Project 3.5

Aggregated Load Shedding

Task 3.5.4

Field Test of Operator-Initiated Load Shedding in Aggregates of Buildings

Deliverable 3.5.4

Report Documenting Field Test

Submitted to Architectural Energy Corporation

Under the

California Energy Commission's

Public Interest Energy Research (PIER) Program

Energy-Efficient and Affordable

Small Commercial and Residential Buildings

California Energy Commission Contract 400-99-011

P. R. Armstrong and L.K. Norford
Massachusetts Institute of Technology
August 2, 2002

Report on Load Shedding Tests and Other Recent Project Activity in LA County Buildings

Abstract

Manual load shedding was performed on 25 June 2002 in the Edmund Edelman Children's Court (EECC) and Internal Services Department (ISD) Building of Los Angeles County. A recently proposed load shedding protocol [Haves] provides a number of load shedding scenarios. All scenarios require heat to be completely shut off. The ideal method of cooling plant modulation is to raise all zone setpoints gradually by the same amount. The practical approximation given by Haves is to raise all setpoints abruptly by the same amount. This will cause chillers to shut down for 30-60 minutes in most buildings. Since the L.A. test building control systems do not provide a way to raise zone setpoints simultaneously, we simply shut down the chillers. We had two motivations, besides expedience, for taking this approach:

1) a system's responses to *step changes* contain the most information[1], and

2) in mild conditions (<50% chiller capacity) the largest possible excitation (step change to zero capacity) is needed to obtain a strong thermal response.

Test results show that by allowing zone temperatures to rise 3-5˚F in one hour, it is possible to shed 250-330 kW (1.2-3.5 W/sf) in equipment loads (chiller, pumps, and tower fan). In addition to the potential for load shedding, there are indications that more efficient operation can be achieved by using a plant control strategy that accounts more accurately for fan, coil, chiller and cooling tower performance characteristics. The relation between zone temperatures and return-air temperature—needed to economically implement automatic load shedding—has been explored in anticipation of developing empirical models.

Logger configuration data and detailed building characteristics data are reported in the appendices.

Description of Test Buildings and Instrumentation

The Children's Court is a 275 ksf structure built in 1992 with perimeter baseboard heating and a single variable air volume system to provide fresh air and cooling. The plant comprises three boilers, two water heaters, and two centrifugal chillers. Two non-intrusive load

[1] The thermal responses to step changes in each input (indoor and outdoor temperatures, solar radiation incident on each building surface orientation, infiltration loads, internal gains, heating and cooling inputs) are sufficient to completely determine a system model...provided the system is linear and time-invariant (LTI). A reasonably accurate system model is key to many load-shedding and energy efficient control strategies including pre-cooling and optimal plant operation.

monitors (NILMs) have been installed, one at the service entrance and one at the VAV/chiller motor control panel (MCP). Thermal instrumentation includes temperature and humidity of return-, mixed- and supply-air. Fan inlet pressure taps have been installed to measure flow rate but the pressure transducers are not yet on line. The NILMs log continuously at 12Hz; thermal parameters are averaged over 1-minute intervals.

The ISD Building is a 70 ksf structure built in 1973 with a constant volume dual duct HVAC system. The plant consists of two boilers and two four-stage reciprocating chillers. Two NILMs have been installed, one at the service entrance and one at the central fan/chiller motor control panel. Thermal instrumentation includes temperature and humidity of return-, mixed-, hot-deck and cold-deck air. Fan inlet pressure taps measure flow rates at the supply and return fans while thermal anemometers measure "mass velocity" (labeled "rhoV" in the plots) to determine the damper-controlled division of supply air between hot- and cold-decks.

Children's Court Operation Under Existing Control Parameters

Consider first the typical weekday of operation (18 June) illustrated[2] in Figure 1. Fans are scheduled to start at 6:00 am. Children's Court internal loads are sufficient, even with the cool nights of Los Angeles, to keep most of the zone temperatures above their cooling set-points all night. Chillers thus start at the same time as the fans on most summer mornings as shown in Figure 1. With the chiller operating initially at part capacity, the capacity of one cooling tower is excessive even with the tower fan at low speed. The fan therefore cycles many times in the first few hours while the building cooling load remains low and fairly constant. A moving average of the tower fan load is presented in Figure 1 for clarity; Figure 2 shows the cycling at maximum (one record per minute) logger resolution. The cooling load begins to rise in earnest at 8:30 am and the tower fan cycling stops shortly after 9:00 am. The load continues to rise until 11:00 am. At ~12:50 the hot water pump shuts off. Probably the last of any zones calling for heat was satisfied at this time; future confirmation may be possible by collecting selected trend logs from the Trane Tracer BAS.

The VAV fan behavior during morning startup is also of interest. The fans ramp up quickly to their programmed maximum in order to cool the many zones with temperatures at or above the daytime setpoint. Note that it is night setup (absence of chiller operation), not necessarily the presence of substantial cooling load, that results in so many "T > setpoint" zone conditions. In fact, cooling loads *are* quite small at 6:00 am, so the initial temperature recovery in zones *is* fast, as indicated in Figure 1 by the rapid drop in return air temperature.

Total flow soon begins to drop as some zone comfort conditions are satisfied and their VAV boxes close. However it is not long before temperature recovery slows as heat release from deep mass comes into play. About the same time, internal and solar loads begin to increase, especially in zones with east- and, to some extent, north-facing windows. Then, as the sun moves south, east-facing windows on the north wing are progressively shaded and, during the same time frame, the deep mass load begins to taper off. Total building load therefore reaches a second local minimum at about 8:00 am. From this point, the total cooling load rises with internal gains, outdoor temperature, and solar (roof, as well as exposed window and wall) loads; the resulting aggregate load is reflected in rising fan and chiller loading.

---

[2] HVAC equipment loads are presented as phase-A amps, rather than Watts, in order to make the plots more readable; it just happens that numerical magnitudes are of the same order as the Fahrenheit temperatures.

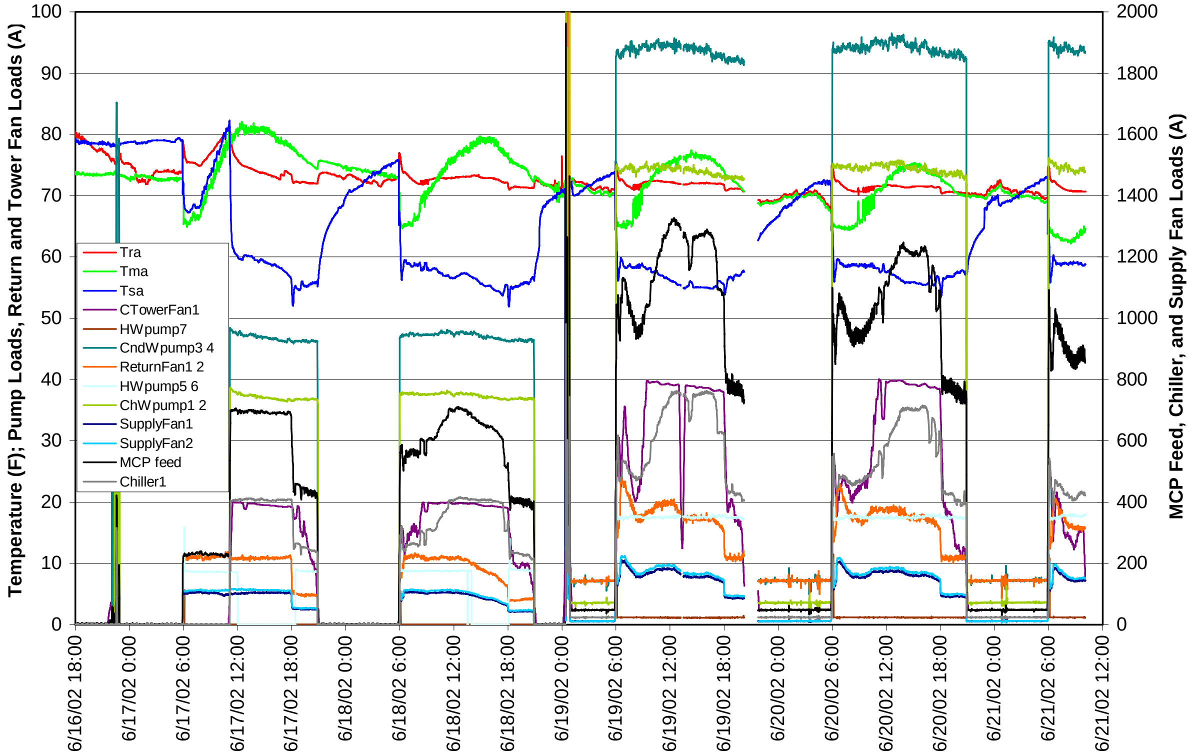

Figure 1. EECC Equipment loads and thermal response 17-21 June

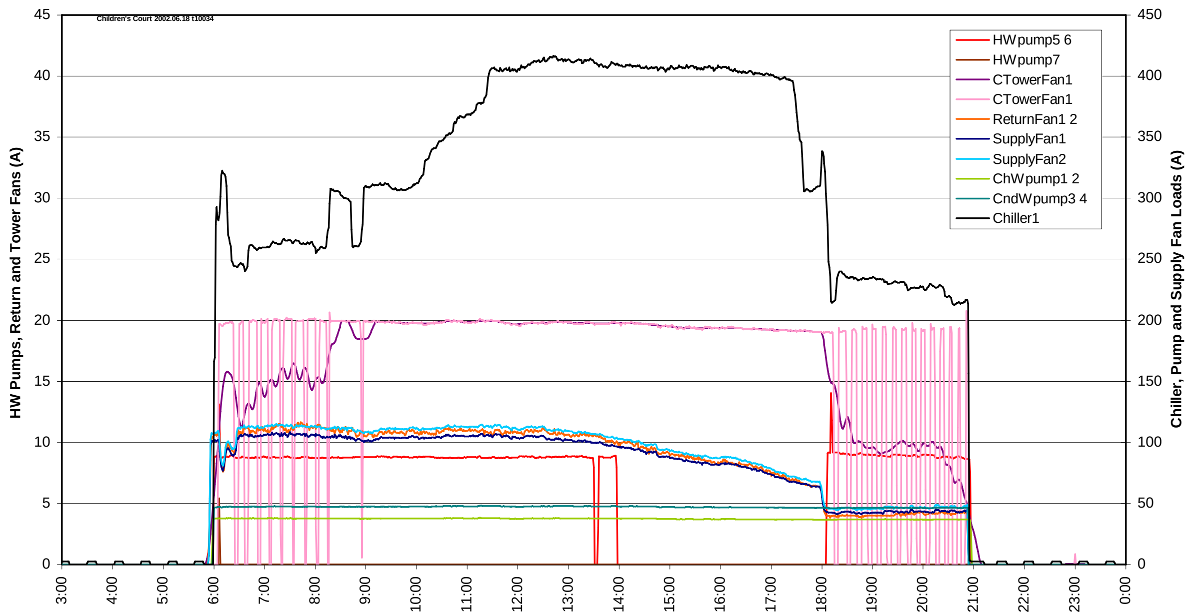

Figure 2. 1- and 15-minute MA tower fan load and related equipment loads, 18 June

It is interesting that supply air temperature drops through most of the day starting even before the cooling tower cycling ends. It appears that supply air temperature control is based on outdoor temperature, as a surrogate for building cooling load, and the VAV system flow rate starts to drop before noon indicating that building mass has stopped releasing heat. Supply temperature should level out or begin to rise at this point. Since it doesn't, the chiller must continue to work hard all afternoon.

