: ASTM A 615/A 615M, Grade 60 (Grade 420); deformed.
   2. Galvanized Reinforcing Bars: ASTM A 767/A 767M, Class II zinc coated, hot-dip galvanized after fabrication and bending; with ASTM A 615/A 615M, Grade 60 (Grade 420) deformed bars.
   3. Epoxy-Coated Reinforcing Bars: ASTM A 775/A 775M or ASTM A 934/A 934M; with ASTM A 615/A 615M, Grade 60 (Grade 420) deformed bars.
   4. Steel Bar Mats: ASTM A 184/A 184M; with ASTM A 615/A 615M, Grade 60 (Grade 420), deformed bars; assembled with clips.

B. Welded wire fabric reinforcement shall conform to the following applicable requirements. Fabric reinforcement shall be furnished in flat sheets. Fabric reinforcement in rolls will not be permitted.

   1. Plain-Steel Welded Wire Reinforcement: ASTM A 185, fabricated from as-drawn steel wire into flat sheets.
C. Joint Dowel Bars: Plain steel bars, ASTM A 615/A 615M, Grade 60 (Grade 420). Cut bars true to length with ends square and free of burrs.

D. Epoxy-Coated Joint Dowel Bars: ASTM A 775/A 775M; with ASTM A 615/A 615M, Grade 60 (Grade 420), plain steel bars.

E. Tie Bars: ASTM A 615/A 615M, Grade 60 (Grade 420), deformed.

F. Bar Supports: Bolsters, chairs, spacers, and other devices for spacing, supporting, and fastening reinforcing bars, welded wire reinforcement, and dowels in place. Manufacture bar supports according to CRSI's "Manual of Standard Practice" from steel wire, plastic, or precast concrete of greater compressive strength than concrete, and as follows:

1. Equip wire bar supports with sand plates or horizontal runners where base material will not support chair legs.
2. For epoxy-coated reinforcement, use epoxy-coated or other dielectric-polymer-coated wire bar supports.

G. Epoxy Repair Coating: Liquid two-part epoxy repair coating, compatible with epoxy coating on reinforcement.


2.3 PORTLAND CEMENT CONCRETE

A. Portland cement concrete for pavements and slabs shall be air-entrained type with a maximum watercement ratio of 0.50 conforming to ACI 325.9R. Minimum compressive strengths at 28 days shall be as follows: Flexural strength with third point loading - 650 psi; compressive strength - 4000 psi.

1. Concrete shall be air-entrained type, conforming to ASTM C 94. Air content by volume shall be 6% ± 1%, and shall be tested in accordance with ASTM C 231.
2. Concrete slump shall be no less than 2 in. nor greater than 4 in., determined in accordance with ASTM C 143.
3. Cement shall be Portland cement, conforming to ASTM C 150, Type I or II. Only one color of cement, all of the same manufacturer, shall be used for the work. Type III cement shall be used only with the prior approval of the Architect.
4. Fine and coarse aggregates shall conform to ASTM C 33.
5. Concrete shall contain a water reducing agent to minimize cement and water content of the concrete mix at the specified slump. Water reducing agent shall conform to ASTM C 494.
6. No calcium chloride or admixtures containing calcium chloride shall be added to the concrete. No admixtures other than those specified shall be used in the concrete without the specific written permission of the Architect in each case.

2.4 CHEMICAL ADMIXTURES

A. Chemical Admixtures: Provide admixtures certified by manufacturer to be compatible with other admixtures and to contain not more than 0.1 percent water-soluble chloride ions by mass of cementitious material.

1. Water-Reducing Admixture: ASTM C 494/C 494M, Type A.
2. Retarding Admixture: ASTM C 494/C 494M, Type B.

2.5 HANDICAP RAMPS

A. Color hardener and curing compound shall be manufactured and supplied by the Bomanite Corporation, 81 Encina Avenue, Palo Alto, CA 94301; tel. 800-854-2094, or approved equal.

1. Color hardener shall be Bomanite Color Hardener, or approved equal. Color for concrete shall have visual contrast with surrounding paving in accordance with ADA Guideline A4.29.2 “Detectable Warnings on Walking Surfaces”.

2. Curing compound shall be liquid applied, Bomanite Color Curing Compound, or approved equal.

3. Surface sealer shall be non-yellowing type which breathes water vapor, as manufactured by ProSoCo, Sika Chemical Corporation, Dural-International Corporation, or approved equal.

2.6 CURING MATERIALS FOR UNCOLORED CONCRETE

A. Curing shall be by moist curing or by use of curing compound.

B. Absorptive Cover: AASHTO M 182, Class 2, burlap cloth made from jute or kenaf, weighing approximately 9 oz./sq. yd. (305 g/sq. m) dry.

C. Moisture-Retaining Cover: Curing paper shall be nonstaining, fiber reinforced laminated kraft bituminous product conforming to ASTM C 171. Four mil polyethylene sheeting may be substituted for curing paper.

D. Curing compound shall be a resin-base, white pigmented compound conforming to ASTM C 309, Type 2.

E. Water: Potable.

2.7 EXPANSION JOINTS

A. Unless otherwise indicated on the Drawings, expansion joints shall be located 30 ft. o.c., maximum.

B. Expansion joint filler shall be preformed, nonbituminous type joint filler conforming to ASTM D 1752, Type II, similar to Sealtight Cork Expansion Joint Filler, manufactured by W.R. Meadows, Inc., Elgin, IL 60120, or approved equal.

1. Premolded filler shall be one piece for the full depth and width of the joint leaving a sealant recess as indicated.

2. Use of multiple pieces of lesser dimensions to make up required depth and width of joint will not be permitted.

3. Except as otherwise noted on the Drawings, joint filler shall be 1/2 in. thick.

C. Expansion joints between pours of different colors shall be “Snap Cap”, manufactured by W. R. MEADOWS, INC., 300 Industrial Drive P.O. Box 338 Hampshire, IL 60140-0338 Phone: (847) 214-2100; (800) 342-5976; Fax: (847) 683-4544; E-mail: wrmil@wrmeadows.com, or approved equal. Unless otherwise indicated, Snap Cap shall be ½ in. wide.
2.8 CONTROL JOINTS

A. Control joints indicated to be sawn shall be made by saw cutting concrete slab after concrete is finished and when the surface is stiff enough to support the weight of workmen without damage to the slab. Saw blade shall cut into slab at least 1 in., but in no case less than 25% of slab depth.

2.9 CONSTRUCTION JOINTS

A. Transverse construction joints shall be placed whenever placing of concrete is suspended for more than 30 minutes.

1. Butt joint with dowels or thickened edge joint shall be used if construction joints occurs at location of control joint.
2. Keyed joints with tiebars shall be used if the joint occurs at any other location.

2.10 GROUT

A. Grout shall be mixed in the proportions of one part Portland cement to two parts sand, by volume. Only sufficient water shall be used to enable grout to barely hold its shape when squeezed into a ball in the hand. Sand for grout shall be "Fine Aggregate", conforming to ASTM C 33.

B. Nonshrink grout shall be pre-mixed non-shrinking, high strength grout. Compressive strength in 28 days shall be 5,000 psi minimum, but in no case less than the specified strength of the adjacent concrete. Manufacturer shall provide evidence that the material meets the requirements of the COE CRD-C 621 (558). Grout permanently exposed to view shall be nonoxidizing; metallic grout may be used in other locations.

1. Nonshrink grout shall be one of the following, or approved equal:

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Product</th>
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<tbody>
<tr>
<td>Gifford-Hill Co.</td>
<td>Supreme</td>
</tr>
<tr>
<td>Master Builders Co.</td>
<td>Embeco</td>
</tr>
<tr>
<td>U.S. Grout Corporation</td>
<td>Five Star Grout</td>
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2.11 SEALANT

A. Sealant for sealing of control joints and expansion joints in concrete walks shall be a two component polyurethane based sealant conforming to ASTM C 920 and to Fed. Spec. TTS00227, Class A, with a Shore A hardness of 30±5, or better. Sealant shall be Tremco THC900, manufactured by Tremco, Cleveland, OH 44104, or approved equal.

1. Color of sealant shall be selected by the Architect from the manufacturer's full color range.
2. Primer shall be that recommended by the sealant manufacturer for the use intended.
3. Joint backing where required shall be as recommended by the sealant manufacturer.

2.12 BOND BREAKER
A. Bond breaker shall be asphalt felt conforming to ASTM D 226, Type I or 6 mil polyethylene sheeting.

2.13 SALT GUARD MATERIAL (Water Based)

A. Manufacturer: PROSOCO, Inc., 3741 Greenway Circle, Lawrence, KS 66046. Phone: (800) 255-4255; Fax: (785) 830-9797 or approved equal.

1. Paving Salt Guard shall be Consolideck® Saltguard® WB, a ready-to-use water-based, VOC compliant silane/siloxane water repellent and “chloride screen” for the protection of concrete and masonry surfaces. Saltguard® WB protects surfaces from moisture intrusion and chemical attack of chloride salts, screens chlorides from penetrating through concrete to reinforcing steel and reduces rebar corrosion and surface spalling caused by water-carried salts.

   a. FORM: White liquid
   b. SPECIFIC GRAVITY: 0.997
   c. pH: 7 to 8
   d. WEIGHT/GALLON: 8.24 pounds
   e. ACTIVE CONTENT: 10 percent
   f. FLASH POINT: greater than 212 degrees F (greater than 100 degrees C)
   g. FREEZE POINT: 32 degrees F (0 degrees C)
   h. VOC CONTENT: less than 25 g/L Low Solids Coating. Complies with all known national, state and district AIM VOC regulations.

B. Limitations

1. Not for use on natural stone, except sandstone.
2. Always test for proper penetration when applying to tightly troweled concrete.
3. Will not prevent water penetration through structural cracks, defects or open joints.
4. Not suitable for application to coated surfaces or surfaces previously treated with water repellents or liquid hardeners.
5. Water repellency of treated surfaces will increase for up to 14 days after application.
6. Not suitable for protecting surfaces subjected to constant water spray (car washes).
7. Not suitable for application to synthetic resin paints, gypsum or other non-masonry surfaces.

PART 3 EXECUTION

3.1 PREPARATION OF SUBGRADE

A. Areas to be paved will be compacted and brought to subgrade elevation before work of this section is performed. Final fine grading, filling, and compaction of areas to receive paving, as required to form a firm, uniform, accurate, and unyielding subgrade at required elevations and to required lines, shall be done under this Section.

B. Existing subgrade material which will not readily compact as required shall be removed and replaced with satisfactory materials. Additional materials needed to bring subgrade to required line and grade and to replace unsuitable material removed shall be material conforming to this Section.
C. Subgrade of areas to be paved shall be recompacted as required to bring top 8 in. of material immediately below gravel base course to a compaction at optimum moisture of at least 95% of maximum density, as determined by ASTM D 1557. Subgrade compaction shall extend for a distance of at least 1 ft. beyond pavement edge.

   1. Field testing shall be conducted to determine in-place density, accompanied by visual inspection of the compaction methods being used.

D. Excavation required in pavement subgrade shall be completed before fine grading and final compaction of subgrade are performed. Where excavation must be performed in completed subgrade, subbase, base, or pavement, subsequent backfill and compaction shall be performed as directed by the Architect as specified. Completed subgrade after filling such areas shall be uniformly and properly graded.

E. Areas being graded or compacted shall be kept shaped and drained during construction. Ruts greater than or equal to 2 in. deep in subgrade, shall be graded out, reshaped as required, and recompacted before placing pavement.

F. Materials shall not be stored or stockpiled on subgrade.

G. Disposal of debris and other material excavated under this section, and material unsuitable for or in excess of requirements for completing work of this section shall be disposed of offsite.

H. Prepared subgrade will be inspected by the Architect. Subgrade shall be approved by the Architect before installation of gravel base course. Disturbance to subgrade caused by inspection procedures shall be repaired under this section of the specification.

3.2 AGGREGATE BASE COURSE

A. Aggregate base course for paving and the spreading, grading, and compaction methods employed shall conform to standard requirements for usual base course of this type for first class road work, and the following:

   1. MHD Specifications Section 405, "Gravel Base Course".

B. Width of base course shall be greater than or equal to the width of pavement surface, if continuous lateral support is provided during rolling, and shall extend at least 2 x base thickness beyond edge of the course above, if not so supported.

C. Aggregate material shall be applied in lifts less than or equal to 6 in. thick, compacted measure. Each lift shall be separately compacted to specified density, using a 6 ton smooth drum vibratory roller equivalent to a 6 ton static roller, or an approved equivalent. Smaller areas or areas impossible to reach with large drum rollers shall be compacted to specified density using a vibrating plate compactor.

   1. Material shall be placed adjacent to wall, manhole, catch basin, and other structures only after they have been set to required grade and level.
2. Rolling shall begin at sides and progress to center of crowned areas, and shall begin on low side and progress toward high side of sloped areas. Rolling shall continue until material does not creep or wave ahead of roller wheels.

3. Surface irregularities which exceed 1/2 in. as measured by means of a 10 ft. long straightedge, shall be replaced and properly recompacted.

D. Base course shall be compacted at optimum moisture content to not less than 95% of maximum density as determined by ASTM D 1557.

E. Subgrade and base course shall be kept clean and uncontaminated. Less select materials shall not be permitted to become mixed with gravel. Materials spilled outside pavement lines shall be removed and area repaired.

F. Portions of subgrade or of construction above which become contaminated, softened, or dislodged by passing of traffic, or otherwise injured, shall be cleaned, replaced, or otherwise repaired to conform to the requirements of this specification before proceeding with next operation.

3.3 STEEL REINFORCEMENT

A. General: Comply with CRSI's "Manual of Standard Practice" for fabricating, placing, and supporting reinforcement.

B. Before being placed in position, reinforcing for reinforced concrete shall be thoroughly cleaned of loose mill and rust scale, dirt, ice, and other foreign material which may reduce the bond between the concrete and reinforcing. Where there is delay in placing concrete after reinforcement is in place, bars shall be reinspected and cleaned when necessary.

C. Any bar showing cracks after bending shall be discarded.

D. Unless otherwise indicated on the Drawings, reinforcing shall extend within 2 in. of formwork and expansion joints. Reinforcing shall continue through control joints. Adjacent sheets of fabric reinforcing shall lap 6 in.

E. After forms have been coated with form release agent, but before concrete is placed, reinforcing steel anchors shall be securely wired in the exact position called for, and shall be maintained in that position until concrete is placed and compacted. Chair bars and supports shall be provided in a number and arrangement satisfactory to the Architect.

F. Install welded wire reinforcement in lengths as long as practicable. Lap adjoining pieces at least one full mesh, and lace splices with wire. Offset laps of adjoining widths to prevent continuous laps in either direction.

G. Epoxy-Coated Reinforcement: Use epoxy-coated steel wire ties to fasten epoxy-coated reinforcement. Repair cut and damaged epoxy coatings with epoxy repair coating according to ASTM D 3963/D 3963M.

3.4 PORTLAND CEMENT CONCRETE PAVING
A. Paving mix, equipment, methods of mixing and placing, and precautions to be observed as to weather, condition of base etc., shall meet the requirements of ACI 325.9R. Pavement shall be constructed in accordance with the Drawings.

B. The Architect shall be notified of concrete placement sufficiently in advance of start of operation to allow his representative to complete preliminary inspection of the work, including subgrade, forms, and reinforcing steel, if used.

C. Normal concrete placement procedures shall be followed. Concrete shall arrive at the jobsite so that no additional water will be required to produce the desired slump. When conditions develop that required addition of water to produce the desired slump, permission of the Architect must be obtained. The concrete shall be transported from the mixer to its place of deposit by a method that will prevent segregation or loss of material.

D. Work shall not be performed during rainy weather or when temperature is less than 40o F. (4.4o C).

E. Adjacent work, etc., shall be protected from stain and damage during entire operation. Damaged and stained areas shall be replaced or repaired to equal their original conditions.

F. Existing concrete, earth, and other water-permeable material against which new concrete is to be placed shall thoroughly damp when concrete is placed. There shall be no free water on surface.

G. Concrete which has set or partially set before placing shall not be employed. Retempering of concrete will not be permitted.

H. Concrete shall be thoroughly spaded and tamped to secure a solid and homogeneous mass, thoroughly worked around reinforcement and into corners of forms.

I. When joining fresh concrete to concrete which has attained full set, latter shall be cleaned of foreign matter, and mortar scum and laitance shall be removed by chipping and washing. Clean, roughened base surface shall be saturated with water, but shall have no free water on surface. A coat of 1:1 cement-sand grout, approximately 1/8 in. thick, shall be well scrubbed into thoroughly dampened concrete base. New concrete shall be placed immediately, before grout has dried or set.

3.5 FINISHING

A. Concrete flatwork surfaces shall be screeded off, bullfloated, power or hand floated, troweled and finished true to line and grade, and free of hollows and bumps. Surface shall be dense, smooth, and at exact level and slope required.

1. Where indicated on the Drawings, horizontal surfaces of concrete surfaces which will be exposed shall be given a light broomed finish, with direction of grooves in concrete surface perpendicular to length of concrete pavement. After concrete has set sufficiently to prevent coarse aggregate from being torn from surface, but before it has completely set, brooms shall be drawn across it to
produce a pattern of small parallel grooves. Broomed surface shall be uniform, with no smooth, unduly rough or porous spots, or other irregularities. Coarse aggregate shall not be dislodged by brooming operation.

B. Immediately following finishing operations, arrises at edges and both sides of expansion joints shall be rounded to a 1/4 in. radius. Control joints to be tooled shall be scored into slab surface with scoring tool. Adjacent edges of control joint shall at same time be finished to a 1/4 in. radius.

C. Where finishing is performed before end of curing period, concrete shall not be permitted to dry out, and shall be kept continuously moist from time of placing until end of curing period, or until curing membrane is applied.

3.6 CURING

A. It is essential that concrete be kept continuously damp from time of placement until end of specified curing period. It is equally essential that water not be added to surface during floating and troweling operations, and not earlier than 24 hours after concrete placement. Between finishing operations surface shall be protected from rapid drying by a covering of waterproofing paper. Surface shall be damp when the covering is placed over it, and shall be kept damp by means of a fog spray of water, applied as often as necessary to prevent drying, but not sooner than 24 hours after placing concrete. None of the water so applied shall be troweled or floated into surface.