Modulation of the two-speed tower can only be achieved by cycling, putting stress on the fan, motor and belts. Cycling can be reduced by widening the deadband for the cooling tower return temperature at which the tower fan switches between low- and high-speed operation. Optimal efficiency is generally obtained when fan, pump, and chiller powers rise and fall together. Because this is often not the case at EECC, it appears that significant improvements could be made in plant operation, i.e. in optimizing the conjoint fan, tower and chiller operating map.

At least one zone is again calling for heat beginning at about 4:10 pm and this results in operation of pump 7 recommencing but no noticeable increase in chiller load. (Further tests to establish the impacts of simultaneous heating and cooling are yet to be devised.)

Figure 3 shows the loads and temperatures through a sequence three days' operation beginning Sunday 23 June. The fans do not normally operate on Sundays; nevertheless, based on the time histories of supply, mixed and return temperatures (T_{sa}, T_{ma}, T_{ra}) we can surmise the following. As long as the average building interior temperature is below outdoors, return airflow is reversed by buoyancy induced circulation (down the return air shaft) and the mixed and return air temperatures track. However, by Sunday night the building interior is quite warm resulting in upward flow to, and exhaust at, the roof; the return air plenum temperature rises abruptly at this point. Early morning local circulation in the intake plenum appears to entrain enough outside air to keep the mixed air plenum temperature somewhere between the return and outdoor temperatures. The drop in mixed air temperature when fans start indicates that outdoor temperature is substantially lower.

The supply air plenum is isolated from the upstream (coil, filter, fresh air intake, and exhaust) plenums by a set of dampers at the supply fan discharge point that only open when the fan is on. The data show that the penthouse roof is sufficiently insulated, and the supply-air

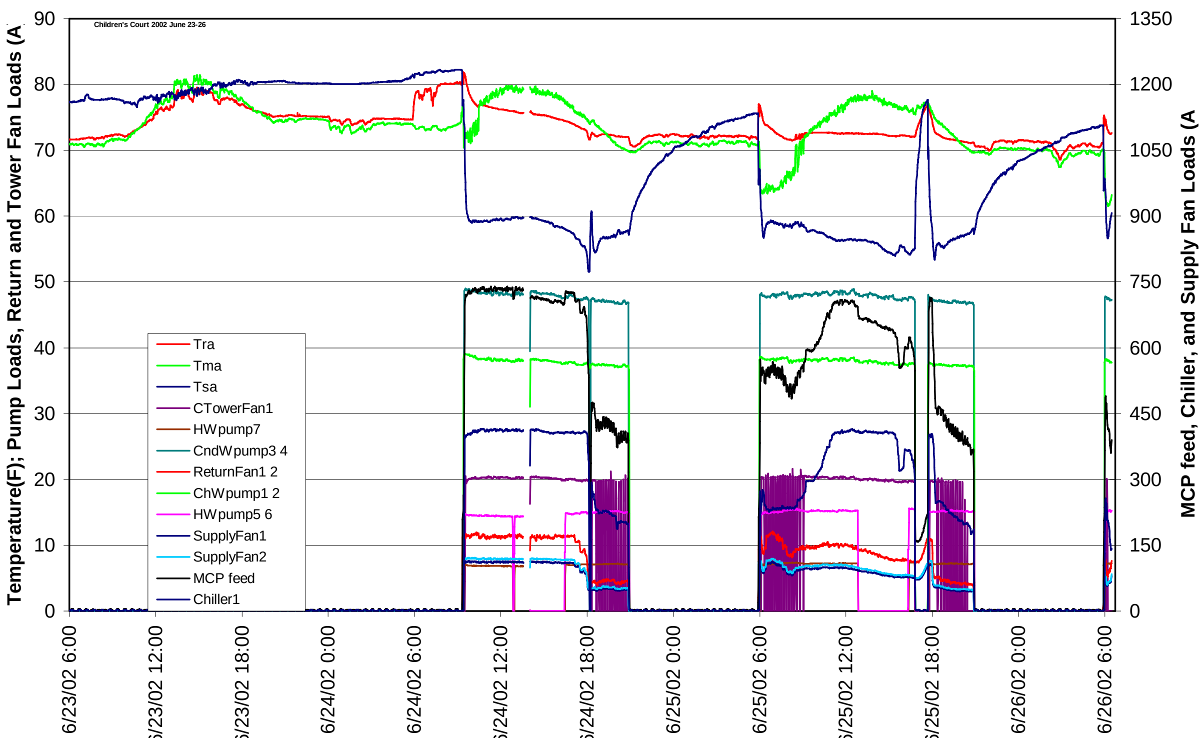

Figure 3. Children's Court Equipment loads and thermal response 23-26 June

plenum floor sufficiently massive, to almost completely attenuate *diurnal* skin loads (outdoor temperature swing and solar loads). The supply air plenum temperature *gradually* ramps up because weekend average sol-air temperature is well above the initial plenum temperature.

Referring again to Figure 1, on the morning of 17 June supply and return fans start at 6:00 am, as usual, but the chiller had been accidentally disabled and do not start until 11:00 am. We see a steady 75°F return air for 3 hours followed by a rapid rise to 83°F in the next 2.5 hours. Room temperature loggers were not deployed at the time of these observations; the fan-start-without-chiller test may therefore be repeated on a Saturday during the next site visit in order to obtain simultaneous room temperature data.

ISD Building Operation Under Existing Control Parameters

Equipment loads and temperatures from Sunday 23 June through Wednesday 26 June are plotted in Figure 4. Fans are currently operated 5:30 am to 5:30 pm Weekdays and left off Saturday-Sunday. There is, however, evidence of substantial passive flow through the building, largely via its air distribution system[3]. The hot deck coil seems to play an important role in the unintended airflows. The hot deck temperature is 4-8˚F above the return, mixed, and cold deck temperatures throughout the weekend. The hot water pumps are off but the boilers are hot all weekend. It is apparent, then, that both hot water and air are circulating by free convection thus adding uncontrolled heat to the building at a relatively steady rate all weekend. On the next site visit we will valve off the hot deck coil one day and compare boiler gas consumption on the two weekend days. On weekday nights, all air distribution temperatures are generally lower, but the hot deck temperature still stays 1-7˚F above the other temperatures. The nighttime average indoor-outdoor temperature difference is less during the week because the building is cooled down each day. The overall buoyancy-induced airflow in the building is therefore probably less than on weekends.

The temperature trajectories and staging of chillers and cooling tower fans provide a number of insights into weekday operation of the building. A very simple model would have air return at the cooling setpoint—which would be uniform across all zones. In reality, even in quasi-steady operation, return air temperature is a weighted average of zone temperatures and zone loads where the weights are determined by zone airflows. With proportional control (common in this vintage and many current buildings), zone temperature deviates from zone setpoint in proportion to zone load. Return air temperature therefore fluctuates and can tell us a good deal about thermal loads and how the HVAC system responds to them. Note that while the fans start at 5:30 am, the chillers are locked out until 6:00 am on weekdays. June 24 sees considerable initial load after the long period of weekend setup (in marked contrast to the March situation[4] when chillers remained off until about mid day). The cooling tower cycles to high a number of times. However, the cooling load from internal gains and envelope loads is moderate so the chillers do not progress to high capacity operation until mid-afternoon (2:30-4:00 pm). Low capacity operation is not quite sufficient to maintain building temperature. Return and cold deck temperatures gradually rise throughout the day and the tower fan begins cycling to high speed with increasing duty fraction from noon to 2:30 pm.

---

[3] From Les Norford's briefing notes for the April 15, 2002, CEC Contractors meeting: "...a characteristic diurnal RH cycle that appears to stem from some unintended natural ventilation. Cold, high RH air is drawn by the chimney effect through a leaky or open OA damper and up through the building via, mainly, the supply and return air duct networks. Further evidence is seen in the fan inlet pressures which show a small but systematic diurnal cycle. Note that air is being drawn backwards through the return fan at night."

[4] ibid.

When the chiller goes to high capacity, cold-deck temperature drops substantially, the zone temperatures respond by a (roughly 1st order) mixed exponential response reflected in the return-air temperature trajectory, and the tower fan goes to and remains at high speed.

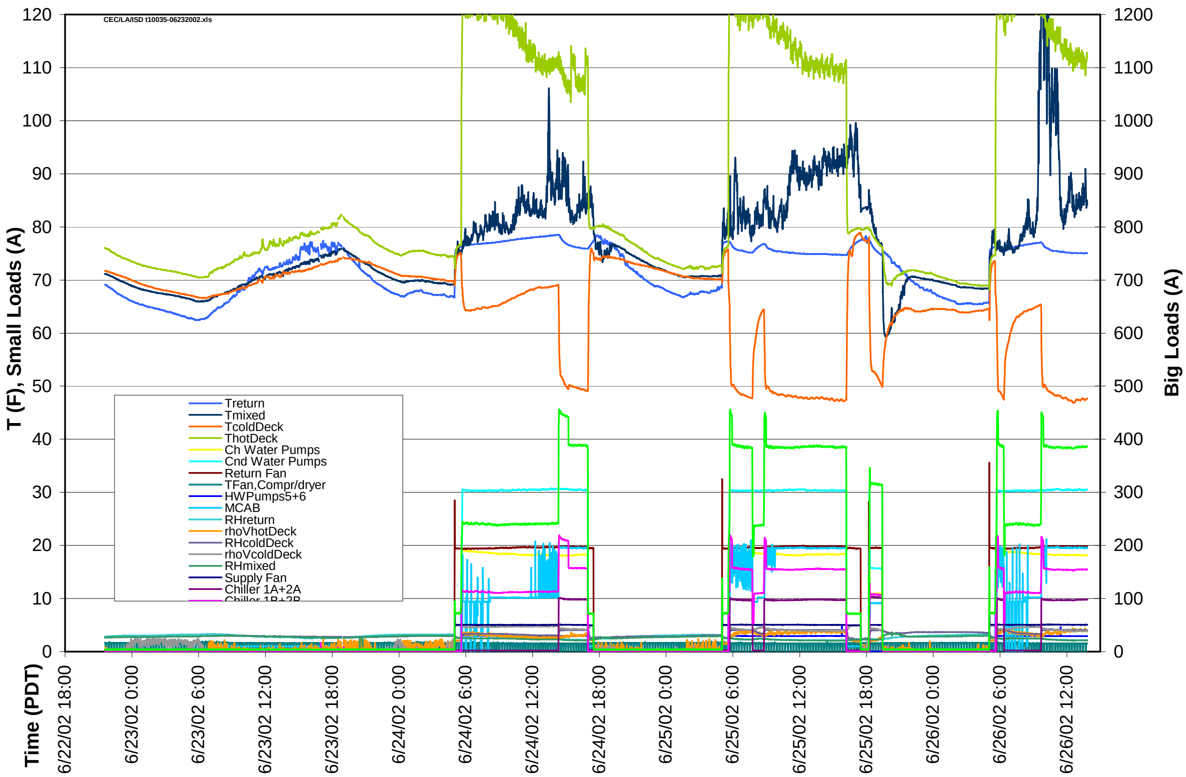

Figure 4. ISD equipment loads and thermal response

The NILM can play a particularly useful and economic role in detecting such control faults. The signal from a current transducer mounted on just one phase of the motor control center feed is monitored by the NILM as shown in Figure 5. The signals monitored by conventional end-use metering (7 current transformers just for the A-phase signals, some of which represent multiple loads or stages) are also shown in the plot. The NILM can identify loads by the size of each step change and by the shape, in 8-dimensional complex harmonic space, of each start transient. The exact time of each start and stop is recorded and the nature of cycling loads is thus completely observed. The NILM also notes transients that do not fit known loads. This can lead to identification of the many kinds of faults that change the shape of a start transient. Regarding the control faults mentioned previously, it is clear that the chiller staging is incorrect because the observed transient at 14:20 corresponds to the nearly simultaneous turning on of three additional compressors [Apr 2001 V-section training report] instead of turning on one compressor at a time as justified by a continued rise in the building total cooling load. The control-induced tower fan cycling is precisely recorded by the NILM and, with the addition of a modestly sophisticated cycling diagnostics algorithm [Luo 2001], would be identified as a fault.