B. Concrete surfaces shall be cured by completely covering with curing paper or application of a curing compound.

1. Concrete cured using waterproof paper shall be completely covered with paper with seams lapped and sealed with tape. Concrete surface shall not be allowed to become moistened between 24 and 36 hours after placing concrete. During curing period surface shall be checked frequently, and sprayed with water as often as necessary to prevent drying, but not earlier than 24 hours after placing concrete.

2. If concrete is cured with a curing compound, compound shall be applied at a rate of 200 sq. ft. per gallon, in two applications perpendicular to each other.

3. Curing period shall be seven days minimum.

3.7 CURING COLORED CONCRETE

A. Colored concrete shall not under any circumstances, be cured using water fog misting or ponding, burlap, plastic sheeting, or other wet covering.

B. Curing material and method shall be in strict conformance with color pigment manufacturer's guidelines and recommendations.

C. Only if additional protection is absolutely required, the surface should remain uncovered for at least 4 days, after which time new and unwrinkled non-staining reinforced waterproof kraft curing paper may be used.

3.8 HANDICAP RAMPS
A. Paving mix, equipment, methods of mixing and placing, and precautions to be observed as to weather, condition of base etc., shall meet the requirements of ACI 316 for any concrete paving in similar conditions. Handicap ramps shall be constructed in accordance with the Drawings, and ADA Guidelines 4.7.10, and 4.29.2.

B. Normal concrete placement procedures shall be followed. Concrete shall arrive at the jobsite so that no additional water will be required to produce the desired slump. When conditions develop that required addition of water to produce the desired slump, permission of the Architect must be obtained. The concrete shall be transported from the mixer to its place of deposit by a method that will prevent segregation or loss of material.

C. Application of color hardener and color curing compound, and finishing procedures shall be in accordance with manufacturer's recommendations and ADA Guidelines for Diagonal Curb Ramps, and Detectable Warnings on Walking Surfaces.

3.9 CONSTRUCTION JOINTS

A. Construction Joints: Set construction joints at side and end terminations of pavement and at locations where pavement operations are stopped for more than one-half hour unless pavement terminates at isolation joints.

1. Continue steel reinforcement across construction joints, unless otherwise indicated. Do not continue reinforcement through sides of pavement strips, unless otherwise indicated.
2. Provide tie bars at sides of pavement strips where indicated.
3. Butt Joints: Use [bonding agent] [epoxy bonding adhesive] at joint locations where fresh concrete is placed against hardened or partially hardened concrete surfaces.
4. Keyed Joints: Provide preformed keyway-section forms or bulkhead forms with keys, unless otherwise indicated. Embed keys at least 1-1/2 inches (38 mm) into concrete.
5. Doweled Joints: Install dowel bars and support assemblies at joints where indicated. Lubricate or asphalt-coat one-half of dowel length to prevent concrete bonding to one side of joint.

3.10 EXPANSION JOINTS

A. Expansion joints (isolation joints) shall be 1/2 in. wide and unless otherwise indicated on the Drawings, shall be located 30 ft. o.c. and at places where pavement meets other structures. Expansion joint shall be formed in the concrete to required width with preformed joint filler in place. Joint filler shall extend the full width and depth of the slab. Joint filler shall extend the full length of the expansion joint.

1. For concrete pavements, depth of joint filler shall be as required to form a 1-1/4 in. deep sealant and backer rod recess below finished concrete surface.

B. Snap Cap Expansion Joint: To install, slide SNAP-CAP over the top of the expansion joint. Place the concrete and screed to finish grade as usual. When concrete is cured, insert a screwdriver through the top of SNAP-CAP, pull free and discard. The joint shall be sealed.

3.11 CONTROL JOINTS
A. Control joints indicated shall be sawn by using a diamond blade concrete power saw. Joint shall be made after concrete is finished and when the surface is stiff enough to support the weight of workmen without damage to the slab. Saw shall cut into slab at least 1 in., but in no case less than 25% of slab depth.

3.12 CONTROL JOINTS/CONTRACTION JOINTS

A. General: Joint shall be made after concrete is finished and when the surface is stiff enough to support the weight of workmen without damage to the slab, but before slab has achieved its final set. Saw cut joints shall be straight and accurate to line.

B. Contraction Joints: Form weakened-plane contraction joints, sectioning concrete into areas as indicated. Construct contraction joints for a depth equal to at least 1 in., but in no case less than one-fourth of the concrete thickness, as follows:

1. Saw cut joints shall be sawn flush to vertical surfaces.
2. Unless otherwise indicated on the Drawings, control joints in pedestrian pavements shall be located 10 ft. o.c. maximum.
3. Doweled Contraction Joints: Install dowel bars and support assemblies at joints where indicated. Lubricate or asphalt coat one-half of dowel length to prevent concrete bonding to one side of joint.

3.13 COLD WEATHER CONCRETING

A. Materials for concrete shall be heated when concrete is mixed, placed, or cured when the mean daily temperature is below 40°F. or is excepted to fall to below 40°F. within 72 hours, and the concrete after placing shall be protected by covering, heat, or both.

B. Details of handling and protecting of concrete during freezing weather shall be subject to the approval and direction of the Architect. Procedures shall be in accordance with provisions of ACI 306R.

3.14 HOT WEATHER CONCRETING

A. Concrete just placed shall be protected from the direct rays of the sun and the forms and reinforcement just prior to placing shall be sprinkled with cold water. Every effort shall be made to minimize delays which will result in excessive mixing of the concrete after arrival on the job.

B. During periods of excessively hot weather (95°F., or above), ingredients in the concrete shall be cooled insofar as possible and cold mixing water shall be used to maintain the temperature of the concrete at permissible levels all in accordance with the provisions of ACI 305. Any concrete with a temperature above 95°F., when ready for placement will not be acceptable, and will be rejected.

C. Temperature records shall be maintained throughout the period of hot weather giving air temperature, general weather conditions (calm, windy, clear, cloudy, etc.) and relative humidity. Records shall include checks on temperature of concrete as delivered and after placing in forms. Data should be correlated with the progress of
the work so that conditions surrounding the construction of any part of the structure can be ascertained.

3.15 SEALING OF JOINTS

A. Where indicated on the Drawings, expansion joints and control joints shall be sealed with joint sealant in accordance with the precautions specified in the Appendix of ASTM C 962.

3.16 FIELD QUALITY CONTROL

A. Testing Services: Testing of composite samples of fresh concrete obtained according to ASTM C 172 shall be performed according to the following requirements:

1. Testing Frequency: Obtain at least 1 composite sample for each 5000 sq. ft. or fraction thereof of each concrete mix placed each day.
   a. When frequency of testing will provide fewer than five compressive-strength tests for each concrete mixture, testing shall be conducted from at least five randomly selected batches or from each batch if fewer than five are used.

2. Slump: ASTM C 143/C 143M; one test at point of placement for each composite sample, but not less than one test for each day's pour of each concrete mix. Perform additional tests when concrete consistency appears to change.

3. Air Content: ASTM C 231, pressure method; one test for each composite sample, but not less than one test for each day's pour of each concrete mix.

4. Concrete Temperature: ASTM C 1064; one test hourly when air temperature is 40 deg F (4.4 deg C) and below and when 80 deg F (27 deg C) and above, and one test for each composite sample.

5. Compression Test Specimens: ASTM C 31/C 31M; cast and laboratory cure one set of three standard cylinder specimens for each composite sample.

6. Compressive-Strength Tests: ASTM C 39/C 39M; test 1 specimen at 7 days and 2 specimens at 28 days.
   a. A compressive-strength test shall be the average compressive strength from 2 specimens obtained from same composite sample and tested at 28 days.

C. Strength of each concrete mix will be satisfactory if average of any 3 consecutive compressive-strength tests equals or exceeds specified compressive strength and no compressive-strength test value falls below specified compressive strength by more than 500 psi (3.4 MPa).

D. Test results shall be reported in writing to Architect, concrete manufacturer, and Contractor within 48 hours of testing. Reports of compressive-strength tests shall contain Project identification name and number, date of concrete placement, name of concrete testing and inspecting agency, location of concrete batch in Work, design compressive strength at 28 days, concrete mixture proportions and materials, compressive breaking strength, and type of break for both 7- and 28-day tests.
E. Nondestructive Testing: Impact hammer, sonoscope, or other nondestructive device may be permitted by Architect but will not be used as sole basis for approval or rejection of concrete.

F. Additional Tests: Testing and inspecting agency shall make additional tests of concrete when test results indicate that slump, air entrainment, compressive strengths, or other requirements have not been met, as directed by Architect.

G. Remove and replace concrete pavement where test results indicate that it does not comply with specified requirements.

H. Additional testing and inspecting, at Contractor's expense, will be performed to determine compliance of replaced or additional work with specified requirements.

3.17 PROTECTION OF CONCRETE SURFACES

A. Concrete surfaces shall be protected from traffic or damage until surfaces have hardened sufficiently. If necessary 1/2 in. thick plywood sheets shall be used to protect the exposed surface.

B. Drill test cores, where directed by Architect, when necessary to determine magnitude of cracks or defective areas. Fill drilled core holes in satisfactory pavement areas with portland cement concrete bonded to pavement with epoxy adhesive.

END OF SECTION
SECTION 329115
MIT PLANTING SOILS

PART 1 - GENERAL

1.1 GENERAL PROVISIONS

A. Attention is directed to the CONTRACT AND GENERAL CONDITIONS and all Sections within DIVISION 01 - GENERAL REQUIREMENTS which are hereby made a part of this Section of the Specifications.

B. Examine all Drawings and all Sections of the Specifications for requirements and provisions affecting the Work of this Section.

1.2 DESCRIPTION OF WORK

A. The work of this Section consists of providing all equipment and materials and do all work necessary to supply and place planting soils as indicated on the Contract Documents and as specified. Supplying and placement of planting soils shall include, but not be limited to:

1. Sampling and testing of planting soil components, including existing topsoil, loam borrow, sand and compost.
2. Sampling and testing of blended planting soil mixes.
3. Supplying, placing, spreading and grading of planting soil, including:
   a. Plant Bed Soil (for Trees, Shrubs and Ground Covers)
   b. High Use Lawn Planting Soil
   c. Sand Based Structural Planting Soil
   d. Bioinfiltration Planting Soil
4. Providing all other sampling, testing, supplying, placing, spreading and grading of planting soils as required by this Section.

1.3 DEFINITIONS

A. Owner: an MIT Landscape Architect, and/or MIT Grounds Supervisor.

B Finish Grade: Elevation of finished surfaces.

C. Subgrade: Surface or elevation of subgrade soil remaining after completing excavation, or top surface of a fill or backfill immediately beneath planting soil.

D. Topsoil: Soil that is present at the top layer of the existing soil profile at the Project site. This shall be considered the “Base Loam 1” component of Planting Soil mixes.

E. Loam: Soil that contains a combination of particles typically almost equal in parts sand, silt and clay and including organic matter.

F. Loam Borrow: Loam soil formed under natural conditions and obtained from off-site sources without admixtures of sand or organic matter sources (composts). This shall be considered the “Base Loam 2” component of Planting Soil mixes when Base Loam 1 component is found to be contaminated with subsoil, or there is insufficient quantity of Base Loam 1 to complete the work of this Section.

G. Sand: Clean, inert, rounded to sub-angular grains of quartz or other durable rock free from loam or clay, surface coatings and deleterious materials graded as specified herein.
H. Compost (Organic Amendment Material): a stable, humus-like material produced from the aerobic decomposition and curing of leaf yard waste, composted for a minimum of one year (12 months), free of debris, stones larger than 1/2", larger branches and roots and wood chips over 1" in length or diameter. The compost shall be a dark brown to black color and be capable of supporting plant growth with appropriate management practices in conjunction with addition of fertilizer and other amendments as applicable, with no visible free water or dust, with no unpleasant odor.

I. Planting Soil: Unless otherwise indicated throughout this Section, the term “Planting Soil” shall apply to either on-site blended planting soil or pre-blended planting soil from off-site source, as indicated.

J. Blended Planting Soil: To the extent available, existing on-site topsoil stripped and stockpiled for reuse, existing in-place topsoil; and/or loam borrow; that is modified on-site with planting soil components and soil amendments to meet the specific Planting Soil mix requirements specified herein.
   1. The lawn and planting soils shall consist of a blend of natural topsoil and/or loam borrow, uniform sand, and organic material. The quality of the blend depends on the quality of the original components. The Contractor shall be responsible for locating and obtaining approval of sources of natural topsoil, uniform sand, and organic material that meet the Specification requirements. The Contractor shall then be responsible for mixing the components. Approximate mixing ratios are provided, but may require adjustment, depending on the final materials and with the approval of the Landscape Architect and testing laboratory, in order to meet Specification requirements for each blend.
   2. Base Components
      a. Base Loam shall be approved topsoil and/or loam borrow.
      b. Sand shall be uniformly graded coarse sand.
      c. Organic Material shall be fully decomposed organic material – Compost.

K. Pre-Blended Planting Soil: Planting Soil produced off-site by homogeneously blending natural loam soil with planting soil components and soil amendments to meet the specific Planting Soil Mix requirements specified herein, and delivered to the Project site.
   1. Lawn and planting soils consist of a blend of natural loam soil, uniform sand, and organic material. The quality of the blend depends on the quality of the original components. The Contractor is responsible for locating and obtaining approval of the source capable of producing the pre-blended planting soil meeting the Specification requirements of this Section.

1.4 QUALITY ASSURANCE

A. Soil-Testing Laboratory: UMass Soil and Plant Tissue Testing Lab West Experiment Station
682 North Pleasant Street University of Massachusetts Amherst, MA 01003 Phone: (413) 545-2311 Fax: (413) 545-1931 E-mail: soiltest@psis.umass.edu Website: http://www.umass.edu/plsoils/soiltest/.

B. Soil Analysis: For each unamended soil type, furnish soil analysis and a written report by UMass Soil and Plant Tissue Testing Lab stating percentages of organic matter; gradation of sand, silt, and clay content; cation exchange capacity; sodium absorption ratio; deleterious material; pH; and mineral and plant-nutrient content of the soil.
   1. Report shall also state recommendations for ratio of soil components and soil amendments to be incorporated. State recommendations in weight per 1000 sq. ft. (92.9 sq. m) or volume per cu. yd. (0.76 cu. m) for nitrogen, phosphorus, and potash nutrients and soil amendments to be added to produce a gradation, organic content and pH for planting soil suitable for supporting healthy, viable plant growth.
2. The soil-testing laboratory shall oversee soil sampling; with depth, location, and number of samples to be taken per instructions from the Owner. A minimum of three representative samples shall be taken from every 200 cubic yards of stockpiled topsoil to be used or amended for planting purposes.

C. Work will be subject to inspection at all times by the Owner. The Owner reserves the right to engage an independent testing laboratory to analyze and test materials used in the construction of the work. Where directed by the Owner, the testing laboratory will make material analyses and will report to the Owner whether materials conform to the requirements of this specification.

1. Cost of tests and material analyses made by the testing laboratory will be borne by the Owner when they indicate compliance with the specification, and by the Contractor when they indicate non-compliance.
2. Testing equipment will be provided by and tests performed by the testing laboratory.

D. Samples of individual components of planting soil mixes shall be submitted by the Contractor for testing and analysis to UMass Soil and Plant Tissue Testing Lab. Include verification testing of on-site stripped and stockpiled topsoil. Comply with specific materials requirements specified.

1. No base component material shall be used until certified test reports by UMass Soil and Plant Tissue Testing Lab have been received and approved by the Owner.

E. Owner may request additional testing by Contractor for confirmation of mix quality and/or soil mix amendments at any time until final acceptance.

1.5 TESTING AND SUBMITTALS

A. Certificates: Provide certificates required by authorities having jurisdiction, especially for any composted materials. Contractor shall submit certification that all planting soil components and all planting soil mixes meet all environmental standards of the MIT Standard Specifications Section 312322 - MIT IMPORTED FILL CRITERIA AND MANAGEMENT.

B. Contractor Testing:

1. At least 7 days prior to intended use, the Contractor shall provide the samples and submittals for approval in conformance with the requirements of this Section. Do not order materials until Owner's approval of test results has been obtained. Delivered materials shall closely match the approved samples. Acceptance shall not constitute final acceptance. Owner reserves the right to reject on or after delivery any material that does not meet these Specifications.
2. Contractor shall be responsible for recognizing that these critical project materials warrant timely and serious attention, that the testing process to achieve Approved materials should be considered a lead time item, and that under no circumstance shall failure to comply with all specification requirements be an excuse for “staying on project construction schedule.”
3. Testing shall be at the Contractor’s expense. Contractor shall deliver all samples to UMass Soil and Plant Tissue Testing Lab via overnight courier. Contractor shall submit test results.

C. Testing reports shall include the following tests and recommendations. Report shall indicate whether or not the material meets the required specifications and any proposed recommendation for amending the soil mix component to meet specifications. Testing is required at the following intervals:
1. Testing of individual components for planting soil mixes. Tests are as described in Paragraph 1.7, D.
2. In-place tests: Compaction tests of each type of material placed in accordance with Paragraph 1.7, D.
3. Testing of Subgrade: Prior to placement of the planting soil profile, perc test the subgrade as described in this Section. Coordinate the testing of the subgrade with the Sitework Contractor before the planting soil is placed.

D. Test Reports: Submit certified reports for tests as described in this Section.

1. Tests shall be conducted in accordance UMass Soil and Plant Tissue Testing Lab; Tests include the following:
   a. Test for soil Organic Matter by loss of weight on ignition, as described in Northeastern Regional Publication No. 493, p. 59.
   b. Test for soil CEC by exchangeable acidity method as described in Northeastern Regional Publication No. 493, p. 64.
   c. Test for soil Soluble Salts shall be by the 1:2 (v:v) soil:water Extract Method as described in Northeastern Regional Publication No. 493, p. 74.
   d. Test for Buffer pH by the SMP method as described in Northeastern Regional Publication No. 493.
   e. Tests for pH shall be conducted on a 1:1 soil to distilled water ratio.
2. Certified reports on analyses from producers of composted organic materials are required, particularly when sources are changed. Analyses will include all tests for criteria specified herein.
   a. In-place density tests shall be carried out at a rate of one test per 2,000 square feet for each type of material placed.

E. Samples: Prior to ordering soil mix components, submit 1 gallon samples to Testing Laboratory for approval.

1. Submittals of Planting Soil Base Components:
   a. Base Loam
   b. Compost
   c. Sand

F. Soil Test Reports: Submit reports for planting soil base components above for approval. Only after approval of components, submit reports for soil blend mixes for approval. All reports must be from recent analyses, less than 90 days old and represent materials that are available for delivery to the site.

G. Submit reports for each of the above samples as described in Paragraph 1.7D.: Submit sample from each proposed source for testing and approval. Deliver samples to the testing laboratory and pay costs. Send report directly to the Owner.

H. Sources for Sand and Compost: Submit information identifying sources for all soil components and the firm responsible for mixing and delivery of planting soil mix.

1. Testing Laboratory and Owner shall have the right to reject any soil supplier.
2. Submit supplier name, address, telephone and fax numbers and contact name.
3. Submit certification that accepted supplier is able to provide sufficient quantities of materials for the entire project.

1.6 EXAMINATION OF CONDITIONS
A. All areas of the existing site where topsoil is to be sampled for testing shall be inspected by the Contractor before starting work and any issues that might inhibit or prevent the sampling operation shall be reported to the Owner prior to beginning this work.

B. The Contractor and any sub-Contractor responsible for the execution of the Work of this Section shall review and confirm in writing that the subgrade soil elevations have been brought to the proper subgrade elevations prior to proceeding with the spreading of planting soil.

C. Carefully review the requirements of this Section to understand the requirements of percolation testing, compaction, slope and absence of debris of the subgrade prior to spreading planting soil.

1.7 DELIVERY, STORAGE AND HANDLING

A. Material shall not be handled, hauled, placed, spread or compacted when it is wet as after a heavy rainfall or is frozen. Soil shall be handled only when the moisture content is less than at field capacity. Testing Laboratory and the Owner shall be consulted to determine if the soil is too wet to handle.

B. Store and handle packaged materials in strict compliance with manufacturer’s instructions and recommendations. Protect all materials from weather, damage, injury and theft.

C. Sequence deliveries to avoid delay. Deliver materials only after preparations for placement of planting soil have been completed.

D. Prohibit vehicular and pedestrian traffic on or around stockpiled planting soil.

E. Protection of Planting Soil on-site: All planting soil delivered or stockpiled on the site shall be protected from erosion at all times. Materials shall be spread immediately. Otherwise, materials that sit on site for more than 24 hours shall be covered with tarpaulin or other soil erosion system acceptable to the Owner and surrounded by silt fence.

1.8 PROJECT/SITE CONDITIONS

A. Soil Moisture Content

1. Contractor shall not move, blend or grade soil when moisture content is so great that excessive compaction will occur, nor when it is so dry that dust will form in the air or that clods will not break readily, nor when it is frozen. Apply water, if necessary, or allow to dry to bring soil moisture between 60% of optimum moisture content as determined by ASTM D698 for compaction, grading and plantings.

2. Field Soil Moisture Test
   a. Form soil in palm of hand, if soil retains shape and crumbles upon touching, the soil may be worked.
   b. If the soil will not retain shape it is too dry and should not be worked.
   c. If the soil retains shape and will not crumble, it is too wet and should not be worked.
   d. If the soil glistens or free water is observed when the sample is patted in the palm of hand the soil is too wet and should not be worked.

PART 2 PRODUCTS

2.1 PLANTING SOIL COMPONENTS

A. Base Loam 1:
1. Shall be stockpiled topsoil stripped from the site as required for mixing with Sand and Compost to produce the Planting Soil Mixes specified herein. If Base Loam 1 does not meet the grain size distribution, organic content, pH or chemical analysis for loam borrow specified below, is found to be contaminated with subsoil during stripping or storage, or quantities are not sufficient to complete the work of this Section, the Contractor shall supply Base Loam 2 from off-site sources.

B. Base Loam 2:

1. Shall be loam borrow, a "sandy loam" determined by mechanical analysis (ASTM D 422) and based on the "USDA Classification System". It shall be of uniform composition, without admixture of subsoil. All loam borrow shall be mechanically screened and free of subsoil, stones 1 in. or larger diameter, earth clods, sticks, stumps, clay lumps, roots or other objectionable, extraneous matter or debris. Base Loam 2 shall also be free of extraneous materials harmful to plant growth; free of obnoxious weeds and invasive plants; not infested with nematodes; grubs; or other pests. Base Loam shall not be delivered or used for planting while in a frozen or muddy condition. Base Loam 2 for mixing shall conform to the following grain size distribution for material passing the #10 sieve:

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<thead>
<tr>
<th>U.S. Sieve Size Number</th>
<th>Percent Passing</th>
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<tbody>
<tr>
<td>10</td>
<td>---</td>
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<tr>
<td>18</td>
<td>85</td>
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<td>35</td>
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<td>270</td>
<td>32</td>
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<tr>
<td>0.002mm</td>
<td>3</td>
</tr>
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</table>

2. The ratio of the particle size for 80% passing (D80) to the particle size for 30% passing (D30) shall be 8 or less (D80/D30 < 8).

3. Maximum size shall be one-inch largest dimension. The maximum retained on the #10 sieve shall be 20% by weight of the total sample. Tests shall be by combined hydrometer and wet sieving in compliance with ASTM D422 after destruction of organic matter by ignition.

4. The organic content shall be between 4.0 and 8.0 percent by weight.

5. pH shall be between 5.0 and 6.0.

6. Chemical analysis shall be undertaken for Phosphorus, Potassium, Calcium Magnesium, Aluminum, Iron, Manganese, Lead, Cation Exchange Capacity, Soluble Salts, acidity (pH) and buffer pH in accordance with MIT Standard Specification Section 312322, MIT IMPORTED FILL CRITERIA AND MANAGEMENT.

C. Sand

1. Sand for Planting Soil Mixes shall be uniformly graded medium to coarse sand consisting of clean, inert, rounded to sub-angular grains of quartz or other durable rock free from loam or clay, surface coatings and deleterious materials with the following gradation.

<table>
<thead>
<tr>
<th>U.S. Sieve Size Number</th>
<th>Percent Passing</th>
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<tbody>
<tr>
<td>10</td>
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<tr>
<td>18</td>
<td>60</td>
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<td>35</td>
<td>25</td>
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<tr>
<td>60</td>
<td>8</td>
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</table>
2. Maximum size shall be one-inch largest dimension. The maximum retained on the #10 sieve shall be 20% by weight of the total sample.

3. The ratio of the particle size for 70% passing \( (D_{70}) \) to the particle size for 20% passing \( (D_{20}) \) shall be 2.8 or less \( (D_{70}/D_{20} < 2.8) \). Tests shall be by combined hydrometer and wet sieving in compliance with ASTM D422.

4. pH shall be less than 7.5.

D. Compost

1. Organic Matter for amending planting soil mixes shall be a stable, humus-like material produced from the aerobic decomposition and curing of Leaf Yard Waste Compost, composted for a minimum of one year (12 months). Compost shall be free of debris such as plastics, metal, concrete or other debris. Compost shall be free of stones larger than 1/2", larger branches and roots, and wood chips over 1" in length or diameter. The compost shall be a dark brown to black color and be capable of supporting plant growth with appropriate management practices in conjunction with amendments as applicable, with no visible free water or dust, with no unpleasant odor, and meeting criteria of UMass Soil and Plant Tissue Testing Lab.

d. Organic Content shall be at least 20 percent (dry weight). One hundred percent of the material shall pass a 3/8-inch (or smaller) screen.

g. The compost shall be screened to 1/2 inch maximum particle size and shall contain not more that 3 percent material finer that 0.002mm as determined by hydrometer test on ashed material.

h. Nutrient content shall be determined by the UMass Soil and Plant Tissue Testing Lab and utilized to evaluate soil required amendments for the mixed soils.

2.2 PLANTING SOIL MIXES - GENERAL

A. Uniformly mix ingredients by windrowing/tilling on an approved hard surface area. Organic matter shall be maintained moist, not wet, during mixing. Amendments shall not be added unless directed by a Testing Laboratory to extent and quantity of amendments required. Percentages of components, unless otherwise noted, will be established upon completion of individual test results for components of the various mixes.

B. After component percentages are determined by the Testing Laboratory, each planting soil mix shall be tested for physical and chemical analysis as specified in Paragraph 1.7 of this Section.

2.3 TREE, SHRUB, GROUND COVER AND PERENNIAL PLANTING BED SOIL

A. Tree, Shrub, Ground Cover and Perennial Planting Bed Soil

1. Tree, Shrub, Ground Cover and Perennial Planting Bed Soil shall consist of a blend of approximately equal parts by volume of Sand, Base Loam and Compost \( (1S:1L:1C) \). Blending of the components shall be carried out with earth moving equipment prior to placement. The components shall be blended to create a uniform mixture with an organic content between 5.0 and 10.0 percent by weight and pH range as recommended by UMass Soil and Plant Tissue Testing Lab for types of plant material proposed.

2. Final mix shall conform to the following gradation requirements for material passing a Number 10 sieve.

<table>
<thead>
<tr>
<th>Percent Passing</th>
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<tr>
<td>140</td>
</tr>
<tr>
<td>270</td>
</tr>
<tr>
<td>0.002mm</td>
</tr>
</tbody>
</table>

| 0  | 8 |
| 0  | 3 |
| 0  | 0.5 |
U.S. Sieve Size No. | Minimum | Maximum
---|---|---
10 | 100 | 100
18 | 85 | 95
35 | 60 | 85
60 | 42 | 65
140 | 21 | 44
270 | 18 | 24
0.002 mm | 2 | 4

3. Maximum size shall be one half-inch largest dimension. The maximum retained on the #10 sieve shall be 10% by weight of the total sample.
4. The ratio of the particle size for 80% passing (D_{80}) to the particle size for 30% passing (D_{30}) shall be 6 or less (D_{80}/D_{30} < 6).

2.4 HIGH USE LAWN PLANTING SOIL

1. Base Loam, Sand and Compost, each as specified above, shall be combined in an approximate mix ratio of two parts by volume Sand to one part by volume Base Loam to one and one half parts by volume Compost (2S:1L:1.5C) to create a uniform blend which meets the following requirements.
2. Gradation for Material Passing the Number 10 Sieve:

<table>
<thead>
<tr>
<th>U.S. Sieve Size No.</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>18</td>
<td>70</td>
<td>90</td>
</tr>
<tr>
<td>35</td>
<td>45</td>
<td>72</td>
</tr>
<tr>
<td>60</td>
<td>26</td>
<td>40</td>
</tr>
<tr>
<td>140</td>
<td>14</td>
<td>20</td>
</tr>
<tr>
<td>270</td>
<td>10</td>
<td>13</td>
</tr>
<tr>
<td>0.002 mm</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>

3. Maximum size shall be one-inch largest dimension. The maximum retained on the #10 sieve shall be 20% by weight of the total sample.
4. Ratio of the particle size for 70% passing (D_{70}) to the particle size for 20% passing (D_{20}) shall be 4.2 or less (D_{70}/D_{20} < 4.2).
6. Organic content shall be between 4.0 and 6.0 percent by weight.
7. pH shall be between 6.2 and 6.8

2.5 SAND-BASED STRUCTURAL PLANTING SOIL

A. Sand-Based Structural Soil Planting Medium:

1. Base Loam, Sand and Compost, each as specified above, shall be combined in an approximate mix ratio of four parts by volume Sand to one part by volume Imported Base Loam to one and one half part by volume Compost (4S:1L:1.5C) to create a uniform blend which meets the following requirements.
2. Gradation for Material Passing the Number 10 Sieve:

<table>
<thead>
<tr>
<th>U.S. Sieve Size Number</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>100</td>
<td>-</td>
</tr>
<tr>
<td>18</td>
<td>68</td>
<td>90</td>
</tr>
<tr>
<td>35</td>
<td>38</td>
<td>63</td>
</tr>
<tr>
<td>60</td>
<td>18</td>
<td>39</td>
</tr>
<tr>
<td>140</td>
<td>9</td>
<td>18</td>
</tr>
</tbody>
</table>
3. Maximum size shall be one-inch largest dimension. The maximum retained on the #10 sieve shall be 15% by weight of the total sample.

4. Ratio of the particle size for 70% passing (D70) to the particle size for 20% passing (D20) shall be 3.2 or less. (D70/D20 < 3.2)

5. Saturated hydraulic conductivity of the mix: not less than 6 inches per hour, according to ASTM D5856-95 (2000) when compacted to a minimum of 92% Standard Proctor, ASTM 698.

6. Organic content: between 2.5 and 3.5 percent by weight.

7. The pH shall be between 6.0 and 6.5.

8. When conducting horticultural testing described above, conduct Standard Proctor Test ASTM 698 to obtain maximum dry density and optimum moisture content values.

2.6 SOD FARM GROWING MEDIUM

A. Sod Farm Growing Medium:

1. Soil in which sod was grown shall be USDA classified as sand and shall conform to the following grain size distribution for material passing the #10 sieve:

<table>
<thead>
<tr>
<th>Percent Passing</th>
<th>U.S. Sieve Size Number Minimum</th>
<th>U.S. Sieve Size Number Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>100</td>
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<tr>
<td>18</td>
<td>85</td>
<td>100</td>
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<tr>
<td>35</td>
<td>60</td>
<td>85</td>
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<tr>
<td>80</td>
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<td>40</td>
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<tr>
<td>140</td>
<td>6</td>
<td>26</td>
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<tr>
<td>270</td>
<td>4</td>
<td>18</td>
</tr>
<tr>
<td>0.002mm</td>
<td>2</td>
<td>5</td>
</tr>
</tbody>
</table>

2. The maximum particle size shall be 1/2 inch.

3. The maximum retained on the #10 sieve shall be 10% by weight of the total sample. Tests shall be by combined hydrometer and wet sieving in compliance with ASTM D422.

2.7 BIOINFILTRATION PLANTING SOIL

A. Bioinfiltration Planting Soil

1. Base Loam, Sand and Compost, each as specified above, shall be combined in an approximate mix ratio of two parts by volume Sand to one part by volume Base Loam to one half part by volume Compost (2S:1L:0.5C) to create a uniform blend which meets the following requirements.

2. Gradation for Material Passing the Number 10 Sieve:

<table>
<thead>
<tr>
<th>US Sieve Size Number</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>100</td>
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<tr>
<td>18</td>
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<td>60</td>
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<td>140</td>
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<tr>
<td>270</td>
<td>9</td>
<td>12</td>
</tr>
<tr>
<td>0.002mm</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>
3. Maximum size shall be one-inch largest dimension. The maximum retained on the #10 sieve shall be 15% by weight of the total sample.
4. Ratio of the particle size for 70% passing (D70) to the particle size for 20% passing (D20) shall be 5.0 or less (D70/D20 <5.0)
5. Organic content shall be between 2.0 and 3.0 percent by weight.

B. Bioinfiltration Subsoil

1. Bioinfiltration Subsoil shall be placed in profiles where Bioinfiltration Planting Soil exceed twelve inches.
2. Bioinfiltration Subsoil shall meet the same gradation as Bioinfiltration Planting Soil. Compost shall be reduced in the blend to manufacture a soil containing an organic content from 1.0 to 2.0 percent by weight.

2.8 PRE-PLANT FERTILIZER

A. Complete, fertilizer made from all-natural ingredients complying with State and Federal fertilizer laws. Fertilizer shall contain the following available plant food by weight, unless soils test indicate a need for different composition:

<table>
<thead>
<tr>
<th></th>
<th>Nitrogen</th>
<th>Phosphorous</th>
<th>Potash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deciduous Trees and Shrubs</td>
<td>2%</td>
<td>3%</td>
<td>3%</td>
</tr>
<tr>
<td>Evergreen Trees and Shrubs</td>
<td>2%</td>
<td>3%</td>
<td>3%</td>
</tr>
</tbody>
</table>


C. Fertilizer to be delivered in original unopened standard size bags showing weight, analysis ingredients and manufacturer's name.

2.9 SOIL AMENDMENTS

A. Follow soil test report recommendations for soil additives for planting soils.

B. Superphosphate shall be composed of finely ground phosphate rock as commonly used for agricultural purposes, and containing not less than 20% available phosphoric acid. The superphosphate shall be delivered to the site in the original unopened containers, each bearing the manufacturer's guaranteed analysis. Any superphosphate which becomes caked or otherwise damaged making it unsuitable for use, will be rejected.

C. Limestone shall be an approved agricultural limestone containing no less than 50% of total carbonates, and 25% total magnesium with a neutralizing value of at least 100%. The material shall be ground to such a fineness that 40% will pass through a No. 100 U.S. Standard Sieve, and 98% will pass through a No. 20 U.S. Standard Sieve. The lime shall be uniform in composition, dry and free flowing, and shall be delivered to the site in the original unopened containers, each bearing the manufacturer's guaranteed analysis. Any lime which becomes caked or otherwise damaged making it unsuitable for use, will be rejected.

D. Commercial fertilizer shall be a product complying with the State and United States fertilizer laws. Deliver fertilizer to the site in the original unopened containers bearing the manufacturer's certificate of compliance covering analysis and which shall be furnished to the Owner. Fertilizer shall contain not less than the percentages of weight of ingredients as recommended by the soil analysis.

1. Fertilizer for planting shall be formulated for top-dressing, soil surface application to plants. Fertilizer shall be designed and certified by the manufacturer to provide controlled release...
of fertilizer continuously for not less than 9 months. One hundred percent of the nitrogen content shall be derived from organic materials. Nitrogen source shall be coated to ensure slow release. Fertilizer percentages of weight of ingredients shall be as recommended by the soil testing and analysis specified, performed, and paid for under this Section.

E. Aluminum Sulfate: Commercial grade, unadulterated.

2.10 WATER

A. Water: furnished by Owner, unless otherwise specified, and suitable for irrigation and free from ingredients harmful to plant life. Hose and other watering equipment furnished by Contractor.

PART 3 EXECUTION

3.1 PRE-INSTALLATION EXAMINATION AND PREPARATION

A. Refer to Section 015640, MIT TEMPORARY TREE AND SOIL PROTECTION.

B. Coordinate activities with other project contractors so that there is no soil disturbance from traffic or other construction activities subsequent to placement.

C. Pre-Installation Examination Required: The Contractor shall examine previous work, related work, and conditions under which this work is to be performed and shall notify Owner in writing of all deficiencies and conditions detrimental to the proper completion of this work. Beginning work means Contractor accepts substrates, previous work, and conditions. The Contractor shall not place any planting soil until all work in adjacent areas is complete and approved by the Owner.