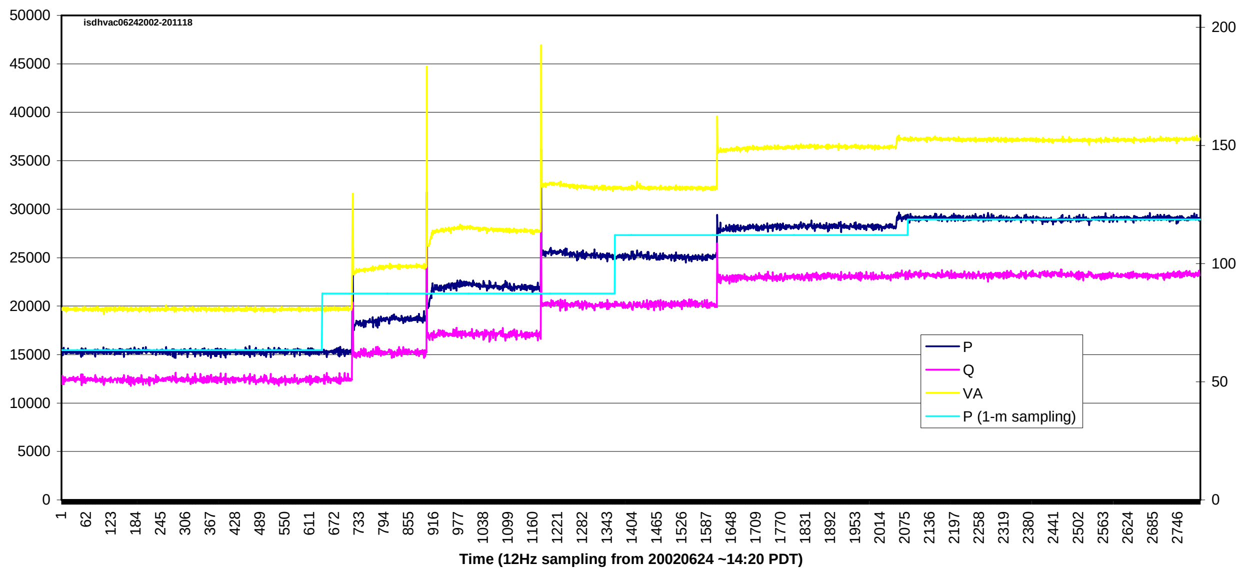

Figure 5. Faulty chiller loading sequence as recorded by the NILM (12Hz sampling) and the end-use logger (1-minute sampling)

On Tuesday the initial mean zone temperature is a bit higher than on Monday and the chillers start at high capacity and remain there until almost 8:00 am during which time return air temperature falls monotonically. The chiller backs off to low capacity for over an hour, then returns, at ~9:00 am, to high capacity until late afternoon when it was decided that conditions were right for performance of a load shed test.

Finally, consider the behavior of deck temperatures and flow rates shown in Figure 6. A well designed and operated dual-deck CV system is thermally inefficient at best, but the perverse beauty is that it will usually continue to provide excellent zone control even when its deck temperature controls are broken or badly tuned—often at the expense of much greater energy waste. ISD is a good, albeit by no means extreme, example. First, some notes on sensor limitations. The thermal anemometers give a positive signal (labeled *rhoV*[5]) regardless of flow direction and are therefore not entirely reliable data sources when the fans are off. However, they do qualitatively confirm the passive flow behaviors postulated earlier on the basis of temperature data. The boilers have on-off, rather than modulating, burner controls. A moving average filter has therefore been applied to the burner duty cycle data (relays connected 24 June) in order to provide a clearer picture of boiler loads. Cycling is still very evident under light (fans off) load but it is clear that the average boiler load is markedly higher Sunday night than Monday night, confirming again the passive flow hypothesis.

The disturbing thing about the boiler load is that it is increasing, rather than decreasing with increasing cooling load. Also note the fluctuations, indicative of damper hunting, in hot-deck flow rate. These are undesirable behaviors that a good fault detection system should be able to identify.

---

[5]For a given medium (air in this case) the signal is related, via $Nu = kRe^n$, to the ρV term in Re, which is always taken as positive [Armstrong 1985]. Thermal anemometry thus measures “mass velocity” (sfpm) not actual velocity (afpm); the former is often the more useful.

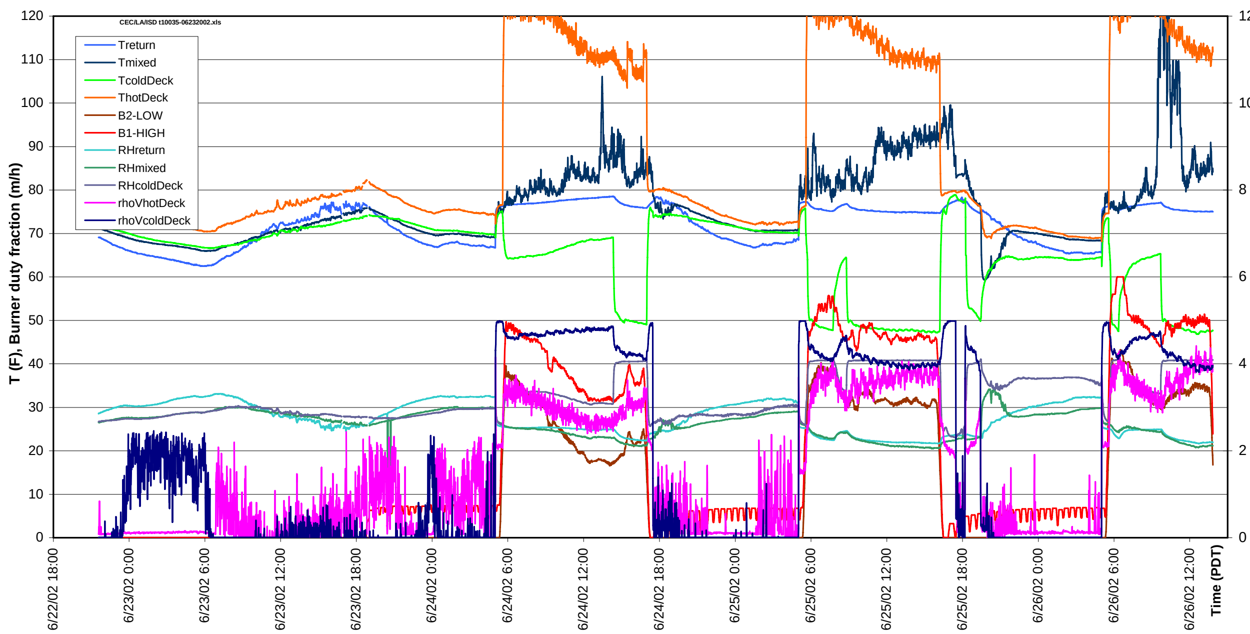

Figure 6. ISD boiler loads and hot- and cold-deck flow rates and temperatures

Load-Shedding Protocol and Instrumentation

The most extreme action given by the Haves-Smothers protocol is by no means the most extreme electric load shedding scenario possible nor does it represent the most extreme thermal excitation possible. Rather, the protocol aims to provide significant load reduction with modest comfort impact over short (1- to 4-hour) time frames. In the case of EECC, the test was implemented by disabling HVAC equipment in the sequence indicated below:

1) supply fan speed frozen at current setting (32Hz)

2) return fan speed frozen at current setting (25Hz)

3) hot water pumps to OFF

4) chilled water pumps to OFF

5) chiller and tower pumps and fans turn off automatically after step 4.

Zone temperatures were measured by micro-loggers in the following EECC locations:

Floor	Wing	Side	Dept.	Room	Serial No	Comment
G	N	core		0101	332630	sheriff (reception and open office)
L	N	core			495205	large open office
2	N	W		2700	495199	large open office near phone closet T2N4
2	E	N			332268	large private office (Jo Schiff)
3	E	core	406		332633	court room converted to arts & crafts
3	N	core		3511	522461	
4	E	S		400C	522645	four-person office (Angela Smith)
4	N	core	417		522637	courtroom
5	E	core	421		522640	courtroom (Judge John L.Henning)
5	C	S		hall	522638	on T-stat near copy machine & stairwell
5	N	core		424	332631	courtroom
6	N				522643	three-person office and reception (Lisa Romero/Ann Fragraso)

EECC Load-Shedding Test Results

The 25 June test was effected by simply turning off the chilled-water and hot-water pumps. The chiller (immediately) and cooling tower (within one minute) then shut down automatically. The averages of temperatures shown in Figure 7 were 72.05˚F for zones and 72.16˚F for return air; both were very steady (standard deviation <0.1˚F) over the 100 minutes preceding the test. It is not surprising that the return air is warmer than the average temperature across zones because return air is taken from the ceiling level and usually picks up some heat from ceiling lights as it leaves a room. Both temperatures begin to rise almost from the instant—indicated by the 400A (330kVA) drop in MCP load at 16:48—that the plant was shut down. Both rise along similarly shaped trajectories after the chiller stops but the return air temperature rises more rapidly. This, too, is not surprising because the zone temperature sensors were placed on file or desktop cabinets or on wall thermostats where the proximate slower responding surface temperatures affect the measurements by radiant coupling. The zone sensors are indicating something close to "operative temperature" defined [ASHRAE 2001] as the average of air temperature and mean radiant temperature (MRT). The zone average and return air temperatures after 53 minutes without cooling were 74.65 and 76.89˚F. When the chiller is turned back on, the air temperature again responds more quickly than the zone sensors and we see that it approaches within 0.1˚F of the pre-test temperature 50 minutes later. At this point the return temperature is 0.8˚F below the sluggishly responding average zone temperature. As is expected, zone air temperature drops below the pre-test value after the chiller is restarted to compensate for the higher MRTs perceived by zone thermostats.

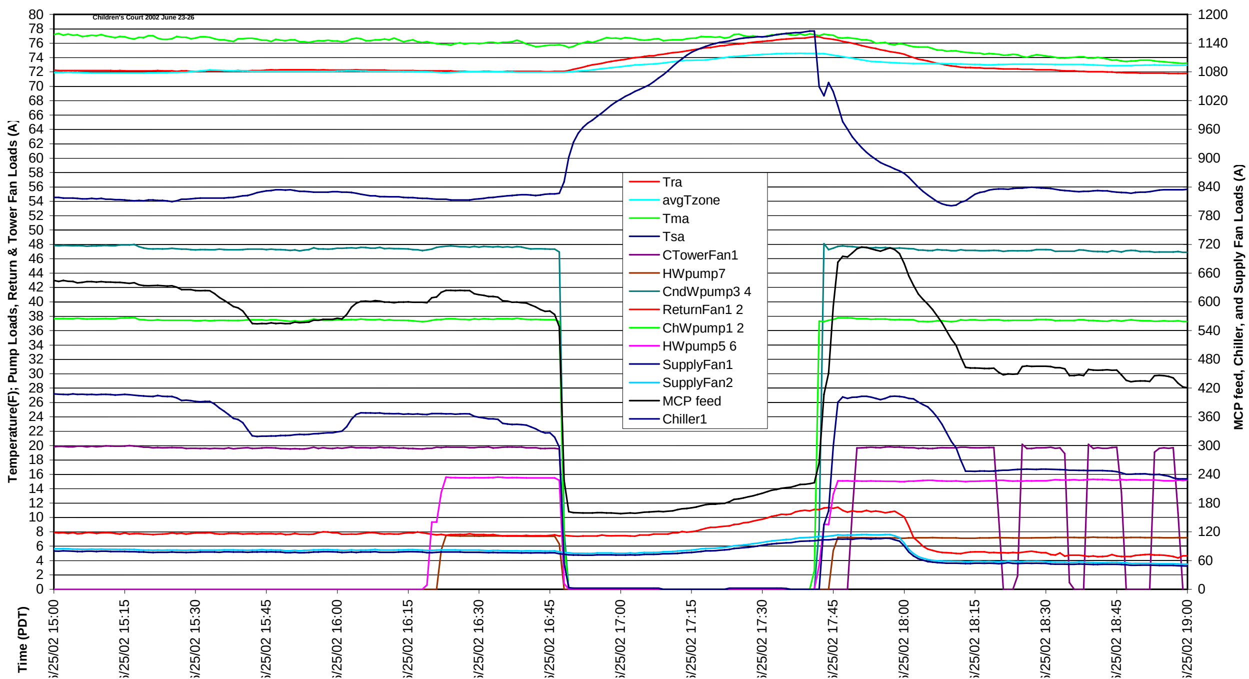

Figure 7. Children's Court load shedding test with fan speed under static pressure control

ISD Load-Shedding Test Results

ISD cooling equipment was shut down, as at EECC, by turning off hot and chilled water pumps. The chiller and cooling tower shut down automatically. Prior to shut down, return air and average zone temperatures were 74.8 and 72.0 ±0.1°F. The higher return air temperature may be partly caused by air leaking from the hot deck. This hypothesis will be tested on the next site visit. Also note in Figure 8 that the return air temperature is less responsive to the step change than the average zone temperature. Supply duct leaks could only account for this if they were on the order of 50% of supplied air; leakage and other possible causes must be further investigated. Note that over half the total building load (250kVA) was cut during the test. A further 12% was cut when the fans were shut off at 5:30 pm. Average zone temperature rose 5.5°F in the first 40 minutes (fans on) and 0.5°F in the next 40 minutes (fans off). Zone temperature responds quickly after the test, in part because the hot deck was not restored until much later; return air temperature responds slowly. It is not clear why, with the large zone temperature rise, the chillers did not return to high capacity at the end of the test.

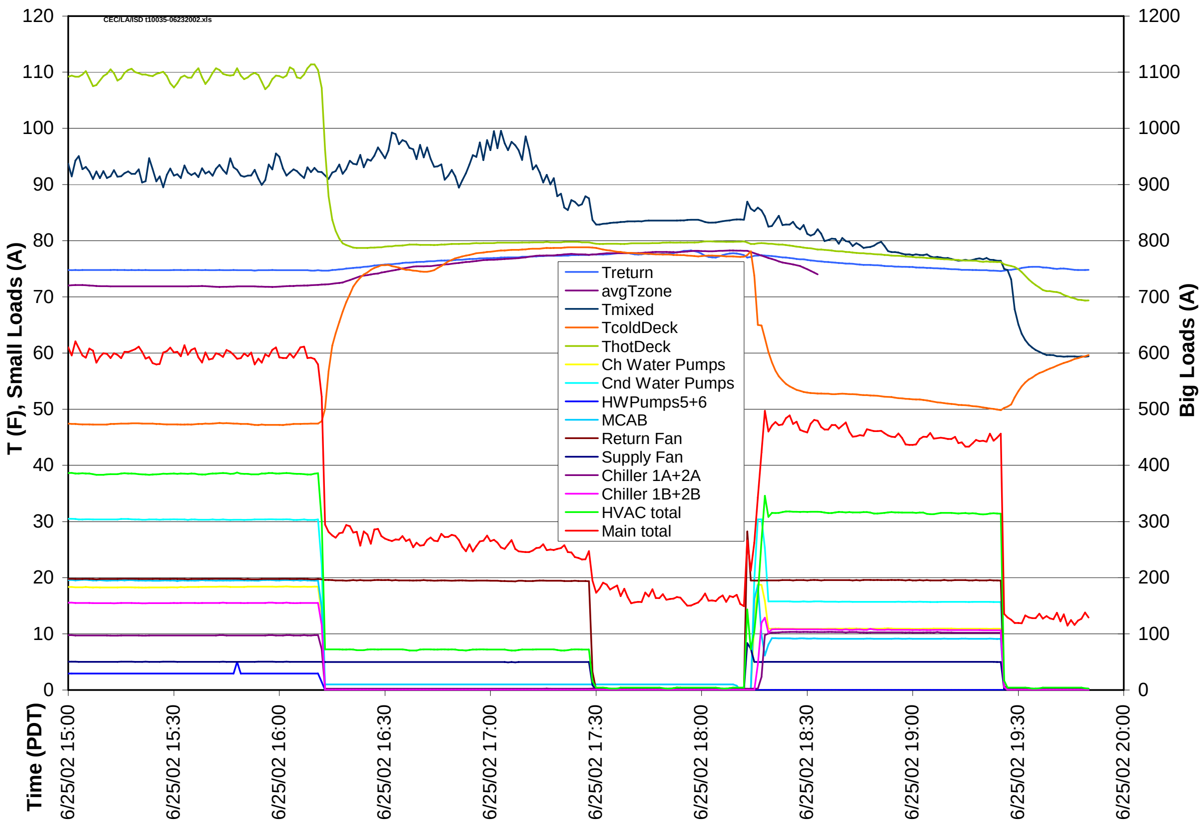

Figure 8. ISD load shedding test.

Zone Thermal Conditions

It is an option, with most control systems, to maintain temperature control of individual zones through the night and weekend ("24x7"); this is not considered necessary in most buildings because they are not occupied 24x7. However, there may be advantages to imposing some level of temperature control[6] during unoccupied hours. To this end, we consider the zone temperature trajectories (transient behavior and dispersion among zones) observed during the recent site visit. The zone temperatures, their average, and the standard deviation across

[6]One practical, efficient strategy is to leave fans on when outside air enthalpy is lower than return air enthalpy but reduce the supply pressure setpoint and lock out chillers. By additionally programming supply pressure to reset with return-outdoor enthalpy difference, a more nearly optimal, but still practical (not to imply that optimal is always necessarily impractical), strategy can be obtained involving significantly reduced fan energy.

zones, are plotted in Figures 9 and 10. Note that loggers resided together in a bag prior to deployment (2002.06.21 15:00-16:30 PDT), thus the data taken prior to deployment is only useful for showing that the loggers track each other quite well.

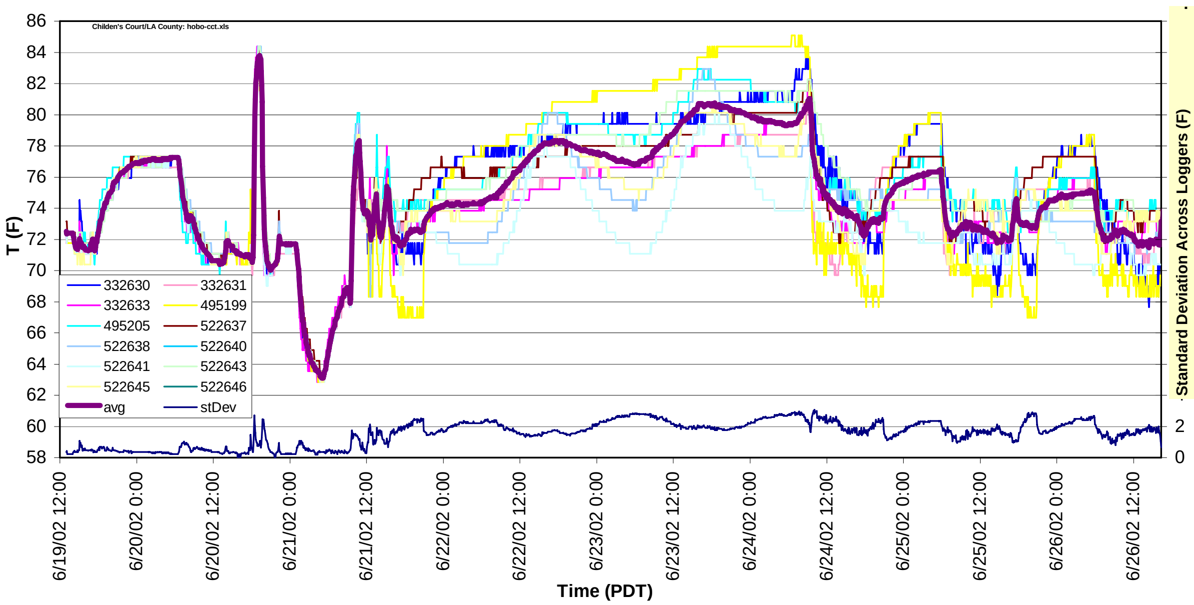

Figure 9. Children's Court micro-logger data from launch time (2002.06.19 13:00 PDT) through first download/relaunch (2002.06.26 16:00-16:45 PDT).

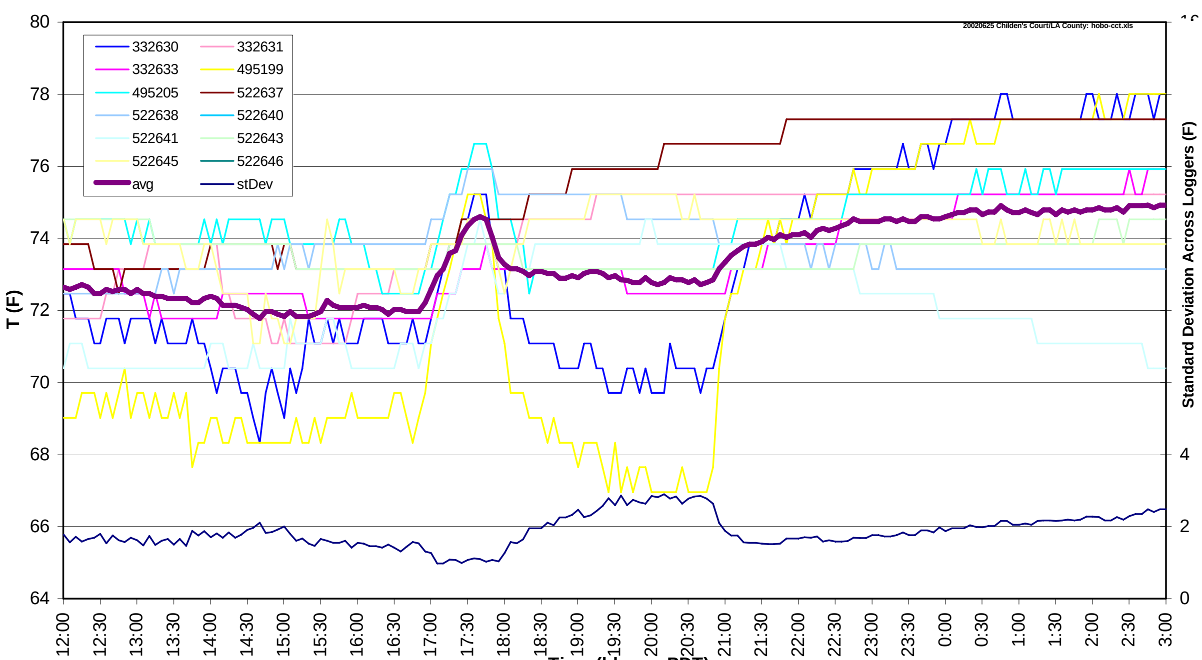

Figure 10. Children's Court zones before, during, after the chiller OFF step test of 25 June

Summary

Initial load shedding tests were performed. In addition to obtaining data for improved (model-based) control, we became familiar with important details of the buildings' equipment and conventional controls as well as aspects of their thermal behavior that experiences have shown to be surprisingly varied from one building to another. Using an aggressive interpretation of the Haves-Smothers protocol, the tests reduced whole building loads by up to 60% (1.2 to 3.5 W/sf) and HVAC loads by essentially 100%. Leaving chillers off for one hour resulted in zone temperatures increasing by 2.6 to 5.5˚F and return air temperatures increasing by 2.7 to 4.7˚F.