D. Examination of Subgrade: The subgrade shall be examined by the Contractor prior to the start of soil placement and planting. Any deficiencies shall be noted and related to the Landscape Architect in writing prior to acceptance of the subgrade by the Landscape Contractor. Deficiencies include, but shall not be limited to the following:

1. Prepared subgrade must infiltrate water at the rate of at least two inches per hour.
2. Construction debris present within the planting areas.
3. The subgrade is at incorrect depths for installing the designed soil profile and drainage layer.
4. Incomplete irrigation and/or subsurface drainage installation.
5. Incomplete lighting and exterior electrical installation.
6. Conflict with underground utilities.
7. Subgrade contaminated with oils, compressible material, silt or clay.

E. Do not proceed with Subgrade Preparations or placement of Lawn Soil, until all utility work in the area has been installed.

1. The Contractor shall identify the locations of underground utilities prior to proceeding with soil work and shall protect all utilities from damage.

3.2 EXCAVATION AND REMOVAL

A. Portions of the project site may require removal and replacement of existing soils to accommodate the new soil profile. Other portions of the project site will require in situ decompaction and amendment of soils.

B. Some of the stripped topsoil shall be re-used on the project site, as determined by soil testing, and after approval by the Owner and Testing Laboratory.
C. No off-campus removal or transport of soils without written permission from Owner (MIT EH&S).

3.3 MIXING OF PLANTING SOIL MIXES

A. Soil blends shall be produced with equipment that blends together each component in a thorough and uniform manner. This may be accomplished by a minimum of three handling events on a hard surfaced area with earth moving equipment or by alternately passing soil components through a screener.

B. Base components and Soil Mix stockpiles should be protected from wind and rain and shall not be permitted to be stored in standing water.

3.4 SUBGRADE PREPARATION, INSPECTION AND PERCOLATION TESTING

A. After subgrade levels have been reached, the Architect or Soil Scientist shall observe de-compaction and preparation of the subgrade according to this Section and inspect soil conditions to evaluate subsurface drainage conditions.

B. Coordinate the following scarification work to eliminate subgrade compaction and improve drainage conditions when located in lawn areas outside of Critical Root Zones.

1. Heavy Site Subgrade Compaction Mitigation:
   a. Heavily compacted subgrade areas such as, but not limited to, temporary parking areas, material stockpile areas, temporary roadways, construction areas and areas around structures and other similar areas.
   b. Prior to establishing the final subgrade, these areas shall be dug up or ripped to a depth of (18) inches to break up the soil hard pan, then re-compacted with two passes of the tracks of a wide track bulldozer size D-6 or smaller, or other approved equipment. Vibratory compaction of subgrade in planted areas is prohibited.

2. General Site Subgrade Preparation for Lawn Soil and Planted Areas:
   a. Subgrade preparation shall be conducted after subgrade elevations have been established and approved and all utility and other construction activities have concluded.
   b. The entire subgrade shall be loosened to a minimum depth of 8-inches using the teeth of an excavator or other suitable equipment in a coarse manner. The object is to shatter the subsoil and relieve over-compaction.
   c. The subgrade shall then re-compact with two passes of the tracks of a wide track bulldozer size D-6 or smaller, or other approved equipment. Vibratory compaction of subgrade in planted areas is prohibited.

C. After Subgrade has been prepared as described above, it shall be recompressed by using the tracks of a wide-tracked bulldozer, multiple passes of a skid steer loader, or the curled bucket of an excavator. Verify the subgrade passes water at or greater than the minimum requirement.

D. Remove all stones or debris greater than 6” in any dimension from the subgrade prior to placing any Lawn or Planting Soils.

E. After the subgrade has been prepared, Percolation Tests shall be performed according to the following test procedures.

1. Utilize perforated canisters or buckets seven to ten inches in diameter and a minimum of six inches high.
2. A test hole shall be hand dug at the soil horizon to be tested approximately one-inch larger than the diameter of the test canister and approximately six inches deep. The sides of the test hole shall not be smoothed.

3. Place one-half inch of clean coarse sand in the bottom of the hole and place the canister firmly into the hole. The space around the canister shall then be filled with coarse sand. Tamp the coarse sand to firmly fill any void space around the test canister.

4. Fill the canister with water to the soil horizon level and allow to drain until approximately one inch of water remains, or a minimum of 1 hour.

5. Refill the canister to the soil horizon level. After the water level drops approximately one inch, start the test. Record time versus water level as the water level drops. The percolation rate is the length of time for the water level to drop per inch. The field scientist shall record the rate of percolation for a minimum of two hours or until the water level has dropped a minimum of three inches after the start of measurements.

6. Prepared subgrade shall infiltrate water at a minimum rate of two-inches per hour. If subgrade fails to pass water at the minimum rate, notify Architect and soil scientist. Additional subgrade preparation may be required.

3.5 PREPARATION OF TREE PITS

A. After tree planting pits have been excavated to the dimensions shown on the plans, the entire bottom area of the pit shall be loosened to a minimum depth of two feet utilizing the bucket of a backhoe or equivalent equipment. The entire loosened area shall then be compressed firmly with the bucket of the backhoe. The central portion of the pit, beneath the rootball, shall be compressed adequately to support the rootball and prevent settlement.

3.6 PLACEMENT OF PLANTING SOIL IN PLANTING BEDS

A. Planting Bed Medium shall be spread in lifts not greater than twelve inches and compacted to a density between 82 and 86 percent Standard Proctor Maximum Dry Density. The surface area of each lift, including the subgrade after it has been compressed by a backhoe, shall be scarified by raking prior to placing the next lift.

B. Place and spread planting medium to a depth greater than required such that after settlement, finished grade conforming to the lines, grades and elevations shown on the Drawings. Ensure proper drainage in an uninterrupted pattern free of hollows and pockets.

C. Remove stiff clods, lumps, brush, roots, stumps, litter and other foreign material and stones over one inch in diameter and dispose of legally off site.

3.7 PLACEMENT OF PLANTING SOILS IN HIGH USE LAWN AREAS

A. Lawn Root Zone Medium shall be spread over the area and shall be compressed with a minimum of two perpendicular passes of the tracks of a bulldozer size Caterpillar D-4 or D-5 or equivalent to a density of 86 to 88% Standard Proctor maximum dry density. No vibratory compaction of the subgrade or the planting medium shall take place. No rubber-tired equipment or heavy equipment except for a small bulldozer shall pass over soils after they have been loosened or planting medium spread. If the Contractor plans to utilize such areas for any use of heavy equipment, this work should be carried out prior to beginning the process of loosening soils.

B. Place and spread planting mixture and soil to a depth greater than required such that after settlement, finished grade conforming to the lines, grades and elevations shown on the Drawings. Ensure proper drainage in an uninterrupted pattern free of hollows and pockets.

C. Remove stiff clods, lumps, brush, roots, stumps, litter and other foreign material and stones over one inch in diameter and dispose of legally off site.
3.8 PLACEMENT OF BIOINFILTRATION PLANTING MEDIUM

A. Bioinfiltration Planting Medium shall be spread in lifts not greater than twelve inches and compacted to a density between 84 and 86 percent Standard Proctor Maximum Dry Density. The surface area of each lift, including the subgrade after it has been compressed by a backhoe, shall be scarified by raking prior to placing the next lift.

B. Place and spread planting medium to a depth greater than required such that after settlement, finished grade conforming to the lines, grades and elevations shown on the Drawings. Ensure proper drainage in an uninterrupted pattern free of hollows and pockets.

C. Remove stiff clods, lumps, brush, roots, stumps, litter and other foreign material and stones over one inch in diameter and dispose of legally off site.

3.9 PLACEMENT OF STRUCTURAL SOIL

A. Sand-Based Structural Planting Medium shall be spread in lifts not greater than eight inches and compacted with a minimum of three passes of vibratory compaction equipment to a density between 92 and 96 percent Standard Proctor Maximum Dry Density. Sand-Based Structural Planting Medium shall be placed to a minimum depth of two feet within the areas shown on the Drawings, except as otherwise indicated.

1. Density testing for Sand Based Structural Soil must be by ASTM D6938-10 Nuclear Methods, after ASTM D698 Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort. Density testing shall be conducted at a minimum of one test for each plant bed for each lift. Independent testing agency must be on-site to conduct soil moisture and density tests during installation of Sand Based Structural Soil.

B. A minimum of eight inches of 3/4 inch crushed stone shall be placed over the Sand-Based Structural Planting Medium in sidewalk areas and a minimum of twelve inches shall be placed in vehicular areas to provide support for the overlying surface. Perforated pipes shall be placed within the crushed stone and connected to open air conditions to provide aeration within the stone per Drawings.

3.10 FINE GRADING

A. Grade Stakes: Sufficient grade stakes shall be set for checking the finished grades. Stakes must be set in the bottom of swales and at the top of slopes. Deviation from indicated elevations that are greater than one-tenth of a foot shall not be permitted. Connect contours and spot elevations with an even slope. Finish grades shall be smooth and continuous with no abrupt changes at the top or bottom of slopes.

B. Unless off-site pre-blended planting soil is used, soil additives shall be spread and thoroughly incorporated into the layer of planting soil by harrowing or other methods reviewed by the Owner.

1. Contractor shall add soil amendments as recommended by the soil analysis and retest planting soil after amendments are completed.

C. Pre-blended planting soil shall be sampled and tested as specified.

D. Soil Compaction:

1. During the compaction process, all depressions caused by settlement or rolling shall be
filled with additional planting soil and the surface shall be regraded and rolled until presenting a smooth and even finish corresponding to the required grades.

2. Percolation Tests: Compact each lift sufficiently to reduce settling but not enough to prevent the movement of water and feeder roots through the soil. The planting soil in each lift should feel firm to the foot in all areas and make only slight heel prints. At completion of the planting soil installation, the soil should offer a firm, even resistance when a soil sampling tube is inserted from lift to lift. After the placement of each lift, perform percolation tests to determine if the planting soil has been over compacted. Perform the following percolation test procedure:
   a. Dig a hole in the installed planting soil that is a minimum of 4 inches in diameter. Holes in 6-inch lift in turf areas shall be 4 inches deep. Holes in 12-inch lifts in plant beds shall be 8 inches deep. Do not penetrate through the lift being tested.
   b. Fill the hole with water and let it drain completely. Immediately refill the hole with water and measure the rate of fall in the water level.
   c. In the event that the water drains at a rate less than one inch per hour, till the planting soil to a depth required to break the over compaction.
   d. Perform a minimum of one soil percolation test per 10,000 square feet area of turf area and 2,500 square feet of tree and shrub planting area.

3. Contractor shall install planting soil in successive horizontal lifts no thicker than 6 inches in turf areas and 12 inches in plant bed areas to the desired compaction as described in this Section. Contractor shall install the planting soil at a higher level to anticipate any reduction of planting soil volume due to settling, erosion, decomposition, and other similar processes during the warranty period. Contractor shall ensure that the full 6 inches of planting soil are obtained by digging holes in the planting soil at the same frequency as for compaction testing.

4. Movement of equipment: Select equipment and otherwise phase the installation of the planting soil to ensure that wheeled equipment does not travel over subgrade or already installed planting soil. Movement of tracked equipment over said soils will be reviewed and considered for approval by the Owner. If it is determined by the Owner that wheeled equipment must travel over already installed soil, provide a written description of sequencing of work that ensures that compacted soil is loosened and un-compacted as the work progresses or place a one-inch thick steel plate over the length and width of any travel way to cover planting soil to protect it from compaction.

E. Disturbance outside of limit of work: Disturbed areas outside the limit of work and outside CRZ shall be graded smooth and spread with a minimum of six (6) inches of planting soil to the finished grade.

F. Stockpiles: Upon written approval by the Owner, Contractor shall remove all excess, unused existing on-site topsoil from the site and dispose of it in a legal manner.

311 LAWN SOILS AT CRITICAL ROOT ZONES

A. The Contractor shall engage a board certified master arborist with a minimum of 5 years of experience, including experience with supersonic air tools such as the “Airspade” for the project. All excavation, and backfilling within Critical Root Zones shall be by approved equipment by the arborist or under the supervision of the arborist.
   1. Air Spading is a state of the art excavating tool that uses high volumes of compressed air to remove and break up soil without damaging roots. Air spading allows the contractor to amend lawn and planting soils within Critical Root Zones with minimal disruption to the root structure.
   2. Delineate the areas of soil disturbance within the Critical Root Zones. The Contractor’s arborist is to perform subsurface root exploration and evaluate root distribution in the area of the disturbance.
   3. As a guideline, the minimum tree protection zone is the distance from trunk of tree is established by taking the tree’s diameter at breast height in inches, and
converting it to feet. (For example, 12" caliper tree translates into a 12’ offset from the edge of the truck to the final cut line.) Site constraints may dictate that final cut line is closer to the trunk than guidelines will allow. Do not perform subsurface exploration near the trunk or within the drip line without the presence of the University arborist.

4. Arborist to incorporate 3-inches of sand the existing soil at Critical Root Zones to a depth of six inches using air spade equipment. The Contractor and the arborist will minimize exposure of tree root systems during the exploration and construction activities.

5. When root systems are potentially exposed for extended time periods of greater than one work day/8 hours, and during or between periods of excavation/construction activity, lay burlap over exposed roots, support edge of excavation and mulch to a depth approved by arborist. Saturate burlap and mulch with water and maintain the burlap in a damp condition during daylight hours as to not allow roots to dry out.

6. If necessary to achieve finish grades, approved high use lawn soil shall be hand placed in Critical Root Zones. The placed soil should be compacted by manual or foot tamping as necessary. No track or wheeled equipment shall be permitted to traverse the tree protection areas.

3.12 PROTECTION

A. The Contractor shall protect landscape work and materials from damage due to landscape operations, operations by other Contractors or trespassers. Maintain protection during installation until acceptance. Treat, repair or replace damaged Lawn Soil installation work immediately.

B. Provide all means necessary, including fences, to protect all soil areas from compaction and contamination by trash, dust, debris, and any toxic material harmful to plants or humans after placement. Any area that becomes compacted, shall be de-compacted and tilled to the extent determined by the soil scientist and recompressed to the density ranges specified. Any uneven or settled areas shall be filled, re-graded and re-compact to meet the requirements of this Specification. Soil that becomes contaminated shall be removed and replaced with specified soil material.

C. Phase the installation of the High Use Lawn Soil such that equipment does not have to travel over already installed soil. Use of haul roads is acceptable provided that the haul road is completely re-worked to meet the requirements of this Specification.

D. Apply filter fabric covering and planking or other engineering controls over soil to minimize compaction and collect dust and debris in any area where the Contractor must work after the installation of High Use Lawn Soil.

E. Till compacted High Use Lawn Soil and replace High Use Lawn Soil that has become over compacted or contaminated as determined by the Soil Scientist or Architect. Non-Compliant High Use Lawn Soil shall be tilled or replaced by the Contractor at no expense to the Owner.

3.13 CLEAN-UP

A. During installation, keep pavements clean and work area in an orderly condition.

B. Keep the site free of trash and debris at all times. Immediately dispose of wrappings or waste materials associated with products necessary for the completion of the work.

C. All trash and debris shall be kept in a central collection container. Do not bury trash and debris in back-fill.
D. Once installation is complete, remove any excess soil from pavements or embedded in fixtures.

3.14 COORDINATION AND EXCESS MATERIALS

A. Coordinate activities with other project contractors so that there is no soil disturbance from traffic or other construction activities subsequent to placement.

B. Excess Planting Soil Mixtures and Materials: Remove the excess planting soil mixture and materials from the site at no additional cost to the Owner unless otherwise requested.

3.15 ACCEPTANCE

A. Confirm that the final grade of planting soil is at the proper finish grade elevations.

END OF SECTION
MIT Utilities
Design Standards

DIVISION 33 — Utilities

May 2018
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APPENDIX C - BUILDING ENTRANCES

APPENDIX D - UTILITIES DETAILS (separate document)
1. MISSION STATEMENT

The design of utility systems and the equipment specified for utilities should allow for maintenance with the priority on public safety.

The equipment life should exceed 40 years with consideration of longer life evaluated against initial capital cost where equipment has not been standardized.

Products are standardized for maintainability and overall system reliability.

MIT promotes creative solutions to design challenges balanced by the constant emphasis on reducing requirements for maintenance of equipment while increasing energy savings.

2. COMMON UTILITIES DESIGN ISSUES

2.1 Demolition Plan

Prepare and implement a demolition plan to safeguard the health and safety of workers at the job site and the general public. Conduct a survey to identify all potential hazards and communicate such matters to MIT’s Utility Group and Environment, Health and Safety Department. Comply with OSHA standard 29 CFR 1926.850(a) for demolition.

2.2 Coordination

Coordinate design work with existing services and the work of other disciplines. Locate all utility services and determine the necessity to maintain them during renovation work.

Coordinate the Construction Documents to ensure that new work does not conflict with ducts, structure, lighting systems, architectural finishes and other work. Verify ceiling heights and pipe locations including low points of pitched piping.

2.3 General Design Requirements

Plan view drawings are to be at a scale of 1” = 20’.

Plan views, including existing utilities, are to be provided.

Profile drawings, including existing drawings, shall be provided.

Cross section drawings shall be provided at key locations for clarity.

Technical specifications for all aspects of the construction shall be provided.
Any utilities subject to traffic (including walkways with service vehicle traffic) shall be designed to H20 loading capability.

Any utilities piping passing under a railroad track shall be installed in a steel casing. Work within the railroad right-of-way shall be subject to the control and requirements of Massachusetts Department of Transportation (Mass DOT).

Provide a Cathodic Protection System for all direct buried steel piping systems and pipe with steel outer casings including chilled water lines, steel conduit for steam and condensate lines, condenser water lines, and steel natural gas lines. Steel lines with adequate outer protection (covering) may not require cathodic protection at the direction of the MIT Program Manager.

2.4 Quality Control

Develop and review field quality control process for testing, cleaning, and initial chemical treatment for appropriate systems.

Comply with governing codes and regulations. Specify products of acceptable manufacturers which have been in satisfactory use in similar service for three years. Use experienced installers. Assure compliance with all governing codes and regulations. Instruct contractors to deliver handle, and store materials in accordance with manufacturer's instructions.

2.5 Code Compliance

Compliance with all local building codes is critical for a project to be successfully completed.

All MIT projects must comply with the Land Disturbance Regulations adopted by the City of Cambridge Commissioner of Public Works. The Land Disturbance Regulations are intended to bring Cambridge into compliance with the Federal Clean Water Act in 40 CFR 122.34.

Excavated soil is likely to be considered contaminated under Massachusetts Contingency Plan (MCP).

2.6 Maintenance Access

Provide manholes and piping systems with adequate venting, draining, shutdown, and maintenance. Valves and instruments must be located for ease of operation, accessibility, and readability.

2.7 Corrosion Protection

Provide cathodic protection systems (anode type) for all direct burial steel pipes with steel outer casings including , without limitation, chilled water lines, steel conduit for steam and condensate lines and condenser water lines. Provide complete cathodic isolation kits for pipe flanges to meet MIT’s pressure service standards.
2.8 Metering

All new building construction or renovation projects require provisions for the installation of meters and field devices necessary for real-time remote collection of utility data. Direct access to meters for calibration is required.

The MEP design engineering team for the project must prepare a single line metering diagram depicting in detail all equipment, conduit, wiring, (power and network communication) junction boxes, network connections and any other devices necessary for a complete metering system to support the scope of the project. This drawing must clearly define and depict each individual trade’s responsibility and point of connection. The clear assignment of responsibility by trade is critical to proper execution of the metering scope. MIT will collaborate with the MEP team to assist in the development of this diagram to suit the required scope within the arrangement of the building. The diagram must depict the actual path of wiring between devices including the room numbers.

2.9 MEP Equipment Naming Standards

Design drawings should include equipment designations in their schedules and plan views which are unique and do not duplicate existing equipment. Contact the MIT Systems Engineering Group to determine which equipment names are available.

Equipment names should conform to the following standard:
XXX_XXXXXX

Examples:
Building 76, Air Handling Unit 12A would be:
M76_AHU12A

Buildings which have no letter prefix assigned in the MIT naming convention (Buildings 1, 2, 3, etc.) will be preceded with an “M”.

Building E17, Chilled Water Pump 2 would be:
E17_CHWMP02

Note that system, equipment, and number are combined as one text string.
The following is the standardized list of system, equipment, and other abbreviations:

<table>
<thead>
<tr>
<th>System</th>
<th>Abbreviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Handling Unit</td>
<td>AHU</td>
</tr>
<tr>
<td>Exhaust Air Handling Unit</td>
<td>EAHU</td>
</tr>
<tr>
<td>Exhaust Fan</td>
<td>EF</td>
</tr>
<tr>
<td>Return Fan</td>
<td>RF</td>
</tr>
<tr>
<td>Pump</td>
<td>PMP</td>
</tr>
</tbody>
</table>
Air Cooled Condensing Unit  ACCU
Heat Exchanger        HX
Heating Converter (shell and tube) CV
Chilled Water         CHW
Process Chilled Cooling Water PCHW
Hot Water             HW
Condenser Water       CND
Domestic Hot Water    DHW
Domestic Cold Water   DCW
Supply                S
Return                R
Temperature           TEMP
Pressure              PRESS
Flow                  FLOW

For example, Domestic Hot Water Return Temperature in Building 2 would be:
M02_DHWRTEMP

### 3. MISCELLANEOUS UTILITIES

#### 3.1 Compressed Air

Compressed air is distributed at 80-90 psi. Currently there is minimal capacity available and distribution is limited. As campus demand grows, supply will be increased and metered.

#### 3.2 Fire Detection and Alarm

Fire detection and installed fire panel is the building responsibility.

#### 3.3 Tel/Data

Tel/data work is directed and wired by IS&T. Utilities provides consulting and the manholes for distribution.

#### 3.4 Emergency Power

Emergency power generation is a building system.

#### 3.5 Lab Waste

Lab waste master plan is under development and will define requirements for permitting and reporting.
3.6 NOx Emissions

NOx data must be reported during the design phase with anticipated start date so that any stationary fuel burning equipment is confirmed to be within the campus 25 ton NOx limits. The campus has a 5 year rolling 25 ton NOx limit on stationary fuel burning equipment.

4. 331000 - WATER UTILITIES

4.1 Domestic Water Information

Domestic water is provided to all buildings on campus by the City of Cambridge Water Department (CWD) either directly or by tapping into the campus distribution network.

CWD maintains a network made up of 200 miles of pipeline, 15,000 service connections, 1,800 fire hydrants and 4,500 valves.

City water pressure varies with the season between 40 psig and 60 psig.

4.2 Domestic Water Design Issues

Domestic water pipes with less than 4 \(\frac{1}{2}\) feet of cover must be insulated and analyzed for potential traffic load impacts. Greater than 5 feet of cover is preferred.

Whenever possible, water mains shall be installed at least 10 feet horizontally from any existing or proposed sewer. If existing conditions prevent a lateral separation of 10 feet, the main should be installed in a separate trench or if it is laid in the same trench it is located on an undisturbed earth shelf on one side of the sewer. The invert of the water main should be at least 18 inches above the top of the sewer. Whenever sewers must cross under water mains, the sewer shall be laid at such an elevation that the top of the sewer is at least 18 inches below the bottom of the water main.

Utility warning tape shall be installed to provide warning and identification of buried piping. Tape shall specify “Cambridge Water” in the street. For water lines on campus, use color-coded detectable utility marking tape.

All valves on MIT property shall be clockwise to close and counter clockwise to open.

Distribution system pipe shall be a minimum of 8 inches in diameter. Mains shall be sized so the velocity is in the range of 2.5 to 5.0 feet per second.

Pipe used for hydrant branches shall be at least 6 inches in diameter. See Detail C-8. Gate valves shall be rated for 200 psig. Butterfly valves shall be rated 150 psig and hydrants shall be rated for 150 psig.
Assume a minimum trench with of pipe diameter plus 2 feet, with a minimum of 3 feet for water main installation. See typical pipe trench detail C-1.

Dead ends should be minimized or eliminated by the looping of all water mains wherever practical.

Line valves shall be spaced at not more than 500 feet as determined by the CWD.

Water service to properties shall consist of a corporation into the main, copper service tubing, and a curb stop at the property line. See detail C-7. Service boxes supplied shall be “Buffalo” type, American manufactured, of a telescopic type with a length from 4 feet to 5 feet.

Redundant water service (feeds) need to be provided in any new facility considered critical during emergency situations.

CWD will provide Neptune Trident meters (High Performance (HP) Turbine meter or Tru/Flo Compound meter) for pipe sizes up to 2 inches inclusive. In addition to the physical meter, transmitter (Tricon transmitter by Neptune) is included that is preprogrammed to CWD standards.

Domestic water flow on non CWD meters (MIT informational meters reporting through MIT’s PI system) shall be measured using ultrasonic transducers as the primary flow element combined with the GE AT600 flow meter. GE will recommend the design parameters.

Pressure measurement will be conducted if requested through PSI taps that will be installed before any process take-offs. Sensor lines from the pressure taps will be wired to two Rosemount Model 3051 Gauge pressure transmitters that have been factory calibrated to a range of 0-150 PSIG. Transmitter will be coupled with a 306 two-valve manifold. Transmitter order number is: 3051TG2A2B21AS5B4Q4J3M5. Manifold order number is: 0306RT22AA11.

Install dedicated water meters for cooling tower makeup and in-ground irrigation systems. These meters are not sub-meters to a main meter. These meters shall be fed directly from the water service entry, separate from the rest of the building, upstream of the domestic water meter. These meters are used to facilitate the tracking of sewer rebates with the city.

The CWD should be contacted regarding water quality and determine if additional pre-treatment is required to correct any hardness or corrosive issues with city water.

Pipe, valves and fittings for domestic water and fire protection use should be confirmed with MIT Utilities.

**4.3 Fire Protection Information**

MIT’s fire protection goal is to provide 100% coverage (including electric rooms) in all of its facilities. In existing buildings, MIT seeks to bring renovated areas into conformance with
Institute standards through a strategy of determining the prudent course between achieving higher levels of fire protection and budgetary responsibility.

MIT owns and operates an independent campus wide fire protection loop. System operating information and system mapping is the responsibility of Facilities.

The campus fire water system is separated into 3 on-campus loops. These are the West loop, the Central loop, and the East loop. The pressures maintained in these loops are as follows.

West Loop: 175 psig.
Central Loop: 150 psig.
East Loop: 150 psig.

Portions of the campus are still fed from city water. Water pressure on campus can vary significantly from day to night and from season to season. Pressure ranges from 40 psig to 60 psig.

4.4 Fire Protection Design Issues

Dead ends should be minimized or eliminated by looping of all mains when practical. When dead ends occur, a blow off valve should be installed for flushing purposes. Blow off valves and hydrants must be protected from operating pressures in excess of 150 psi by a normally closed gate valve or PIV.

No fire service line shall be laid in the same trench with any other public or private utilities, except a water service pipe or within 10 feet of a sewer. Water mains designated as transmission mains shall not be tapped for fire service, except when approved by the Cambridge Water Department (CWD).

Cross-connections and potential cross-connections require backflow preventers.

All pipe and appurtenances used for fire protection systems must have Factory Mutual approval.

Fire Protection piping shall be buried with a minimum of 5 feet of cover to top of pipe.

Utility warning tape shall be installed to provide warning and identification of buried piping. Tape shall specify “MIT Fire Protection”. Use color-coded detectable utility marking tape.

Gate valves and post indicator valves shall have a rated operating pressure which is greater than the system design operating pressure.

All valves on MIT property shall be clockwise to close and counter clockwise to open.

Building mounted indicator valves are not allowed.
Distribution system pipe shall be a minimum of 8 inches in diameter and pipe used for hydrant branches shall be a minimum of 6 inches in diameter. Mains shall be sized so the velocity is in the range of 2.5 to 5 feet per second.

Assume minimum trench width of pipe diameter plus 2 feet, with a minimum of 3 feet for water main installation. See typical pipe trench detail C-1.

Hydrants are to be placed at approximately 500 foot intervals. Normal placement is between properties, along the property line if possible. Fire hydrant model and locations need Cambridge Fire Department approval. See Detail C-8.

All fire protection appurtenances must be reviewed and approved by MIT Facilities.

Fire protection services are not to be metered.

Water supply for the system shall be provided from either a campus loop or directly from city water.

New building alarms shall connect to the MIT Central Fire station in Operations & Maintenance including underground duct banks, manholes, fiber optic cable, copper cable and radio box.

Restrained joints shall be installed at all joints, fittings, hydrants, sleeves, and valves. Thrust blocks shall be included at all changes in direction including tees and hydrant branches.

### 4.5 Quality Assurance

Testing: Hydrostatic tests at minimum 2 times working pressure for 2 hours.

See 2.4 above

### 4.6 Products

Water Service Piping Systems:

2. Piping may include:
   a. Ductile iron.
3. Valves: Suitable for service.
4.7 Installation

Install materials and systems in accordance with manufacturer's instructions and engineer’s approved submittals. Install materials and systems in proper relation with adjacent construction. Coordinate with work of other sections.

After a section of the main has been pressure tested, the contractor is to flush and disinfect the completed main with the results submitted to the CWD. Backfill and protect work from damage.

5. 333000 - SANITARY SEWERAGE UTILITIES

5.1 Sanitary Sewer Information

The City of Cambridge DPW maintains the sanitary system which includes sewer and drain collection. The sewer always discharges into the Massachusetts Water Resource Authority (MWRA) collection network where it has been fully separated from the drain system.

The city’s system also includes combined catchments. During significant rain storms combined sewer systems may fill up beyond their capacity with a mixture of sanitary waste and rain water. A combined sewer overflow (CSO) acts like a relief valve allowing sewerage to discharge into waterways instead of backing up into homes, businesses and streets. Both the Charles River and Alewife Brook receive discharges from Cambridge CSOs at 11 locations. Cambridge is working to reduce and eliminate CSO discharges by separating systems whenever possible.

Improved on-site storm-water management helps mitigate CSO issues.

The City and the MWRA limit temperature, pH, and various pollutants from discharges to the City Sewer System. Connections to the City Sanitary Sewer System require a Sewer Use Discharge Permit from the as well as a Sewer Connection Permit issued by the City of Cambridge.

5.2 Sanitary Sewer Design Issues

All sanitary system elements shall be designed in compliance with the current City of Cambridge Department of Public Works (DPW) standard specifications or other guidelines as directed by that agency. Comply with all local code issues for distance between services, including City of Cambridge DPW “Wastewater and Stormwater Drainage Use Regulations” and City of Cambridge Municipal Code 13.16 for Wastewater and Stormwater Drainage System.

Excavated soil is likely to be considered contaminated under Massachusetts Contingency Plan (MCP). Comply with all requirements of the MCP.
Whenever possible, sewer pipe shall be installed at least 10 feet horizontally from any existing or proposed water main. If horizontal separation is not possible, the pipe should be installed in a separate trench or on an undisturbed earth shelf located on one side of the water main. The top of the sewer main should be at least 18 inches below the invert of the water main.

Assume minimum trench width of pipe plus 2 feet with a minimum of 3 feet for sewer pipe installation. See Detail C-1.

Coordinate the design with existing services and work of other disciplines and other site designers. Utilize test pit data and select test pit locations to identify potential interference location with existing services.

Slope is to be constant between manholes and be based on a minimum velocity of 2 feet per second. Maximum slope is 0.1 foot /foot.

Lateral building services shall be a minimum of 6 inches in diameter.

Design safeguards against backflow for all basement services. Backwater valves and cleanouts must be located for ease of operation and accessibility.

Interior drop manholes should be installed for vertical drops greater than 2 feet. Refer to Detail C-13 and C-14.

Pipelines are not to be used as conductors for trench drainage during construction.

New sewer trunk mains shall be a minimum of 10 inches in diameter.

Use 4 foot diameter manholes for pipes up to 24 inches. See Detail C-12.

Precast bases shall be supported on a compacted level foundation of ¾ inch crushed stone at least 12 inches thick.

All joints between concrete sections shall be watertight.

Connection of sewer pipe to manhole shall be made using mechanical connections. See Detail C-12, flexible manhole sleeves.

Distance between manholes should generally not exceed 400’.

Manhole frames shall be concentric with top of the manhole structure and in a full bed of mortar so that the space between the top of the brick and mortar and the bottom of the flange of the frame shall be completely filled and made watertight. The upper section of the underground structure shall be eccentric to the lower sections to facilitate ladder installation and access.
The inverts shall conform accurately to the size of the adjoining pipes. Side inverts shall be curved and main inverts shall be laid in smooth curves of the longest possible radius, which is tangent to the centerlines of adjoining sewers.

Provide adequate venting and overall design for gas and sand interceptors and grease interceptors.

Connections to the City Sanitary System require a “Sewer Connection Permit” application to be filed with the City of Cambridge DPW.

5.3 Quality Assurance

See 2.4 above.

5.4 Products

5.4.1 Underground Structures and Manholes

Refer to Appendix D for utilities details and manhole details.

For Drop Manholes: An interior drop manhole should be used when the elevation drop is greater than 2 feet between the pipelines.

Use 4-foot diameter manholes for pipes up to 24 inches.

Precast Bases:

1. All manholes shall have precast concrete bases at least 6-inches thick for 4-foot diameter manholes and 8-inches thick for larger manholes.
2. The precast bases shall be manufactured to contain wall openings of the minimum size to receive the ends of the pipes.
3. Precast bases shall be supported on a compacted level foundation of 3/4 inch crushed stone at least 12-inches thick.

Manhole walls shall be precast concrete sections conforming to the applicable requirements of ASTM “Tentative Specifications for Precast Reinforced Concrete Manhole Sections,” Designation C478.

The top conical section shall have a wall thickness not less than 5-inches at the bottom and wall thickness of 8-inches at the top. The conical section shall taper from a minimum of 48-inches diameter to 24-inches diameter at the top.

All joints between concrete sections shall be watertight.
Gaskets for sealing the joints between manhole sections shall be of petroleum resistant materials of a special composition having a texture to assure a watertight and permanent seal. The gasket shall be of a composition and texture, which shall be resistant to sewage, industrial wastes, petroleum products, and groundwater.

Connection of sewer pipe to manhole shall be made using mechanical connections.

1. Flexible pipe-to-manhole connectors shall be Kor-N-Seal or equal.

Distance between sanitary sewer manholes should generally not exceed 400 feet.

Frames and Covers:

1. Manhole frames shall be concentric with top of the manhole and in a full bed of mortar so that the space between the top of the brick and mortar and the bottom of the flange of the frame is completely filled and made water tight.
2. Frames and covers shall have a 24-inch diameter clear opening, 7 inches tall and shall be manufactured by EJ Group Inc, Model 1040A (non-locking), or equal.
3. Frames and covers shall be of cast iron with diamond cover surface and designed for H-20 heavy duty traffic loading. The casting shall meet the AASHTO M306 proof load, and the minimum loading criterion is 40,000 lbs.
4. Covers for all structures shall have the word “SEWER” permanently cast into the surface.

The inverts shall conform accurately to the size of the adjoining pipes. Side inverts shall be curved and main inverts shall be laid in smooth curves of the longest possible radius, which is tangent to the centerlines of adjoining sewers.

Manhole steps for precast reinforced concrete barrel sections shall be cast in with barrel sections and manufactured from steel encapsulated with molded copolymer polypropylene plastic step.

5.4.2 Piping

Sanitary Sewerage Systems include sewerage piping and systems for building wastes.

1. Pipes and Fittings:
   a. Pipe Class: SS.
   b. Reinforced Concrete Pipe (RCP): 12 inch and Larger to ASTM C76, Class III/Class IV Reinforced Concrete Pipe (RCP) with rubber gasket joints to ASTM C443.
   c. Polyvinyl Chloride (PVC) Pipe and Fittings 4 to 15 inch: to ASTM D3034, Polyvinyl chloride pipe, including those required for stubs, shall conform to ASTM Standard Specifications for Type PSM PVC Sewer Pipe and Fittings.
PVC pipes shall have maximum pipe diameter to wall thickness ratio (SDR) of 35.

d. Polyvinyl Chloride (PVC) Fittings 18 to 27 inch: to ASTM F679, Polyvinyl chloride fittings shall conform to ASTM Standard Specifications for Type PSM PVC Sewer Pipe and Fittings.

e. Polyvinyl Chloride (PVC) Joints: to ASTM D3212, joints shall be push-on bell and spigot joints using elastomeric ring gaskets, gaskets shall be a composition and texture which is resistant to common ingredients of sewage and industrial wastes, as well as petroleum products (oil, gasoline, etc.) and ground water.

f. Pipe shall be tested by the flat plate deflection method at a minimum of 45 psi at 5 percent deflection in accordance with ASTM D2412.

g. Standard laying lengths of pipe shall be either 13 or 20 feet.

h. No single piece of pipe shall be laid unless it is generally straight. The center line of the pipe shall not deviate from a straight line drawn between the centers of the openings at the ends of the pipe by more than 1/16 inch per foot of length.

i. Assume minimum trench width of pipe diameter plus 2-feet with a minimum of 3 feet, for sewer pipe installation see Appendix B - TYPICAL PIPE TRENCH DETAIL.

j. Slope is to be constant between manholes and be based on minimum velocity of 2 feet per second. Following are minimum slopes for PVC pipe (n=0.011):

<table>
<thead>
<tr>
<th>Size (inches)</th>
<th>Minimum Slope (ft/foot)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>0.0040</td>
</tr>
<tr>
<td>10</td>
<td>0.0028</td>
</tr>
<tr>
<td>12</td>
<td>0.0022</td>
</tr>
<tr>
<td>15</td>
<td>0.0017</td>
</tr>
<tr>
<td>18</td>
<td>0.0012</td>
</tr>
<tr>
<td>21</td>
<td>0.0010</td>
</tr>
<tr>
<td>24</td>
<td>0.0008</td>
</tr>
</tbody>
</table>

Maximum slope 0.1 ft/foot

2. Pipe and fitting materials may include:

   a. PVC.
   b. Reinforced concrete.