Instrumentation, software upgrades and data collection scripts were being finalized during the June site visit and this resulted in data sets that were incomplete. The following additional instrumentation will be added or repaired in the next site visit:

Met station: install barometric pressure sensor and shadowband pyranometer;

Children's Court: connect RH sensors, repair fan inlet pressure sensor;

ISD: replace velocity sensors with higher range units; install hot-deck thermopile amplifier, repair intermittent mixed air temperature sensor.

A number of faults were identified from the data by inspection. The Children's Court has large temperature variations across zones. The cooling tower fan cycles excessively. One return fan is down and control of building pressure, minimum outside air, and economizer suffer as a result. The coordination of building fans, cooling tower fans and the chiller appears to be significantly sub-optimal. Except for the interzonal temperature variations, all of this can be inferred by inspection (automation of which may be possible) of NILM data.

The ISD has serious control faults involving the modulation of chiller and cooling tower capacity. At one point the chiller capacity increased from stage 1 to stage 4 abruptly (<100s). The cooling tower staging is also incorrect and there is considerable tower fan cycling as well. These faults are detectable from NILM data alone.

Other ISD faults require analysis of thermal time-series data that are, in general, already monitored in most CV dual deck systems by their existing HVAC controls. Coordination of hot deck temperature and damper position is poor, with the result that simultaneous heating and cooling increases with cooling load. Both dampers (or at least the hot deck damper) should be shut when the fans are off. One of the two boilers should be shut down completely in summer. Control of hot deck temperature is difficult in part because the boiler setpoint temperature is fixed. Some means should be found to prevent the boiler-coil convection loop that develops when pumps and fans are off. Hot- (and possibly cold-) deck duct leakage appears to be excessive.

One of two Communication Building return fans is down (see Appendix E).

The discovery of HVAC and controls faults is not surprising in light of our experiences in other buildings. Faults that do not result in persistent occupant complaints often go undetected or, if detected, un-repaired. To have found such a large number of faults with only a few days' data is, however, quite exciting.

Additional faults have been identified by visual observation. Additional testing and analysis will investigate whether or not detection from electrical and thermal sensors is feasible. Both EECC and ISD buildings have been operated with supply air access doors and pressure relief doors open or exhibiting large leaks. The ISD condensate pan leaks so badly that most of the condensate puddles on the mixed air plenum floor rather than being channeled directly to the building waste-water line. Economizer controls do not appear to be working properly in either building.

Future Site Test and Analysis Activities

Next quarter's focus will be to obtain as much useful cooling-mode data from the buildings as possible. Analysis of the data will concentrate on five main areas:

- Load curtailment (1-4 hour cooling equipment load reductions);
- Load control in aggregates of buildings;
- Pre-cooling;
- Optimal plant control;
- Fault-detection and diagnosis.

Tests in July and August will include:

- ISD turning HW pumps off for two hours to see effect on plant loads (fans on);
- ISD turning HW pumps off on one of two weekend days to see effect on convection;
- Shed load by raising setpoints (or reducing chiller capacity manually) and (in EECC) freezing fan speeds;
- Tests to assess simultaneous heating and cooling.

References and Plot Source files

ASHRAE. 2001. *Handbook of Fundamentals*, Atlanta

Haves, Phil. 2002. *Guidelines For Emergency Energy Reduction In Commercial Office Buildings*

Armstrong, P.R. and P.D. Heerman. 1985. "uP-based hot-wire anemometry," First National Conference on Microcomputer Applications for Conservation and Renewable Energy, Tucson

Luo, Dong. 2001. *Detection and Diagnosis of Faults and Energy Monitoring of HVAC Systems with Least-Intrusive Power Analysis*. MIT BT Program PhD Thesis.

http://www.pge.com/002_biz_svc/loadmgmt_programs.shtml (PG&E)

http://www.caiso.com/SystemStatus.html (ISO real-time capacity, load forecast, stage notice)

20020624\CCt\t10034-06182002.xls (16-26 June)

20020626\ISD\isdhvac06242002-201118

KTOOLS\DATA\10035C20020620.xls (18-20 June)

HOBO\CLTOOLS\hobo-isd.xls (19-26 June)

NILM\SITES\LA\ISDchr.xls

KTOOLS\DATA\t10037.xls

20020626\CCt\t10034-06262002.xls

20020624\cct-vsections

20020625\comm-vsections

Appendix A: ISD Floor, Wall and Window Areas

Construction information about the ISD and EECC buildings will be used for thermal modeling. The ISD is built on a 24'x24' structural grid with 10 bays on the long side (almost E-W; the south wall is turned ~30 degrees east) and 4 bays on the short side. The main footprint is thus a bit over 240'x 96'= 23,000 sf . The basement is only 3 bays wide (floors 1 and 2 extend 1 bay further north) giving it a ~240'x 72'= 17,300 sf footprint. The basement is essentially windowless. Windows on the main floors (1 and 2) are placed every 4 feet to fit the 24-foot grid and the floor-to-floor height is 14 feet. The windows are operable (!) but usually remain closed. The third floor (penthouse) has no windows except on the 50-foot east wall, looking on to a rooftop terrace, which is essentially all glass with a 20" (clear) transom strip of fixed lights above an 80" (clear) main span of sliding doors and fixed lights.

There are roof doors at the tops of both stairwells, one at the north-east corner (north-most point) and one near the center of the west end of the building (just west of and adjacent to the elevators).

Window types are described in Table A-1 and their locations are summarized in Tables A-2 and A-3.

Table A-1. ISD Window Types

Type	Dimensions (H x W, in.) Finished	Clear	Clear Area (sf)	Mullion Area (sf)
A (single casement)	66.0 x 36.5	61.5 x 31.25	13.35	3.38
B (narrow fixed)	108.0 x 17.0	64.7 x 13.5	9.44	3.31
		36.0 x 13.5		
C (wide fixed)	108.0 x 99.0	64.7 x 95.5	66.78	7.47
		36.0 x 95.5		
D (door)	83.5 x 36.0	66.7 x 24.8	11.35	9.53
E (narrow transom)	24.0 x 72.0	20.0 x 70.5	9.79	2.21
G (double casement)	66.0 x 22.5	61.5x18.3	7.82	2.50
I (sliding door)	83 x 36	80 x 33	18.33	2.42
J (door-height, fixed)	83 x 40	80 x 37	20.56	2.50
K (transom)	23 x 40	20 x 37	5.14	1.25

Table A-2. ISD Window Inventory

Floor	Wall	Type	Qty	Clear (sf)	Mullion (sf)
1	N	A (single casement)	54	720.7	182.5
1	N	B (narrow fixed)	2	18.9	6.6
1	N	C (wide fixed)	1	66.8	7.5
1	N	D (door)	4	45.4	38.1
1	N	E (narrow transom)	2	19.8	4.4
1	S	A (single casement)	60	800.8	202.8
1	W	H (double casement)	5	78.2	25.0
2	N	A (single casement)	60	800.8	202.8
2	S	A (single casement)	60	800.8	202.8
2	W	H (double casement)	5	78.2	25.0
3	E	I (sliding door)	2	36.66	4.8
3	E	J (door-height, fixed)	12	246.7	30.0
3	E	K (transom)	14	72.0	17.5

Table A-3. ISD Window and Wall Areas

		Wall Dimensions (ft)	Gross(sf)	Clear	Mullion
	N	2x240x14 + 110x11	7,930	1672.3	441.9
	E	2x96x14+72x14+50x11	4,246	355.4	52.3
	S	3x240x14 + 110x11	11,290	1601.6	405.6
	W	2x96x14+72x14+50x11	4,246	156.4	50.0
	roof	240x96	23,040		
	ground	240x(96+12)	25,920		

Appendix B: Children's Court Floor, Wall and Window Areas

The EECC is an 8-story (G, L, 2...6, P) steel frame structure built in an ell with the north and east wings meeting at the southwest corner.

The ground floor extends to the north below a lobby-level terrace and therefore has a larger footprint than the floors above it. The penthouse covers part (a central N-S strip) of the north wing. It comprises chiller, boiler, AHU, electrical, and elevator machine rooms.

Six public elevators serve G through 6; two service elevators serve G through P. The service elevator machine room rises above the main penthouse level. There is a central stairwell near the main elevators and additional stairwells at the north and east gable ends of the building. The gable ends (except for the north extension of the ground floor) are windowless.

Court rooms form the core zones of the 3rd - 5th floors with public areas along the north and east walls and judges' chambers and support offices along the south and west walls.

The ground floor houses offices (including sheriffs'), a cafeteria, the main electrical and phone rooms, and other service areas. The lobby level has public areas and administrative offices. The second floor has public areas, social services and administrative offices. The sixth floor houses leased office space for lawyers.

Window and wall dimensions and floor areas have not been fully documented, however the basic inventory of window types that has been compiled at this time is presented here in Tables B-1 and B-2.

Table B-1. EECC Window Types

	Dimensions (H x W, in.)		Clear	Mullion
Type	Finished	Clear	Area (sf)	Area (sf)
A (office square fixed)				
B (3-bay office)		x		
		x		
		x		
C (4-light fixed)		x		
		x		
		x		
		x		
D (square fixed)				
E (diamond fixed)				
G (cafeteria fixed/door)		x		
I (terrace fixed/door)		x		
J (3-bay hall)				
K (hall square fixed)				
L (tall multi-bay)				

Table B-2. EECC Window Inventory

Floor	Wall	Type	Qty	Clear (sf)	Mullion (sf)
G	N	B	6		
G	E	B	8		
G	E	G	3		
L	N	F	4		
L	N	Main Entrance	1		
L	E	B	4		
L	S	L	7		
L	S	B	4		
L	S	M	1		
L	W	B	10		
2	N	C	4		
3-5	N	C	3 x 8		
3-5	E	C	3 x 6		
3-5	S	A	3 x 8		
3-5	S	K	3 x 3		
3-5	W	A	3 x 10		
5	S	J	1		
5	S	K	1		
6	N	D	8		
6	E	A	6		
6	S	A	8		
6	W	A	10		
7	S	N	1		

Appendix C: ISD Air Flow Measurements

Airflow measurements were made for the ISD constant volume system on 24 June 2002. A handheld Davis thermal anemometer with averaging and other functions was used to traverse channel cross sections at three points in the air flow path: return air plenum inlet, filter bank, and supply fan inlet bells. The data appear in Table C-1. Each cell is an average of n readings (m/s) taken along one or more grid lines. The columns represent grid lines or groups of lines. Each row represents a replication of the entire cross-sectional traverse. The average and standard deviation over a column or row is shown at the end of the corresponding column or row. The average mass velocity (sfpm) for all replications is listed in the lower right for each cross-section and the corresponding flow rate (scfm) is given just below the mass velocity.

Table C-1.