2. Bricks:

   a. Brick shall conform to the applicable requirements of ASTM Standard Specification for “Sewer Brick (made from clay or shale)”, Designation C32, for Grade SA, hard brick, latest revision.
   b. The mortar for brickwork shall be composed of Type II Portland cement and
sand in the proportions of 1:2.

c. The sand shall comply with the “Standard Specifications” for “Fine Aggregate”, for concrete masonry.

3. Crushed stone shall be used as pipe bedding.
4. Compacted sand shall be used from pipe invert to 6 inches above the pipe crown.
5. Enough sand shall be placed between the pipe and the sides of the trench, and thoroughly compacted, to hold the pipe in correct alignment.
6. During construction, open ends of pipe and branches shall be closed with polyvinyl chloride stoppers secured in place in an acceptable manner.
7. Pipelines shall not be used as conductors for trench drainage during construction.
8. Design safeguards against backflow for all basement services.
10. Building Services: Lateral building services shall be a minimum of 6 inch diameter.
12. Connections to the City Sanitary System: Require a “Sewer Connection Permit” application to be filed with the City of Cambridge DPW.

5.5 Installation

Install materials and systems in accordance with manufacturer's instructions and approved submittals. Install materials and systems in proper relation with adjacent construction. Coordinate with work of other sections.

Where connections are made to existing systems, rout out old drainage lines.

Test for proper operation. Clean and protect work from damage.

6. 334000 - STORM DRAINAGE UTILITIES

6.1 Storm Drainage Information

All stormwater elements within public property are designed in accordance with City of Cambridge, Department of Public Works (DPW) specifications. All modifications or connections to a public drainage system require review and approval by the Cambridge DPW, and compliance with their latest regulations.

Refer to “Wastewater and Stormwater Drainage Use Regulations” at the DPW website. The DPW strictly enforces a stormwater policy which is described in detail in “MIT Campus Sustainability Working Group Recommendations - An Integrative Vision for our Buildings, Materials, Stormwater, Landscape and Labs” published November 30, 2015.
All designs must comply with City of Cambridge Stormwater Management Plan and National Pollutant Discharge Elimination System (NPDES) regulations. Any changes or additions in discharges from MIT outfalls could potentially require Cambridge Conservation Commission approval. All modifications or connections to a public drainage system will require review and approval by the Cambridge DPW, and must be in compliance with their latest regulations.

Any modifications or additions to MIT owned and operated drainage system outfalls require National Pollutant Discharge Elimination System (NPDES) permitting. MIT currently has one master NPDES permit which governs several outfalls, which should be amended as required.

The City requires removal of 65% of phosphorus in stormwater generated by new projects with an existing stormwater discharge to the Charles River, and removal of 100% of phosphorus in stormwater generated by new projects with a new stormwater discharge to the Charles River.

Refer to the Environmental, Health, and Safety Thematic Folder for additional regulatory guidance regarding stormwater system design on the MIT campus.

Improved on-site storm-water management helps to mitigate CSO issues.

### 6.2 Storm Drainage Design Issues

Pipes located on public property shall have the following dimensions and features:

1. New storm drain trunk mains shall be a minimum of 15 inch diameter.
2. Catchbasin laterals shall be a minimum of 10 inch diameter.
3. Building service pipes shall be a minimum of 6 inch diameter.
4. Pipe sizes shall be calculated based on achieving self-cleaning velocities during the design storm.
5. Catchbasins shall connect directly to manholes.
6. Refer to City Municipal Code Chapter 13.16 for WASTEWATER AND STORMWATER DRAINAGE SYSTEM information. Refer to "Wastewater and Stormwater Drainage Use Regulations" dated March 31, 2008. This information is available at the DPW website. All stormwater elements within public property shall be designed in accordance with the current City of Cambridge Department of Public Works (DPW) Standard Specifications.

Pipes located on MIT property shall have the following dimensions and features:

1. Pipes which have a diameter less than 12 inches shall be Polyvinyl Chloride (PVC) SDR 35 or heavier as required. Pipes with a diameter of 12 inches and larger shall be reinforced concrete pipe (RCP).
2. Generally, class III concrete pipe is adequate when the pipe has at least 2.5 feet of earth cover. Where 2.5 feet of earth cover is not achievable, Class IV or heavier may be required. The design engineer shall be responsible for determining and specifying the
Whenever possible, roof drains shall discharge to landscaped areas in order to increase runoff
times of concentration and enhance water quality. Roof drain discharges shall not be routed
across walkways or other areas where frozen water would create a safety hazard.

Pipe sizes shall be calculated based on achieving self-cleaning velocities during the design storm.

Inverted siphons should not be designed into stormwater systems to minimize maintenance
issues.

Pipes connecting into manholes and catch-basins shall end flush with inside interior wall and all
openings around pipe entrances and lift holes shall be filled with non-shrink grout. See Detail C-2.

On-site stormwater management shall be designed using Best Management Practices (BMPs).

Drywells shall not be used to accept drainage from large areas such as parking lots.

Manholes shall be precast with a 4 foot inside diameter for drain pipes up to 30 inches O.D.
Manholes shall be 5 foot inside diameter for drain pipes up to 44 inches O.D. See Detail C-3.

Coordinate the design with existing services and work of other disciplines and other site
designers. Utilize test pit data and select test pit locations to identify potential interference
location with existing services.

6.3 Quality Assurance

See 2.4 above.

6.4 Products

6.4.1 Underground Structures with Solid Covers

Concrete drain structures shall be precast four feet inside diameter for drain pipes up to 30 inch
outside diameter. Concrete drain structures shall be five feet inside diameter for drain pipes up to
44 inch outside diameter.

Precast Concrete:

1. Precast reinforced concrete drainage structure sections shall conform to the applicable
requirements of ASTM C478, latest revision.
2. Concrete shall have a minimum 28-day compressive strength of 4,000 psi, utilizing Type
II Portland cement.
3. Reinforcement steel shall be intermediate grade, ASTM A615, and deformed in
accordance with ASTM A615.

4. Welded wire fabric shall conform to ASTM A185. Manholes and drainage structures shall be designed to withstand AASHTO HS-20 loading.

Four foot diameter drainage structures shall have a minimum wall thickness of five inches and bottom minimum thickness of eight inches. Five foot diameter drainage structures shall have a minimum wall thickness of six inches and minimum bottom thickness of eight inches.

Frames and Covers:

1. Manhole frames shall be concentric with top of the manhole and in a full bed of mortar so that the space between the top of the brick and mortar and the bottom of the flange of the frame is completely filled and made water tight.

2. Frames and covers shall have a 24-inch diameter clear opening, 7 inches tall and shall be manufactured by EJ Group, Inc., Model 1040A, or equal. Frames and covers shall be of cast iron with diamond cover surface design and designed for H-20 Heavy Duty traffic loading. The casting shall meet the AASHTO M306 proof load, and the minimum loading criterion is 40,000 lbs.

3. Covers for all structures shall have the word “STORM” permanently cast into the surface.

Drainage structure steps for precast reinforced concrete barrel sections shall be steel encapsulated with molded copolymer polypropylene plastic step.

All drainage structures shall have a 4 foot sump for sediment collection.

Pipes connecting into concrete drain structures shall end flush with interior wall and all openings around pipe entrances and lift holes shall be filled with non-shrink grout.

6.4.2 Underground Structures and Catchbasins

For typical catchbasin configuration, see Appendix G - PRECAST CONCRETE CATCHBASIN.

Precast concrete catch basin shall conform to the applicable requirements of ASTM C478 or ASTM C858, latest revision and designed to withstand AASHTO HS-20 loading.

Precast concrete sumps, 6 foot minimum depth, shall conform to the applicable requirements of ASTM C478. Wall sections shall have a minimum wall thickness of six inches.

Frames and Grates:

1. Manhole frames shall be concentric with top of the manhole and in a full bed of mortar so that the space between the top of the brick and mortar and the bottom of the flange of the frame is completely filled and made water tight.

2. Frames shall have a 23 ¾ -inch diameter clear opening, 8 1/8 inches tall and shall be
3. Frames and grates shall be of cast iron with a cover surface and designed for H-20 heavy duty traffic loading. The casting shall meet the AASHTO M306 proof load, and the minimum loading criterion is 40,000 lbs.

4. Grates for all structures shall have the word “DRAINS TO WATERWAYS” permanently cast into the surface.

Two 4-inch weep holes shall be provided with each catch basin. The pipe through the catch basin wall shall be PVC and a 1/2-inch mesh 23 gauge galvanized wire shall be secured at the end of the pipe to keep the stone out. Two cubic feet of stone sized 3/4-inch to 1-1/2-inch shall be placed around each weep hole. In areas of contamination or high groundwater, weepholes shall not be provided.

Pipes connecting into catchbasins shall end flush with inside interior wall and all openings around pipe entrances and lift holes shall be filled with non-shrink grout.

For catchbasins located in a paved area, an oil and water separator shall be installed at the outlet pipe. An oil and water separator may be in the form of an elbow down, or a hood specifically manufactured for oil and water separation. The separator shall be removable for periodic flushing and cleaning of drain lines.

All catchbasins shall have a 6 foot deep sump for sediment collection.

6.4.3 Pipe, Joints, and Brick

1. Pipes:
   a. Pipe Class: SD.
   b. Reinforced Concrete Pipe (RCP) 12 inch and Larger: to ASTM C76, Class III / Class IV Reinforce Concrete Pipe (RCP) with rubber gasket joints to ASTM C443.
   c. Polyvinyl Chloride (PVC) Pipe 4 to 10 inch: to ASTM D3034, Polyvinyl chloride pipe, including those required for stubs, shall conform to ASTM Standard Specification for Type PSM PVC Sewer Pipe and Fittings. Pipe shall have a minimum diameter to wall thickness ratio of (SDR) of 35.
   d. Pipes shall be tested by the flat plate deflection method at a minimum of 45 psi at 5 percent deflection in accordance with ASTM D2412.
   e. Standard laying lengths either 13 feet or 20 feet.

2. Joints:
Drain and Sewer Plastic Pipes Using Flexible Elastomeric Seals”.

b. Joints shall be push-on bell and spigot joints using elastomeric ring gaskets. Gaskets shall be a composition and texture resistant to common ingredients of sewage and industrial wastes, petroleum products (oil, gasoline, etc.) and groundwater.

3. Brick:
   a. Brick shall comply with the ASTM Standard Specification for “Sewer Brick (made from clay or shale)”, Designation C32, for Grade SA, hard brick.
   b. The mortar for brickwork shall be composed of Type II Portland cement and sand in the proportions of 1:2. The sand shall comply with the “Standard Specifications” for “Fine Aggregate”, for concrete masonry.

6.5 Installation

Install materials and systems in accordance with manufacturer’s instructions and approved submittals. Install materials and systems in proper relation with adjacent construction. Coordinate with work of other sections. Provide cleanouts.

Connect to above-grade and below-grade drainage systems. Drain system to approved location. Test for proper operation. Clean system out and protect work from damage.

7. 337000 - ELECTRICAL UTILITIES

7.1 Electrical Information

Primary voltage delivered to MIT buildings by the Central Utilities Plant (CUP) is 13.8kV.

The 2.4kV service provided historically is not available for expansion and will be phased out in the future.

Substations are interconnected on the secondary side to provide redundant transformer capabilities.

All switches in substations are loop connected to the MIT distribution system either at 2.4kV or 13.8kV.

7.2 Utilities Electrical Design Issues

Any interface with the MIT electrical distribution system should be reviewed with the MIT Utilities Group.
Duct-banks to be concrete encased with 5”, schedule 40 PVC conduits provided. See Details C-4, C-5, C5-A, C5-B & C-6.

Medium voltage cables installed shall be 15kV, 350 kcmil and EPR 133% insulated. There shall be two radial feeders serving each building through separate manholes if possible. Buildings having critical requirements must have two separate entries into the building. All cables in manholes and pull-boxes are to be identified using non-corrosive, permanent tags. The cable shall be marked with the location it is coming from and the location it is going to. Within a manhole cables shall be looped once around the interior after entering and once before leaving. Fire-wrap is required for all cables.

All new building construction or renovation projects require provisions for the installation of meters and field devices necessary for real-time, remote collection of utility data. Solid state micro-processor based Electric Meter shall be installed on unit substation main breaker. The meter shall have an RS232 communication port and a RS485 communication port with OPEN Modus protocol. If new switchgear is being installed, the meter installed in front of the main breaker shall be revenue grade. All breakers in the switchgear shall have Modbus communications included and factory wired.

All penetrations to manholes or buildings are to be made watertight using OZ Gedney water stops for all existing and new cable runs.

All spare conduits need blank plugs as approved by MIT Utilities Group.

Medium voltage load break switches shall be manufactured by G&W Electric Company, no substitutions, and as follows. Each switch shall have the following features:

1. RAM 44-376M-40PI 4way (or as need by MIT facilities) SF6 gas switch.
2. Rated for 15,000 volts.
3. Open stud bushings ICSBO376SF.
4. 42 inch paneled bolted frame.
5. Incoming loop cable: 3-1/C 350 kcmil Cu EPR with shield and insulated 4/0 AWG Cu ground cable.
6. Switches are bottom-fed.

Feeder cable to substation from load break switch shall be 3-1/C 4/0 AWG Cu EPR with shield and insulated #2 AWG Cu ground cable.

There shall be one medium voltage circuit breaker provided for the medium voltage side of each substation transformer.

There shall be one spare position provided for MIT’s future use when a new switch is provided.

There shall be two switches provided for each double-ended substation.
Configure switch cable connections on first switch as follows:

1. Position 1: incoming loop cable.
2. Position 2: feeder cable to substation first MV vacuum circuit breaker.
4. Position 4: Outgoing cable to connect to second switch.

Configure switch cable connections on second switch as follows:

1. Position 1: incoming cable from first switch.
2. Position 2: feeder cable to substation second MV vacuum circuit breaker.

All switches shall be loop connected to the MIT distribution system at 13,800V.

Switches shall be located in the same room as the substation.

**7.3 Quality Assurance**

See 2.4 above.

Devices and Accessories Including Ducts for Communications and Telephone Service: Listed and labeled as defined in NFPA 70, Article 100.

**7.4 Products**

Cable Tags - two-color injection molded product see www.techproducts.com

Arc & Fire Proofing Tape - see www.plymouthrubber.com

15kV Cable - Okoguard-Okoseal type MV-105, 15kV or equal by Kerite - see www.okonite.com

5/8kV Cable - Okoguard-Okoseal type MV-105, 5/8kV or equal by Kerite - see www.okonite.com

SF6 switches - G&W Electric, Inc. - see www.gwelec.com

IR viewport – Fluke CV300 ClirVu Series IR windows - see www.fluke.com

Conduit sealing bushings – OZ Gedney see www.emerson.com
7.5 Installation

Install materials and systems in accordance with manufacturer's instructions and approved submittals. Install materials in proper relation with adjacent construction and with uniform appearance for exposed work. Coordinate with work of other sections.

Test all systems for proper operation.

Restore damaged finishes. Clean and protect work from damage.

8. **337119 - DUCTBANKS**

8.1 Ductbank Information

Underground duct banks and related underground utility structures are used to convey medium voltage power cabling, telecomm cabling, and fire alarm cabling on the MIT campus.

8.2 Ductbank Design Issues

Asbestos containing materials must not be used in ductbanks or underground structures.

Project “as-built” documentation for underground structures and building entrances must include cable locations and termination points.

The designer is responsible for selecting and designing all supports, anchors, and racking.

Adequate sumps must be provided within underground structures to permit pumping. Utilize manufacturers recommended accessories.

Ductbanks shall be of a dimension to meet project requirements, including the following features:

1. Conduits used in ductbanks are to be 5-inch, round, schedule 40 polyvinyl chloride (PVC).
2. Where building services enter building foundations, 10 feet of steel conduit are to penetrate the wall. Seal as specified below.
3. Each single conduit in the ductbank shall be separated and completely encased in concrete. See Appendix K - TYPICAL DUCTBANK.

Ducts shall slope towards manholes and away from building penetrations, including:

1. Conduits shall be laid at a minimum grade of 3 inches per 100 feet.
2. In no case shall conduits be constructed with intermediate low points between structures which will collect water.
3. No isolated low points will be allowed unless reviewed and approved by MIT Utilities and Information Systems and Technology (IS&T).

An application for Grant of Location must be filed with the City of Cambridge Pole and Conduit Commission and approved prior to construction of any ductbank in the public way.

Wherever feasible, electrical and telecommunications ducts are to be constructed within a common trench and ductbank. Building service requirements include:

1. At a minimum, 6 conduits shall be provided for MIT Telecomm (IS&T) and MIT Fire Alarm at each service entry.
2. Two independent and physically separated service entrances shall be provided for new buildings.
3. Service entrances shall be from separate underground structures and from separate ductbank systems.
4. At a minimum, 4 conduits shall be provided for MIT Utility Electric at each service entry.
5. Both ends of the campus medium voltage loop cannot enter through a common underground ductbank.
6. In addition to the requirements of the immediate project, a minimum of 2 spare conduits shall be provided for electrical and 2 spare conduits shall be provided for telecomm.

Refer to Appendix D for details. Ductbanks must be separated before approaching their respective underground structures.

Ductbanks shall be installed so that the top of the concrete is not less than 30 inches below finished grade at the highest points.

Ductbank transitions to building walls and underground structures (including other intersecting ductbanks) shall be designed to prevent shearing and separation.