R/A	1	10.65	10.00	10.84	9.33	10.21	0.685	
n=8	2	11.07	9.73	10.73	9.94	10.37	0.636	
	3	10.68	10.26	10.68	10.16	10.45	0.274	
	4	11.29	10.02	10.61	10.05	10.49	0.597	
	5	10.93	10.22	10.87	10.19	10.55	0.402	
	6	10.92	9.88	10.82	10.47	10.52	0.470	
		10.92	10.02	10.76	10.02	10.43	sfpm=	2053
		0.241	0.201	0.102	0.383	0.128	scfm=	58396
filter	1	1.39	1.2	1.30				
n=27	2	1.29	1.12	1.21				
	3	1.09	1.3	1.20				
	4	1.35	1.25	1.30				
		1.28	1.22	1.25			sfpm=	246
		0.1331666	0.076757	0.056476			scfm=	40806
S/Ain	1	15.24	18.61	16.93				
n=12	2	16.8	17.93	17.37				
	3	17.39	18.5	17.95				
	4	17	17.7	17.35				
		16.61	18.19	17.40			sfpm=	3424
		0.9440118	0.439735	0.418855			scfm=	34245

Appendix D: Children's Court HVAC Equipment Start Transients

Start transients were recorded at 12 Hz by the NILM on 17 June 2002 for each HVAC motor served by the MCP. All repetitions of the start transient for a given device are superimposed on a single plot. In addition to the pumps, fans, and chillers of the building's central plant, the MCP serves several small exhaust fans. These fans run continuously and exhibit significant shaft harmonics. The exhaust fans were left on during collection of start-transient data so that we will be able to test various methods of removing background noise for the NILM's event detection function.

Pump start transients are similar to those measured in other buildings (Sansome, ISD) and discussed in previous reports. The 2-speed cooling tower switch transient is of interest. When switched from off to high speed the area under the curve equals the sum of areas under the off-to-low-speed and low-to-high-speed start transients. The inrush current when switching from low to high speed is larger than the off-to-low inrush current because there is no back emf. After the initial inrush the off-to-high start transient differs from the low-to-high transient mainly in its longer duration. Note particularly the similarity of the ~2-cycle ringing phase exhibited near the end of the transient under both startup conditions. Another point of interest is the initial drop in load that occurs before the low-to-high-speed inrush phase resulting from the low-speed winding being disconnected 0.1s before the high-speed winding contacts close. This is a very distinctive and repeatable part of the transient that will be included in the EECC cooling tower load exemplar.

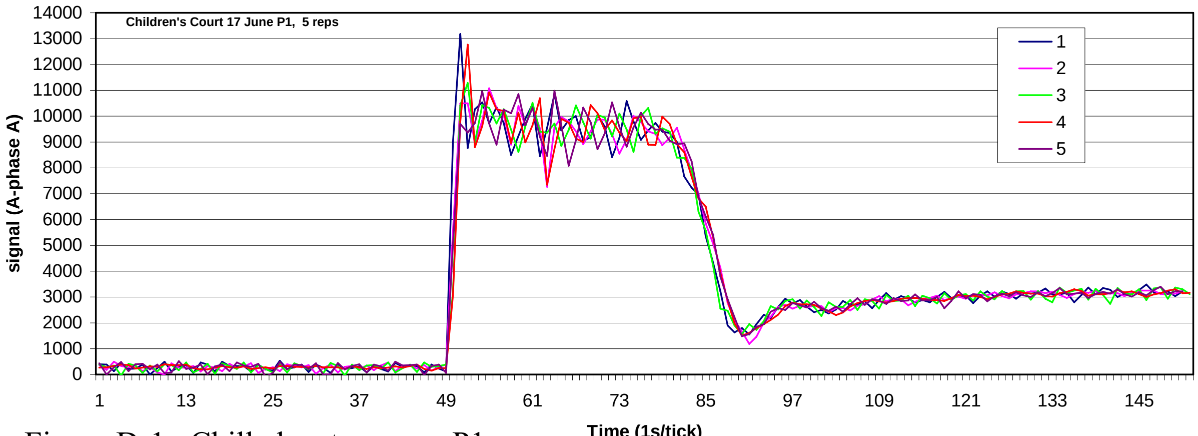

Figure D-1. Chilled water pump P1.

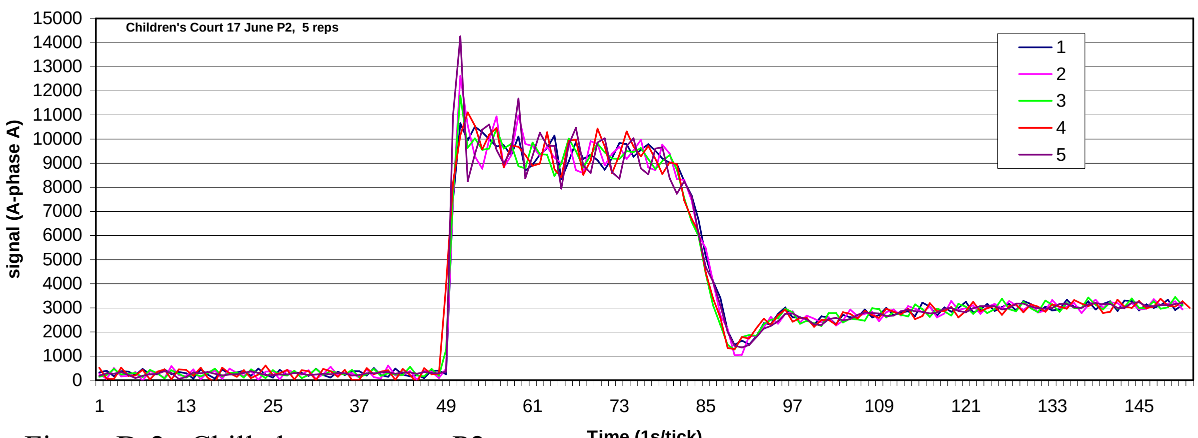

Figure D-2. Chilled water pump P2.

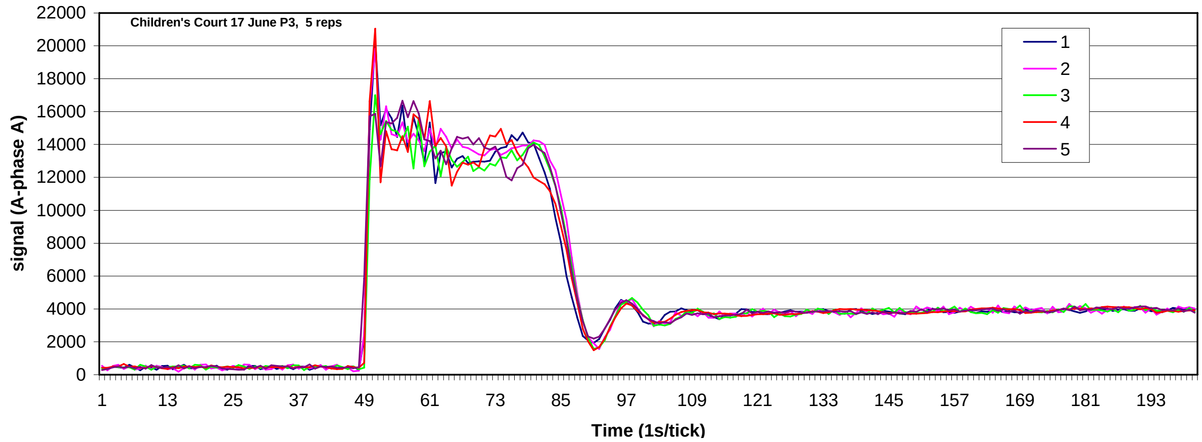

Figure D-3. Condenser water pump P3.

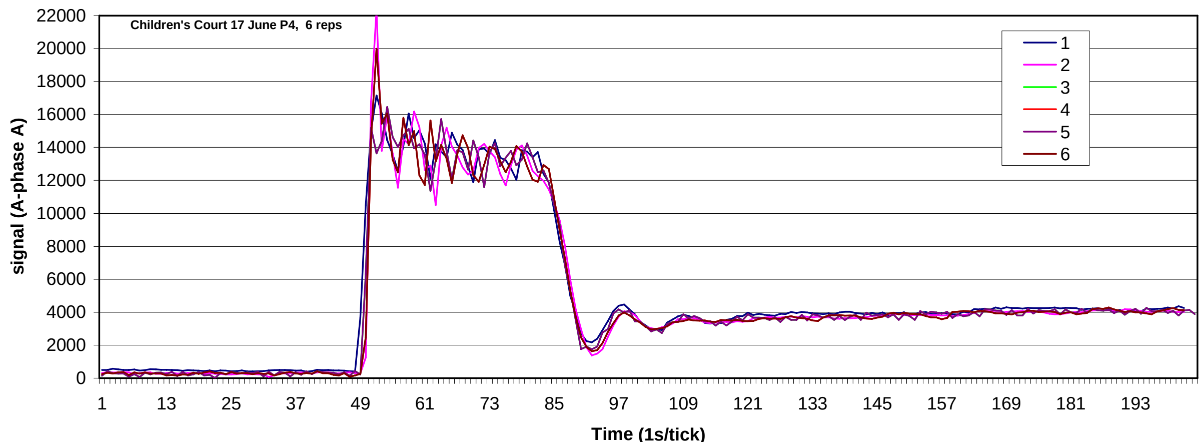

Figure D-4. Condenser water pump P4.

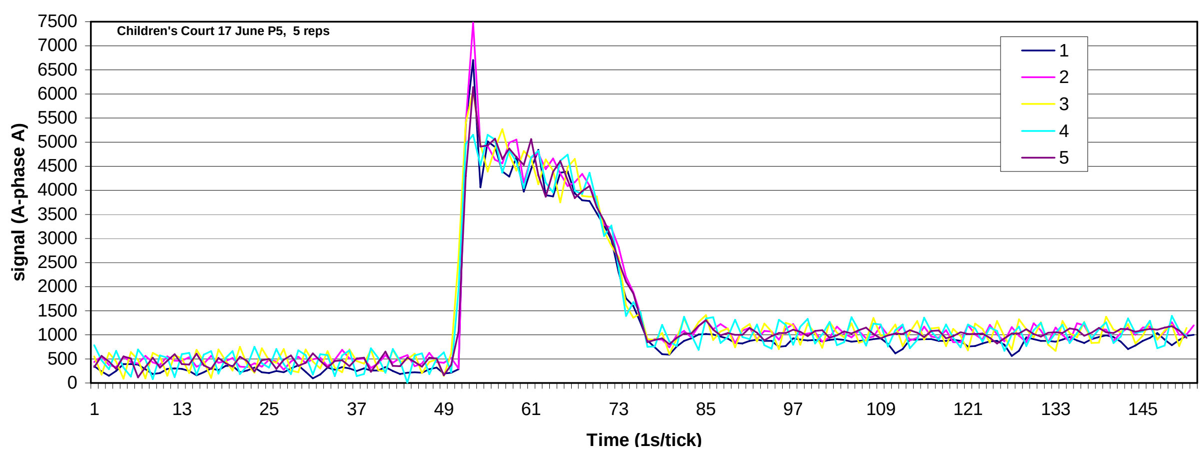

Figure D-5. Hot water pump P5.

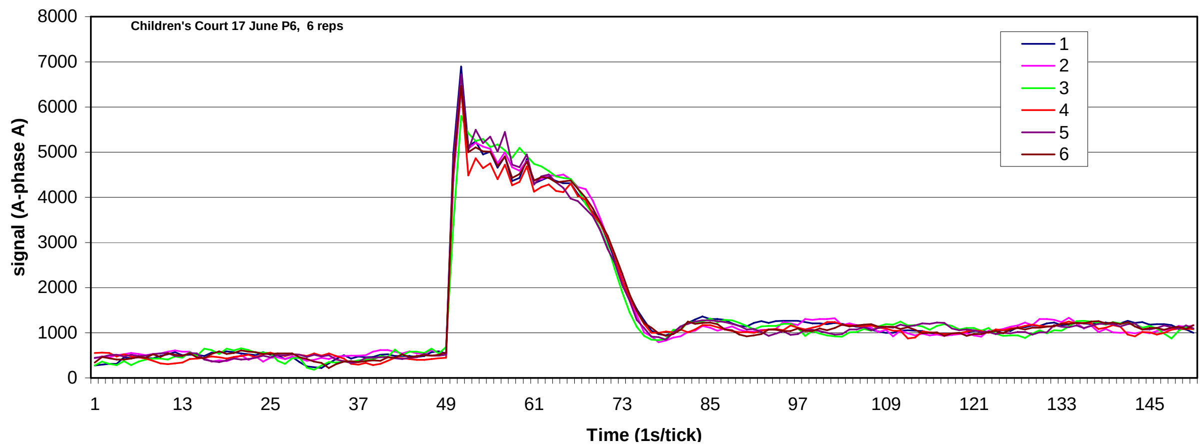

Figure D-6. Hot water pump P6.

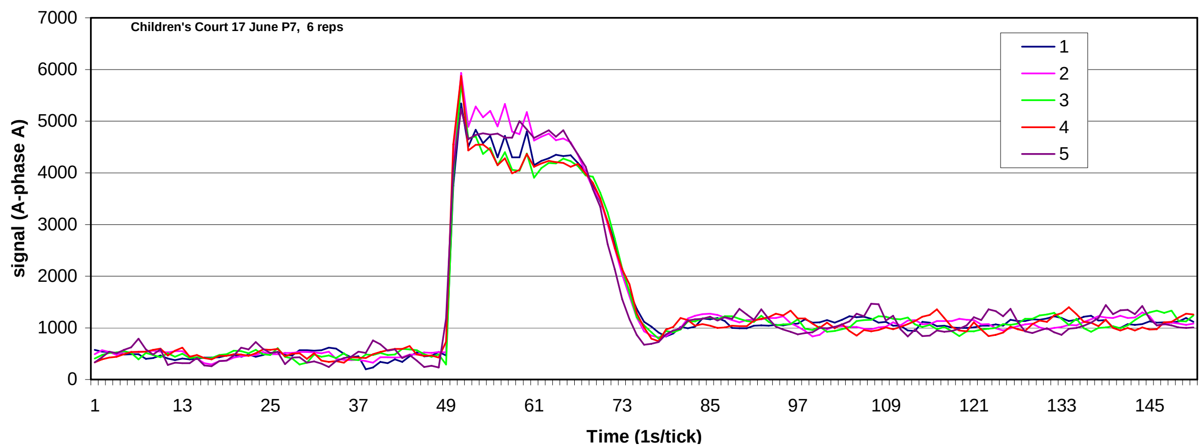

Figure D-7. Hot water pump P7.

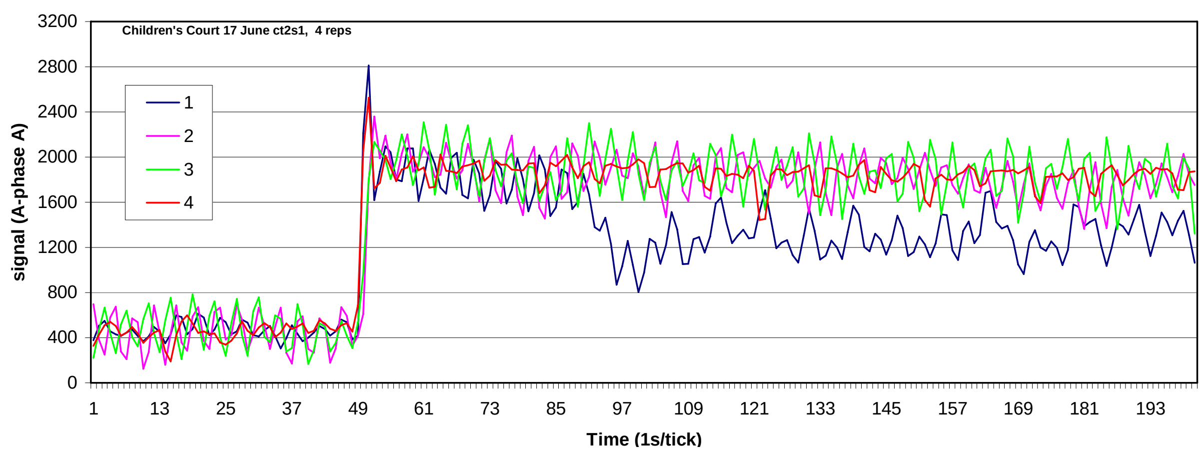

Figure D-8. Cooling tower 1 fan: off to low speed.

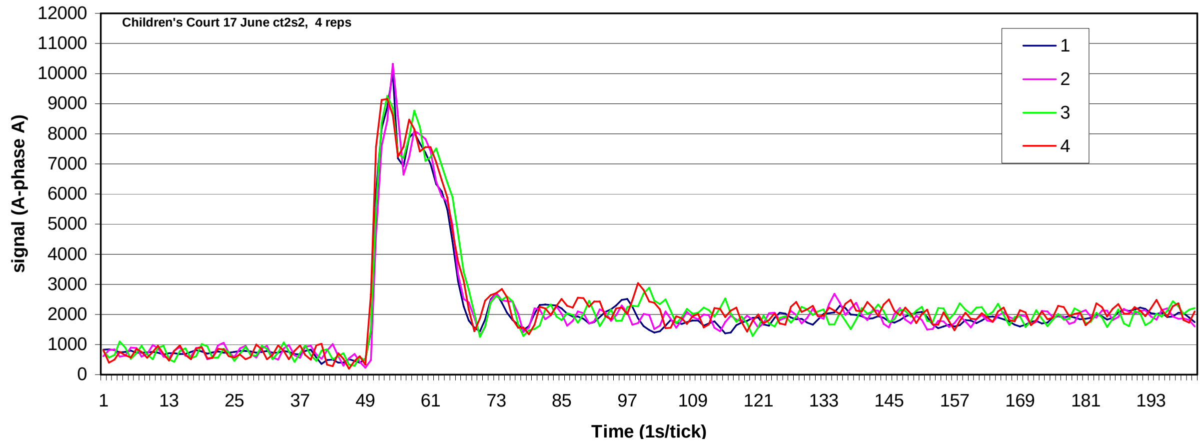

Figure D-9. Cooling tower 1 fan: low to high speed.

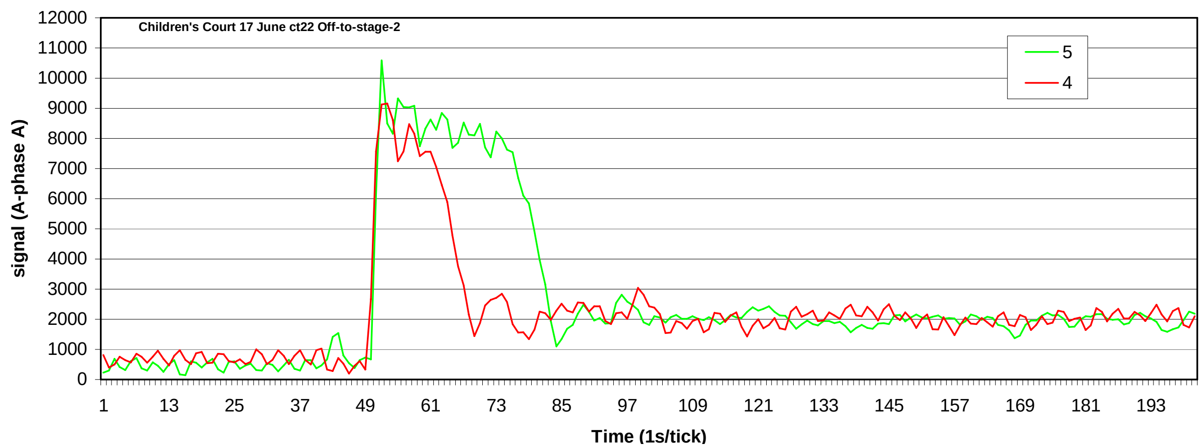

Figure D-10. Cooling tower 1 fan: low-to-high- and off-to-high-speed transients.

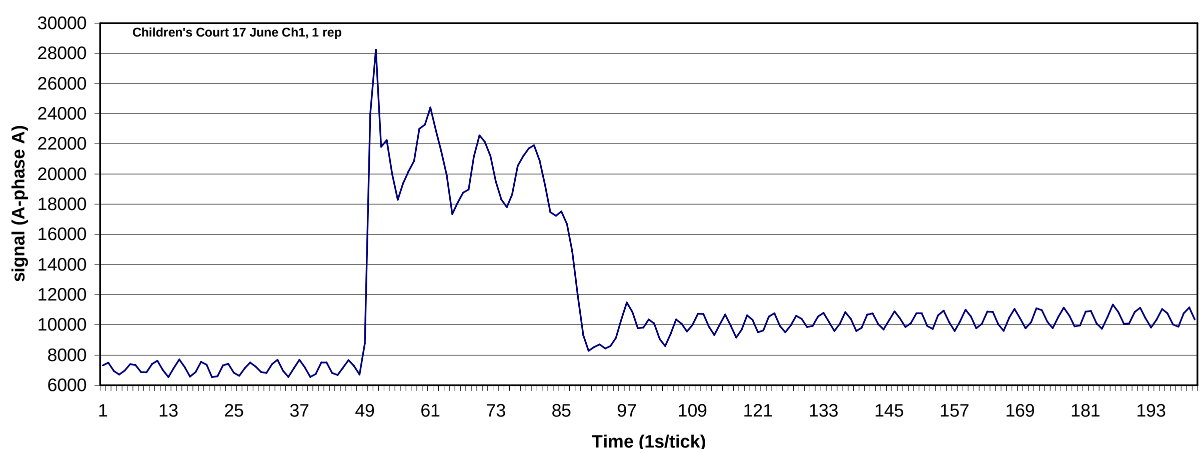

Figure D-11. Chiller 1 motor start transient.

Appendix E: Communications Building HVAC Equipment Start Transients

Start transients were recorded at 120 Hz by the NILM on 18 June 2002 for each air-conditioning compressor and each HVAC supply and return fan motor. The Communications Building has dry condenser coils, so there are no chilled water or condenser water pumps and no cooling tower fans. All repetitions of the start transient for a given device are superimposed on a single plot. Because the NILM is installed at the building service entrance, the tests were run during unoccupied hours to reduce, to some extent, the occurrence of other building load transients.

One of the return fans (R1) was found disabled at its control panel. Starting R1 by hand resulted in an unusual start transient as well as noises indicative of a mechanical fault. Figure E-1 shows the R1 start transient along with two of the R2 start transients. We will investigate the R1 fault in a future site visit and determine if anything about the nature of the fault could have been inferred from the fan's start transient.

Another point of interest is the supply fan off transient. Most motors with wye-delta starters have a simple step change turn-off transient (see April 2001 ISD training plots) however these fans exhibit (Figures E-7 and E-10) a two-step off transient.