Conduits shall terminate in end bells, flush with interior manhole walls, where duct lines enter manholes.

After completion of ductbanks, all ducts shall be rodded and brushed. Graduated mule tape and blank duct plugs shall be installed.

Manholes should be left completely clean by contractor. MIT requires that their butterfly diagrams are updated by the contractor to show changes due to project work. Contactor must also provide before and after photographs to document the changes.

Joints in horizontal runs of conduits within ducts, may be placed side-by-side, but stacked conduit joints shall be staggered along the run at least 6 inches vertically.
Duct spacers shall be provided in all duct lines to support and maintain spacing of ducts during concrete pour. Spacers shall be placed on centers not greater than 4 feet.

Seals:

1. Where a proposed ductbank is connecting into an existing structure, core existing vault and use link seals to provide water tight connections.
   a. For all existing or new conduits which enter underground structures or buildings, the cable/conduit interface shall be sealed with O-Z / Gedney type CSB conduit sealing bushings.
   b. The conduits and area around building service entrances and underground structure penetrations, conduits is to be sealed with the appropriate Link Seal product.

Horizontal and Vertical Alignment:

1. Changed is vertical or horizontal alignment of a ductbank exceeding a total of 10 degrees shall be long sweep bends having a minimum radius of curvature of 25 feet.
2. Manufactured bends may be used if reviewed and approved by MIT during the design process.
3. The sum bending angles on any single run between manholes shall not exceed 180 degrees.
4. Spacing between electrical manholes shall not exceed 300 feet. Refer to sanitary sewer manholes above for more information about maximum spacing and other sanitary sewer manhole requirements.

Underground Structures and Vaults:

1. Telecom and electrical vaults shall be precast reinforced concrete.
2. Concrete shall be 5,000 psi at 28 days. Reinforcing steel shall comply with AASHTO M31, grade 60.
3. Manhole walls and base slab to be minimum 6 inch thick, top slab minimum 8 inch thick.
4. Entire underground structure exterior is to be damp-proofed.
5. Ground rods shall not be installed through the underground structure floor. Grounding conductors shall exit the vault high on the wall and connected to an external grounding system.
6. The interior dimensions of underground structures and vaults shall be minimum 6 by 9 feet by the required depth.
7. Underground structures and vaults shall be designed to support loading from:
   a. Piping and appurtenances
   b. HS-20 loading
c. Lateral soil pressures above and below ground water

8. Underground structures and vaults shall have a sump pit 1 foot in diameter and 4 inch deep. The manhole floor shall be sloped to the slump 1/4 inch per foot.
9. Vaults shall be buried a maximum of 1 foot-6 inches.
10. A pulling eye shall be provided on each of the 4 walls. Pulling eyes shall not be closer than 12 inches to any ductbank window.

Manhole Covers:

1. Frames and covers shall be of composite material by EJ Group, Inc. or approved equal. Frame EJ1480 and cover EJ 3200 with sniffer hole. Cover shall have Titus TwistLIFT locking option.
2. Frames and covers shall be designed for H-20 Heavy Duty traffic loading. The cover and frame shall meet the AASHTO M306 proof load, and the minimum loading criterion is 40,000 lbs.
3. Manhole covers shall have the appropriate words “MIT EMH-XXX (number assigned by MIT Utilities)” or “MIT TMH-XXX (number assigned by MIT IS&T/FIS)” permanently cast into the surface.

Conduits (Piping):

1. Conduits shall be manufactured of PVC, Carlon PV-Duct, Type 40, 90 degree UL rated or approved equal.
2. Material shall have a tensile strength of 7,000 psi at 74.3 deg. F, flexural strength of 11,000 psi and compressive strength of 8,600 psi.

8.3 Quality Assurance

See 2.4 above.

8.4 Installation

Water and debris must be prevented from entering conduits or manholes during construction. The ends of all conduits shall be plugged with blank duct plugs immediately after they are rodded and brushed clean. When cables are pulled the blank duct plugs can be removed from the utilized conduits and segmented OZ Gedney duct plugs shall be installed in their place. Spare ducts shall remain protected by blank duct plugs.

9. 335000 – STEAM AND CONDENSATE UTILITIES
9.1 Steam and Condensate Information

Steam is delivered to buildings at 190-200 psig entry pressure and 380-425 degrees F depending upon location and proximity to CUP.

No direct CUP steam exposure is allowed for humidification. Steam needed for humidification is to be provided by the building with a separate clean steam generating heat exchanger.

Steam required for process needs is to be provided by the building with a separate steam generating heat exchanger.

All condensate must be returned to the Central Utilities Plant.

Pressure reducing station installation is building and project responsibility.

9.2 Steam and Condensate Design Issues

Steam main drip locations and detailing need to be coordinated with the work of other disciplines and MIT Facilities. High-pressure condensate from the drip legs shall not be directly introduced to the pumped condensate return system.

Ease of installation, maintenance and repair of vaults, tunnels and trenches are important design considerations.

Condensate handling and use of flash tanks, injection quills, pump sets and trapping need to be accounted for and properly located.

Label and identify pitch of piping for proper condensate removal.

Provide proper clearances between steam and condensate piping and other piping and structures.

Thermally insulate all hot lines and surfaces. Completely insulate all system components and surfaces including, without limitation, piping, valves, valve bonnets, flanges, strainers, fittings, expansion joints, special valves, control valves and cocks. Insulation thickness shall be based on a 40 year life cycle cost basis. See Details M-1 & MH3.

Comply with the general installation requirements provided by the MIT Utilities Group. See Details M-2, M-3, M-4, M-5, M-6, M-7, M-8, M-9 & C-1. Details are illustrative and will vary depending upon the specific manufacturer providing the product. All direct buried piping to be marine grade and the shrink sleeve enclosures be double sealed in ground water locations.

Provide single trap to hold steam in a heating apparatus or piping system and allow condensate and air to pass. See Detail M-18.

9.3 Quality Assurance

See 2.4 above.
9.4 Products

The recent installations of steam and condensate piping systems are preinsulated composite systems by Thermacore (Duo-Therm 505) and Perma-Pipe (Multi-Therm 500). We require driable, drainable, and air-testable systems. The piping, elbows, tees, expansion loops, end seals, gland seals and anchors are all part of the manufacturer’s engineered system. The exterior of the selected conduit pipe must be suitable for continuous immersion in groundwater with low pH soils. This requires that the steel conduit’s protective coating be of a “marine grade” quality.

All piping in manholes shall be insulated with 30mm thick Pyrogel and covered with an aluminum jacket.

Trench tops and trench exteriors shall be waterproofed with “Bituthene 3000” –Rubberized asphalt/polyethylene waterproofing system or MIT approved equal.

Seal all exterior wall piping penetrations above and below grade with “Link Seals” by Thunderline Corporation, Wayne, Michigan. See Details M-13, M-14, M-15 & M-17. Details are not to scale and dimensions will vary with each manufacturer.

Steam Supply temperature shall be measured using a Rosemount Series 68, 100 ohm Platinum Resistance Temperature Detector (RTD) sensor installed in a thermowell.

Manhole Frames and Covers:

1. Frames and covers shall have a 36-inch diameter clear opening.
2. Frames and covers shall be by Fibrelite, FL75 series. Frames and covers shall be designed for H-20 heavy duty traffic loading.
3. The covers shall say “MIT STEAM”. Below this text the steam vault number shall appear as “STV-XXX”.

All steam valves less than or equal to 2 inches are to be socket welded. Valves greater than 2 inches are to be butt welded. Preferred manufacturer for steam using manually operated gear is Adams. (See Pipe Index)

Steam mass flow shall be measured using a flanged GE Panametrics Ultrasonic Flow Tube as the primary flow element combined with the GS868 energy meter. Rosemount Model 3051 Gauge pressure transmitter shall be provided and coupled with 306 two-valve manifolds. Transmitter mfg. order number: 3051TG4A02A1AS5M5Q4. Manifold shall be Rosemount Model No: 0306RT22AA11.

10. 336000 – MEDIUM TEMPERATURE WATER UTILITIES
10.1 Medium Temperature Water Information

Medium temperature water is currently limited to West and Northwest Campus. Building served are NW30, NW35, and W79.

Supply temperature is reset by CUP based on outside air temperature.

Supply currently provides hot water at 180-240 degrees F but may change if CoGen waste heat becomes the primary generator.

10.2 Medium Temperature Water Design Issues

The existing MTW piping system is by Logstor. It is a preinsulated composite system manufactured to comply with EN 253. It consists of steel piping to carry the hot water, surrounded by a polyurethane foam, with an outer protective casing of high density polyethylene. Tricon and Perma-Pipe (Xtru-therm) are North American equivalents and should be considered for future projects. The piping, elbows, tees, expansion loops, end seals, gland seals and anchors are all part of the manufacturer’s engineered system. The exterior of the selected conduit pipe must be suitable for continuous immersion in groundwater with low pH soils. This requires that the steel conduit’s protective coating be of a “marine grade” quality.

System design should minimize pipe stress where possible. General installation requirements can be found in Details M-5, M-6, M-7 and C-1.

Design peak delta P at the heat exchangers which serve the building shall be in the range of 5-20 psi on the utility side of the exchanger.

Thermally insulate all hot lines and surfaces. Completely insulate all system components and surfaces including, without limitation, piping, valves, valve bonnets, flanges, strainers, fittings, expansion joints, special valves, control valves and cocks. See Detail M-1.

Provide adequate clearances to other piping systems and structures. Exterior wall piping penetrations are detailed in M-15 and M-16.

Arrange hot water supply and return piping so as to minimize heat transfer to chilled water piping.

Provide provisions for cleaning and flushing of piping in system design.

Hot water mass flow shall be measured using a flanged GE Panametrics Ultrasonic Flow Tube as the primary flow element combined with the DF868 energy meter. The flow element design will be conducted by GE directly, with the factory mandating the upstream and downstream straight pipe runs required to obtain the turn down ratios needed. GE Panametrics DF868 Two Rosemount Model 3051 Gauge pressure transmitters shall be provided that have been factory calibrated to a range of 0-150 PSIG. Transmitter will be coupled with a 306 two-valve manifold. Transmitter order number is: 3051TG2A2B21AS5B4Q4J3M5. Manifold order number is: 0306RT22AA11.
Hot Water Supply and Return temperatures shall be measured using a Rosemount series 68, 100 ohm platinum resistance temperature detector (RTD) sensor, or similar, installed in a thermowell.

10.3 Quality Assurance

See 2.4 above.

11. 338000 – CHILLED WATER UTILITIES

11.1 Chilled Water Information

Design Delta T should be 14-16 degrees across building.

There should be no requirement for secondary pumping of distribution system chilled water unless creating a recirculating loop within a building. Location of service relative to CUP and Plant delta P available will determine the pressure available to the building.

Differential pressure requirements at the building should be designed to not exceed 20 psi.

11.2 Chilled Water Design Issues

The designer is responsible for the selection of proper corrosion protection systems and building sealants for site soil conditions to address issues of conductivity, resistivity, acidity and water table elevation.

Chilled water systems on campus historically have been either welded steel pipe or ductile iron. HDPE has been used for temporary bypasses with success. It has not yet been used in a permanently installed system.

Summer setpoint for chilled water temperature delivered to the campus is 42 degrees F. As outdoor conditions enable a transition to non-refrigeration (thermocycle or “free”) cooling at the power plant the setpoint will move upward to a winter condition of 50 degrees F. More detail can be found in HVAC Division 23 of the MIT Design Standards.

The piping system design pressure is 150 psig. Typical system supply static pressure at the plant wall runs in the range of 90 to 130 psig.

Ductile Iron Pipe: Pipe shall conform to AWWA C151, minimum pressure class 250. All ductile iron pipes shall be cement mortar lined in conformance with AWWA C104 and shall have a 1 mil thick exterior petroleum asphaltic coating. Pipe shall be of domestic manufacture: U.S. Pipe, American Ductile Iron Pipe (American Pipe), or Atlantic States. No substitutions. Ductile iron chilled water piping joints are to be mechanically restrained. Where mechanically-restrained factory joints are not possible in design, Megalug joints are required.
Welded Steel Pipe:

All piping 10 inches and under shall be Schedule 40, all twelve inch and larger shall be .375" wall A53 ERW pipe. All piping shall be factory coated with an extruded polyethylene jacket by either Energy Coatings (PRITEC 10-60) or Shaw Coatings (Black Jacket). Fittings and weld joints shall be coated with RAYCHEM shrink sleeves or POLYKEN YGIII tape coating.


For ductile iron systems, provide for temporary restraints during hydrostatic testing if permanent restraints are not yet installed.

Thermally insulate above ground lines and surfaces including all system components including piping, valves, valve bonnets, flanges, strainers, fittings, expansion joints, special valves, control valves and cocks. See Detail M-1.

Refer to the following typical details for exterior wall piping penetration and pipe installation guidelines. See Detail M-5, M-6 and M-7.

Chilled water mass flow shall be measured using a flanged GE Panametrics Ultrasonic Flow Tube as the primary flow element combined with the DF868 energy meter. The flow element design will be conducted by GE directly, with the factory mandating the upstream and downstream straight pipe runs required to obtain the turn down ratios needed. Supply and Return pressure data will be processed through two Rosemount Model 3051 Gauge pressure transmitters that have been factory calibrated to a range of 0-150 PSIG. Transmitters will be coupled with 306 two-valve manifolds. Transmitter order number is: 3051TG2A2B21AS5B4Q4J3M5. Manifold order number is: 0306RT22AA11.

Supply and Return temperatures to be measured using a Rosemount Series 68 100 ohm platinum resistance temperature detector (RTD) sensor or approved substitute.

11.3 Quality Assurance

See 2.4 above.

12. 339000 – NATURAL GAS UTILITIES

12.1 Natural Gas Information

The natural gas provider for the campus is Eversource.

MIT has several segments of a buried gas system.

The gas company is to be provided in writing the total connected load for new services.
12.2 Natural Gas Design Issues

The designer must review the preliminary gas system design with the gas provider early in the design process and regularly thereafter.

The gas company will make the connections to the gas main and will provide the service branch to the building. MIT may be back-charged for this expense.

The gas company is to be provided in writing the total connected load for new gas consumption.

The gas company typically furnishes and installs the gas meter.

Provide swing joints at buildings as required by codes and standards to account for building settlement.

Refer to the Plumbing sections of the MIT Design Standards for laboratory gas requirements.

MIT requires additional metering of natural gas flow to be remotely monitored.

12.3 Quality Assurance

See 2.4 above.
APPENDIX A: SANITARY SEWER OVERVIEW

SANITARY SEWER

- CONNECTION TO CITY SANITARY SYSTEM
- DROP MANHOLE
- STANDARD MANHOLE
- PIPE
- BUILDING SERVICE
APPENDIX B: STORMWATER OVERVIEW
APPENDIX C: BUILDING ENTRANCES
APPENDIX D: UTILITIES DETAILS

C1 - Typical Pipe Trench Detail
C2 - Precast Concrete Catch Basin
C3 - Precast Concrete Drain Manhole
C4 - Typical Ductbank
C5 - Typical Electrical/Telecommunication Structure Plan View
C5A - Typical Electrical/Telecommunication Structure Section View A-A
C5B - Typical Electrical/Telecommunication Structure Section View B-B
C6 - Typical Unformed Ductbank Trench Detail
C7 - Water Service
C8 - Hydrant and Valve
C9 - Tapping Sleeve and Valve
C10 - Blow-Off Hydrant
C11 - Post Indicator Valve
C12 - Typical Sanitary Sewer Manhole
C13 - Inside Drop Manhole (Plan)
C13A - Inside Drop Manhole Elevation

M1 - Steam and Condensate Piping in Manhole - Insulation Installation Detail
M2 - Typical Pipe Slide Detail
M3 - Typical Pipe Guide Detail
M4 - Not used
M5 - Pipe Hanger Support
M6 - Single Pipe Support
M7 - Multiple Pipe Support
M8 - Not used
M9 - Not used
M10 - Valve Vault Vent Penetration
M11 - Dirt Leg and Steam Trap Detail, Low and Medium Pressure - Bldg Return
M12 - Not used
M13 - Not used
M14 - Wall Penetration for Underground Mechanical Services
M15 - Hot Pipe Penetration Detail
M16 - Not used
M17 - Not used
M18 - High Pressure Condensate Return Sparger

MH1 - Typical Manhole Layout Elevation - Steam
MH2 - Not used
MH3 - Typical Manhole Trap Assembly Detail
MH4 - Typical Manhole Vent Detail
MH5 - Typical Manhole Layout - Plan - Steam
MH6 - Typical Manhole Pumping Detail

END OF DOCUMENT
SECTION UNDER GRASS
OMIT TOP SOIL WHERE NO GRASS OCCURS. USE 6" GRAVEL

SECTION UNDER PAVEMENT
RESURFACING AS REQUIRED

TOPSOIL

12" COMPACTED GRAVEL BORROW

TRENCH WIDTH (3'-0" MIN.)

HALF OF TRENCH WIDTH

PIPE DIAMETER

SAND COMPACTED TO 95%

BEDDING MATERIAL (SEE CHART BELOW) COMPACTED TO 95%

COMPACTED BACKFILL (EXCAVATED MATERIAL AS SPECIFIED)

THOROUGHLY COMPACT WITH RAM OR PNEUMATIC TAMPER

UTILITY | BEDDING MATERIAL
---|---
STEAM/CONDENSATE | SAND
HOT WATER | SAND
CHILLED WATER | CRUSHED STONE
DOMESTIC WATER | SAND OR CRUSHED STONE
FIRE PROTECTION | SAND
STORM DRAIN | SCREENED GRAVEL OR CRUSHED STONE
SANITARY SEWER | BEDDING MATERIAL

TYPICAL PIPE TRENCH DETAIL
NOTE:
WEEPHOLES SHALL NOT BE PROVIDED IN AREAS OF CONTAMINATION OR HIGH GROUNDWATER.

PRECAST CONCRETE CATCH BASIN
NOTES:
1. REINFORCING STEEL TO BE INCLUDED AS REQUIRED TO SUIT PROJECT
2. DUCT SPACERS/SUPPORTS TO BE 4' ON CENTER TYPICAL

TYPICAL DUCTBANK
NOTE:
1. PRECAST CONCRETE STRUCTURE SHALL BE DESIGNED FOR HS-20
   LOADING.
2. ENTIRE EXTERIOR OF STRUCTURE SHALL BE COATED WITH BITUMINOUS
   DAMPPROOFING.
3. ELEVATIONS AND DIMENSIONS OF KNOCKOUTS VARY.
4. ALL DUCTBANKS SHALL BE GROUTED TO STRUCTURE.
5. UNDERGROUND STRUCTURE VOLUME IS DETERMINED BY NUMBER OF
   CIRCUITS PASSING THROUGH. CONFIRM SIZING WITH IS&T AND MIT
   UTILITIES.
PROVIDE BRICK COURSES TO RAISE FRAME AND COVER TO GRADE INSIDE SURFACE OF BRICKWORK SHALL BE PARGED

CEMENT MORTAR

32" COMPOSITE MANHOLE COVER WITH 1" SNIFTER HOLE

DASHED LINE INDICATES EXTERIOR MEMBRANE WATERPROOFING.

PULLING EYE

CABLE RACK (TYP)

SHIPLAP JOINT (TYP)

PITCH THE MANHOLE FLOOR 1/4" PER FOOT TO MANHOLE SUMP

12" OF 3/4" CRUSHED STONE

4" CONCRETE MUD MAT

12" DIAMETER BY 4" DEEP SUMP SLOPE FLOOR TO SUMP

COMPACTED UNDISTURBED EARTH

TYPICAL ELECTRICAL/TELECOMMUNICATION STRUCTURE
SECTION VIEW A-A

NTS

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C5A
32"Ø COMPOSITE MANHOLE COVER WITH 1" SNIFER HOLE

FINISHED GRADE

12" THICK WALLS (TYP.)

PROPOSED 5" PVC DUCTS CONCRETE ENCASED

DASHED LINE INDICATES EXTERIOR MEMBRANE WATERPROOFING.

KNOCKOUT (TYP.)

PITCH THE MANHOLE FLOOR 1/4" PER FOOT TO MANHOLE SUMP

12" DIAMETER BY 4" DEEP SUMP SLOPE FLOOR TO SUMP

12" OF 3/4" CRUSHED STONE

COMPACTED UNDISTURBED EARTH

4" CONCRETE MUD MAT

TYPICAL ELECTRICAL/TELECOMMUNICATION STRUCTURE
SECTION VIEW B-B

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NTS

C5B
SECTION UNDER GRASS
OMIT TOPSOIL WHERE NO GRASS OCCURS. USE 6" GRAVEL

SECTION UNDER PAVEMENT
4" TOPSOIL
12" GRAVEL SUBBASE
18"

UNDISTURBED EARTH
COMPACTED COMMON FILL

PROVIDE 3"
CABLE MARKING TAPE

14" MINIMUM

12"

COMPACTED BACKFILL
(Excavated material or common fill as specified)

TYPICAL DUCT BANK

6" MIN., IF ORGANIC SILT OR PEAT IS ENCOUNTERED AT PIPE SUBGRADE, AS DETERMINED BY THE ENGINEER, OVER EXCAVATE A MIN. OF 3' AND REPLACE WITH CRUSHED STONE. COMPACT CRUSHED STONE WITH MIN. 4 PASSES WITH VIBRATION PLATE COMPACTOR

CRUSHED STONE WRAPPED IN GEOTEXTILE FILTER FABRIC

GEOTEXTILE FILTER FABRIC

PROOF ROLL SUBGRADE SURFACE

THROUGHLY COMPACT WITH RAM OR PNEUMATIC TAMPER

4" THICK NEW PAVEMENT (2-1/2" BASE COURSE, 1-1/2" OVERLAY)

CUT AND MATCH EXISTING PAVEMENT AS REQUIRED

UNDISTURBED EXISTING PAVEMENT

TACK COAT EDGES WITH CUT BACK ASPHALT

TYPICAL UNIFORMED DUCT BANK TRENCH DETAIL

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C6
HYDRANT AND VALVE

- HYDRANT TO BE ADJUSTED TO GRADE AS REQUIRED, ROTATE AS NECESSARY
- FINISHED GRADE
- EDGE OF PAVEMENT OR CURB
- COVER Labeled "WATER"
- FLANGE
- ADJUSTABLE SLIDING VALVE BOX
- PROVIDE 4 CU. FT. OF CRUSHED STONE TO AT LEAST 6" ABOVE DRAIN HOLES
- CONCRETE BACKING AGAINST UNDISTURBED MATERIAL
- FLAT STONE OR CONCRETE BLOCK
- USE TWO 6" BENDS OR OFFSET ON LATERAL TO ACHIEVE REQUIRED HYDRANT ELEVATION IF NECESSARY
- 6" D.I. WATER MAIN
- DEPTH VARIES
- 3'-0" MIN.
- ANCHORING TEE
- 6" GATE VALVE

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C8
BLOW-OFF HYDRANT

MAINGUARD 4" 7600 BLOW-OFF HYDRANT

CONCRETE THRUST BLOCK

CRUSHED ROCK

GROUND LINE

METER BOX

5'-0" MIN

FROM P.I.V
POST INDICATOR VALVE
MUELLER A-20806
OR KENNEDY OR PRATT PER FM
APPROVAL GUIDE

FINISHED
GRADE

DEPTH
VARI
ES

LOWER
BARREL

BELL

PIV

RESTRAINING
JOINTS (TYP.)

WATERMAIN

CEMENT LINED
DUCTILE IRON
PIPE

POST INDICATOR VALVE

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C11
NOTES:
1. INNER EDGE OF BRICK TABLE TO BE AT ELEV OF CROWN OF TOP OF PIPE. TABLE TO SLOPE AT 1" PER 1' TO INSIDE OF MANHOLE BASE
2. TYPICAL SANITARY MANHOLE TO BE 4 FT. DIA.

USE BRICK COURSES AS NEEDED TO BRING MANHOLE RIM TO REQUIRED ELEVATION (MAX HEIGHT 10") SEAL INSIDE & OUTSIDE WITH HYDRAULIC CEMENT

STANDARD PRECAST CONE SECTION IN 2', 3' & 4' LENGTHS WITH FLAT OR CONICAL TOP
STANDARD PRECAST BARREL SECTION COMBINATIONS OF 1', 2', 3' OR 4' LENGTHS AS NEEDED TO BRING MANHOLE RIM TO REQUIRED ELEVATION

SEAL ALL JOINTS WITH HYDRAULIC CEMENT
STANDARD PRECAST BASE IN 3' LENGTH
FLEXIBLE MANHOLE SLEEVE (TYP.)

TYPICAL SANITARY SEWER MANHOLE

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INSIDE DROP MANHOLE (PLAN)

**PVC GRAVITY SEWER (SIZE VARIES) (TYP.)**

PLACE JOINT OR COUPLING WITHIN 3' OF WALL ON ALL PIPES

**BRICK INVERT**

INSIDE DROP CONNECTION STRAPPED TO MH WALL.

**WYE BRANCH**

FLOW

**POLYPROPYLENE COATED STEEL MANHOLE STEPS SAFETY TYPE**

**STANDARD MANHOLE FRAME & COVER**

**FLEXIBLE MANHOLE SLEEVE (TYP.)**

SHAPE SMOOTH ROUNDED INVERT FOR ALL SIDE ENTRANCE PIPES
NOTES:
1. DROP MANHOLES SHALL BE USED WHEN ENTRANCE PIPE INVERTS ARE 2' OR GREATER THAN MANHOLE INVERT.
NOTES:

1. PYROGEL XTE SHALL BE THE INSULATING MATERIAL FOR STEAM AND CONDENSATE PIPING EXCEPT AT HANGERS.
2. AT HANGERS USE HYDROUS CALCIUM SILICATE PIPE INSULATION: THERMO-12/GOLD MEETING ASTM C 533, TYPE1; RIGID MOLDED PIPE; ASBESTOS-FREE COLOR CODED THROUGHOUT MATERIAL THICKNESS. COMPRESSIVE STRENGTH: MINIMUM OF 100 PSI.
3. TIE WIRE: 16 GAGE (0.045mm) STAINLESS STEEL WITH TWISTED ENDS ON MAXIMUM 12 INCH (300mm) CENTERS.
4. ALUMINUM JACKET: 0.016 INCH (0.045 mm) THICK SHEET, (EMBOSSED) FINISH, WITH LONGITUDINAL SLIP JOINTS AND 2 INCH (50mm) LAPS, DIE SHAPED FITTING COVERS WITH FACTORY APPLIED MOISTURE BARRIER. STAINLESS STEEL BANDS MINIMUM EVERY 12” O.C.
TYPICAL PIPE SLIDE DETAIL

ANVIL FIG 436, TYPE 4 (GALVANIZED FOR EXTERIOR USE ONLY)

ANVIL FIG 436, TYPE 2 PTFE SLIDE BASE (GALVANIZED FOR EXTERIOR USE ONLY) BOLT TO STRUCTURAL FRAME

WELD TEE TO PIPE AND BOLT SLIDE BASE TO STRUCTURAL FRAME

SPECIFYING ENGINEER TO INDICATE ADEQUATE CLEARANCE

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ANVIL FIG 439, TYPE 3
(GALVANIZED FOR EXTERIOR USE ONLY)

ANVIL FIG 439, TYPE 3
PTFE HOLD DOWN SLIDE
BASE (GALVANIZED FOR EXTERIOR USE ONLY)
BOLT TO STRUCTURAL FRAME

SPECIFYING ENGINEER TO INDICATE ADEQUATE CLEARANCE

TYPICAL PIPE GUIDE DETAIL
HEAVY DUTY CLEVIS HANGER  
(FOR 1/2" UP TO & INCL. 3" PIPE)  
ANVIL FIG 300

ADJUSTABLE HANGER WITH ROLLER  
(FOR 4" TO 6" PIPE)  
ANVIL FIG 181

SUPPORT NUT

GALVANIZED INSULATION SHIELD  
ANVIL FIG 167

MIN. 9 lb/cft DENSITY RIGID INSULATION AT SHIELD

LOCKING NUT

INSULATION

PIPE

PIPE COVERING PROTECTION SADDLE  
(SEE NOTE 3)

NOTES:
1. SPECIFYING ENGINEER TO PROVIDE SPECIFICATIONS FOR HANGER SIZES.
2. PIPE 8" AND LARGER SHALL HAVE ROLLER SUPPORTED WITH DUAL RODS.
3. ANVIL FIG 160 – 166A. (BASE ON INSULATION THICKNESS.)

PIPE HANGER SUPPORT  

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M5
NOTES:
1. SPECIFYING ENGINEER TO PROVIDE DETAIL FOR INSULATION SYSTEM AT POINT OF SUPPORT.
2. ROLLER ASSEMBLY MAY BE FLOOR SUPPORTED USING ADJUSTABLE PIPE ROLL STAND (MSS SP–69 TYPE 46) OR APPROVED EQUAL. ANVIL FIG 177.
NOTES:
1. SPECIFYING ENGINEER TO PROVIDE DETAIL FOR INSULATION SYSTEM AT POINT OF SUPPORT.
2. ROLLER ASSEMBLY MAY BE FLOOR SUPPORTED USING ADJUSTABLE PIPE. ROLL STAND (MSS SP–69 TYPE 46) OR APPROVED EQUAL.
DIRT LEG AND STEAM TRAP DETAIL
LOW & MEDIUM PRESSURE - BLDG RETURN

NOTES:
1. SPECIFYING ENGINEER TO INDICATE DIMENSIONS a & b.
2. TRAPS ARE NOT TO BE INSULATED.
WALL PENETRATION FOR UNDERGROUND MECHANICAL SERVICES

WALL SLEEVE W/LEAK PLATE BY LINK SEAL
SERVICE PIPE OR CONDUIT

WATERPROOF SEALANT

INTERIOR

EXTERIOR

3"

3"

THUNDERLINE LINK SEAL (TYP.) PROVIDE 2 PER PENETRATION (ONLY ONE SHOWN FOR CLARITY)

WALL

CONTINUOUSLY WELDED
SPECIFYING ENGINEER TO INDICATE SUFFICIENT DISTANCE FROM ANY WALL OR STRUCTURE

HOT PIPE

SEALANT

STAINLESS STEEL CLAMPING RING

10 GA. STAINLESS STEEL HOOD, WATERTIGHT WELDED CONSTRUCTION

10 GA. SHEET METAL COLLAR WELDED CONSTRUCTION

ROOF MEMBRANE

INSULATION

ROOF STRUCTURE

1'-0" MIN.
6" MIN.

HOT PIPE PENETRATION DETAIL

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M15
NOTE: PROVIDE A 6" SECTION OF FLEXIBLE BRAIDED METAL HOSE, SUITABLE FOR THE SYSTEM OPERATING PRESSURE AND TEMPERATURE, DIRECTLY BEFORE THE PIPING CONNECTION AT THE FLASH ARRESTOR.

SIDE ELEVATION

PERFORATED PIPE

1"X1/2" THICK GUIDE FINS WELDED TO PERFORATED PIPE (TYP. FOR 3)

3/4" PIPE W/ 78 – 1/8" DIAMETER HOLES SPACED EQUALLY AROUND PERIMETER. 6 ROWS @ 1 – 1/8" ON CENTERS.

SECTION 'A'

HIGH PRESSURE CONDENSATE RETURN SPARGER

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M-18
APPLY AN APPROVED SILICON SEALER BETWEEN THE MANHOLE FRAME AND ROOF CONCRETE.

INSTALL VALVE BOX COVERS DIRECTLY OVER ISOLATION VALVE FOR ALL STEAM VALVE OPERATION. VALVE BOXES ARE TO TERMINATE AT GRADE AND HAVE "STEAM" CAST IN EACH COVER.

INSTALL NEW STEAM AND CONDENSATE PIPING SYSTEM CONDUITS WITH A WALL SLEEVE AND LINK SEAL. FILL THE VOID WITH A MIT APPROVED SILICONE SEALER. SEE MIT DETAIL M-14.

ALL STEAM ISOLATION VALVES 3" AND ABOVE ARE TO BE INSTALLED WITH A 2-1/2" WARM-UP LINE WITH A CLASS 800 GATE VALVE.

300# CLASS TRIPLE OFFSET BUTTERFLY VALVE WITH BUTT WELD ENDS, "ADAMS MAK" OR MIT APPROVED EQUAL.

ALL PIPING WITHIN THE MANHOLE IS TO BE INSULATED WITH WATERPROOF AEROGEL INSULATION.

2" FREE BLOW LINE

INSTALL A DRIP LEG WITH TRAP ASSEMBLY EACH SIDE OF THE MAIN SHUT OFF VALVE.

THE MANHOLE FLOOR IS TO BE PITCH 1/4" PER FT. TO THE SUMP.

ANCHOR STEEL IS TO BE SIZED TO SUIT STEAM PIPING LOAD, THERMAL AND STRESS ANALYSIS. ALSO THE STEEL IS TO BE GALVANIZED OR COATED WITH AN MIT APPROVED GAVANIZING COMPOUND.

LOW POINT SUMP WITH DRAIN TO PUMPING MANHOLE 12" DEEP MIN.

LOCATE THE 2" FREE BLOW BELOW MANHOLE COVER OPENING AND ABOVE THE SUMP TO PERMIT SURFACE OPERATION.

TYPICAL STEAM MANHOLE LAYOUT ELEVATION

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MH1
TYPICAL TRAP ASSEMBLY DETAIL
MANHOLES

2" WELDOLET (TYP)

SEE "TYPICAL STEAM TRAP DRIP LEG DETAIL" DRAWING MH11

3'-0" MINIMUM

2" FREEBLOW TO MANHOLE SUMP

INSTALL THE TRAP INLET 3'-0" MINIMUM FROM THE CENTERLINE AND BELOW THE DRIP LEG.

WHEN THE TRAP ASSEMBLY IS LOCATED IN A MANHOLE, THE FREE BLOW DISCHARGE VALVE MUST BE LOCATED AT AN OPENING WHERE THE VALVE CAN BE OPERATED FROM THE MANHOLE SURFACE.

TIE 3/4" TRAP LINE INTO NEAREST RETURN HEADER.

3/4"

3/4" CLASS 800, FORGED STEEL BW, INSIDE SCREW GATE VALVE (TYP)

3/4" CLASS 800FS, SW LIFT CHECK (TYP)

1/4" TEST TEE WITH 600LB. GATE VALE (TYP)

3/4" CLASS 300, BUCKET TYPE TRAP (TYP) (ARMSTRONG 310)

3/4" FS, 600LB, SW Y-TYPE STRAINER (TYP)

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MENTS

MH3
NOTE:
1. VENTS ARE TO BE LOCATED IF POSSIBLE NEAR A BUILDING WALL AND AWAY FROM OPEN WINDOWS OR INTAKE VENTS.
2. REFER TO MIT DRAWING M-10 FOR VAULT WALL PENETRATIONS.

TYPICAL MANHOLE VENT DETAIL

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MH4
GALVANIZED LADDER ATTACHED WITH STAINLESS STEEL ANCHOR BOLTS.

APPLY BITUTHENE PREPRUFE 3000 WATERPROOFING OR MIT APPROVED EQUAL.

18"x18"x12" DEEP SUMP.

LINK SEAL ASSEMBLY (TYP) (SEE MIT DWG. M-10)

SLOPE THE MANHOLE FLOOR TO THE SUMP

4" SCH. 40 C.S. VENT 3'-0" MIN CLEARANCE (TYP)

3'-0" E.L. FIBRELIKE FRAME & COVER MODEL #F75 WITH (2) 3/4" HOLES DRILLED @180°. THE COVER IS TO HAVE "MIT STEAM" AND THE MANHOLE NUMBER ON THE TOP. (TYP)

TYPICAL MANHOLE LAYOUT - PLAN STEAM

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MH5
CONCRETE ENCASED ELECTRICAL CONDUIT

WATERTIGHT SEAL

WATERTIGHT JUNCTION BOX SEE "SUMP PUMP POWER SUPPLY DETAIL" DRAWING MH7.

PLUG IN TYPE OUTLET WITH WATER RESISTANT TWISTLOCK

ELECTRICAL CORD

18"x18"x12" DEEP SUMP

DRESSER COUPLING

1 1/2" COPPER REDUCER
1 1/2" COPPER ELBOW
1 1/2" COPPER CHECK VALVE
1 1/2" COPPER UNION
1 1/2" TYPE L COPPER TUBING

48" I.D. REINFORCED CONCRETE DRAIN PIPE

LITTLE GIANT SUBMERSIBLE PUMP HIGH TEMPERATURE MODEL NO. HT-10E-CIM

6" COMPACTED 3/4" CRUSHED STONE WRAPPED IN FILTER FABRIC

FIN. GRADE