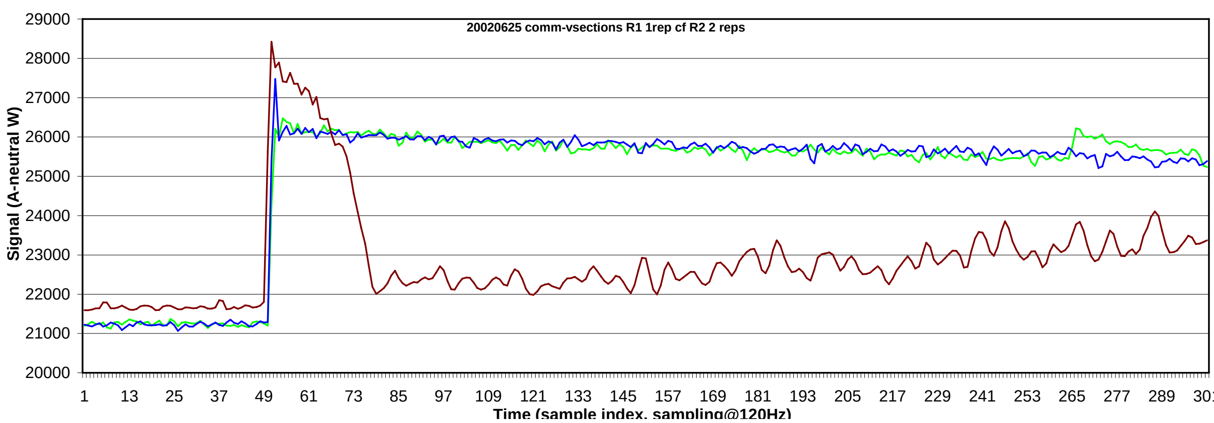

Figure E-1.   Return fan R1 inrush transient compared with corresponding R2 transients.

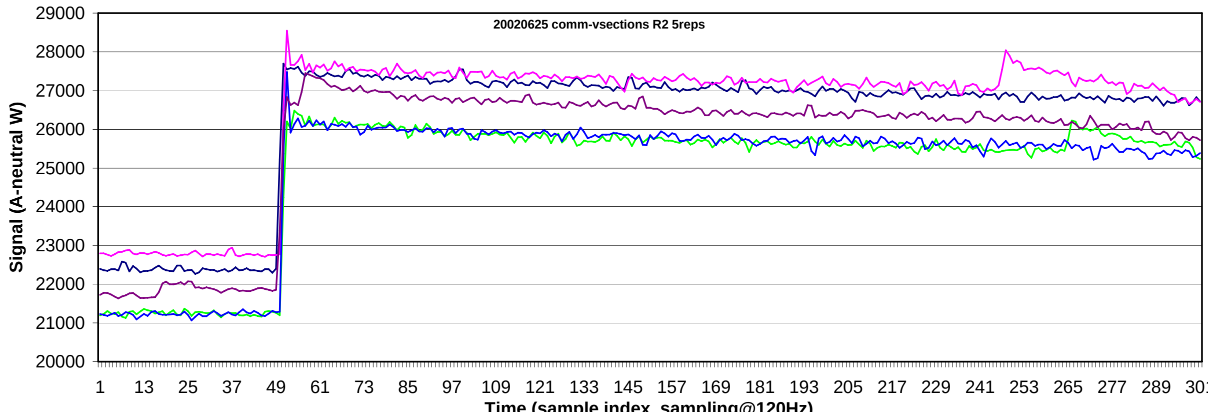

Figure E-2. Return fan R2 inrush current transient.

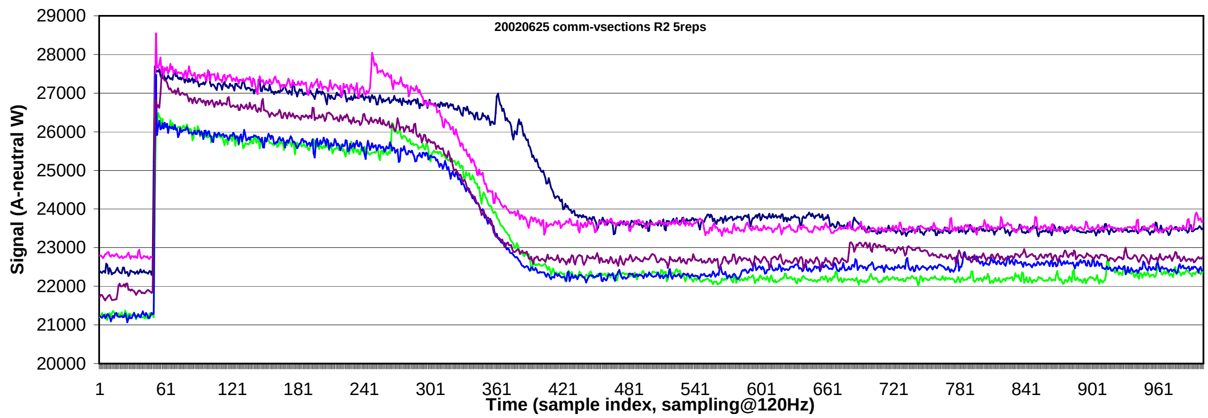

Figure E-3. Return fan R2 rotor acceleration transient.

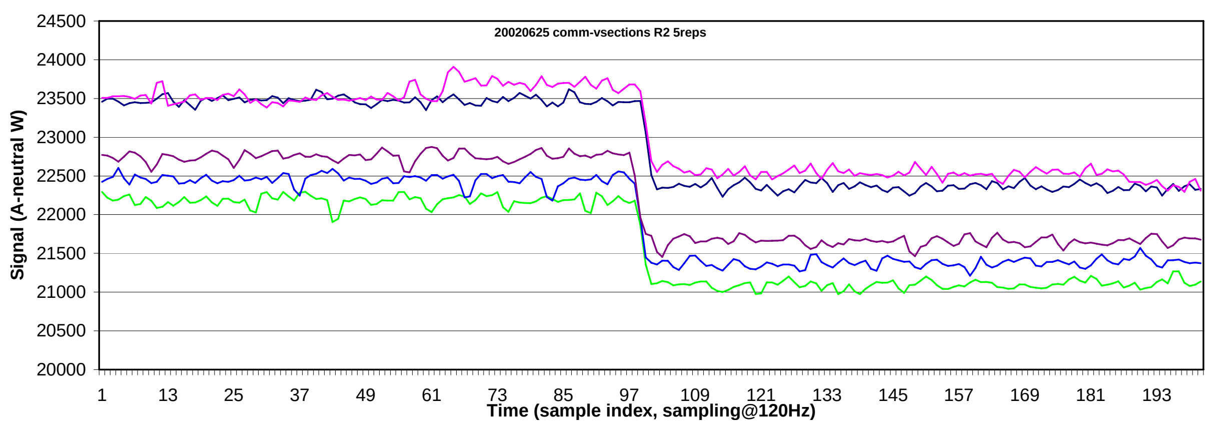

Figure E-4. Return fan R2 off transient.

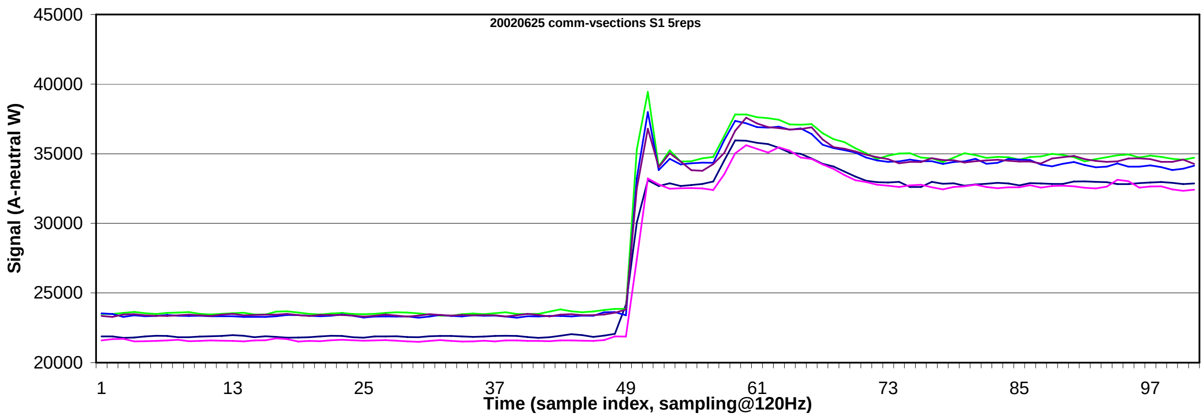

Figure E-5. Supply fan S1 inrush current transient.

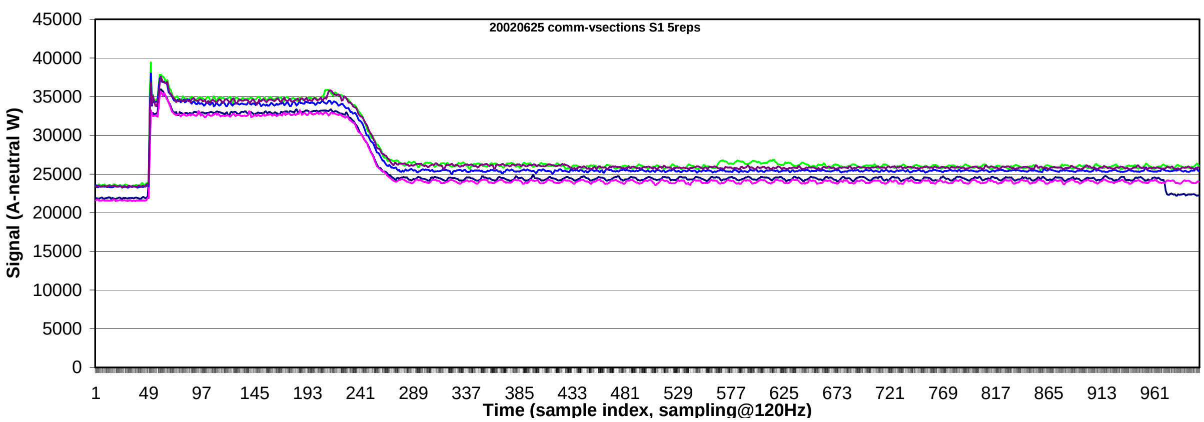

Figure E-6. Supply fan S1 rotor acceleration transient.

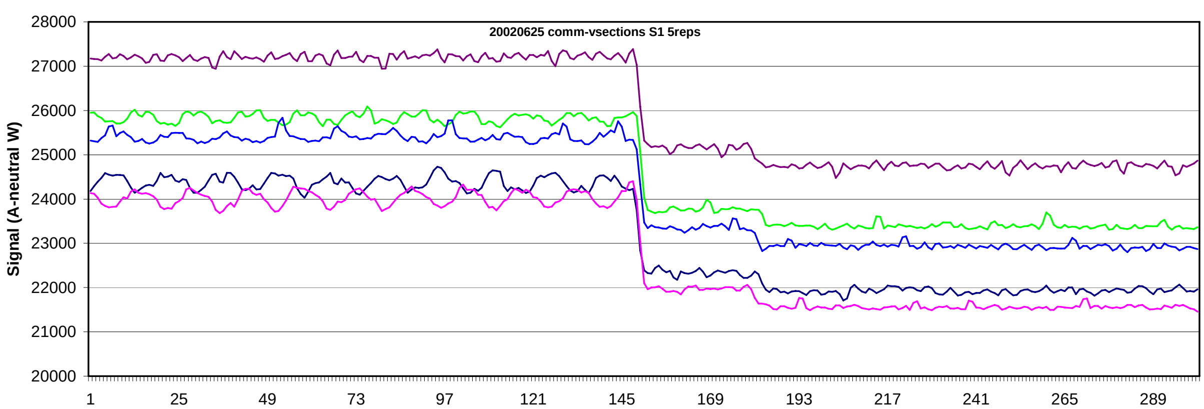

Figure E-7. Supply fan S1 off transient.

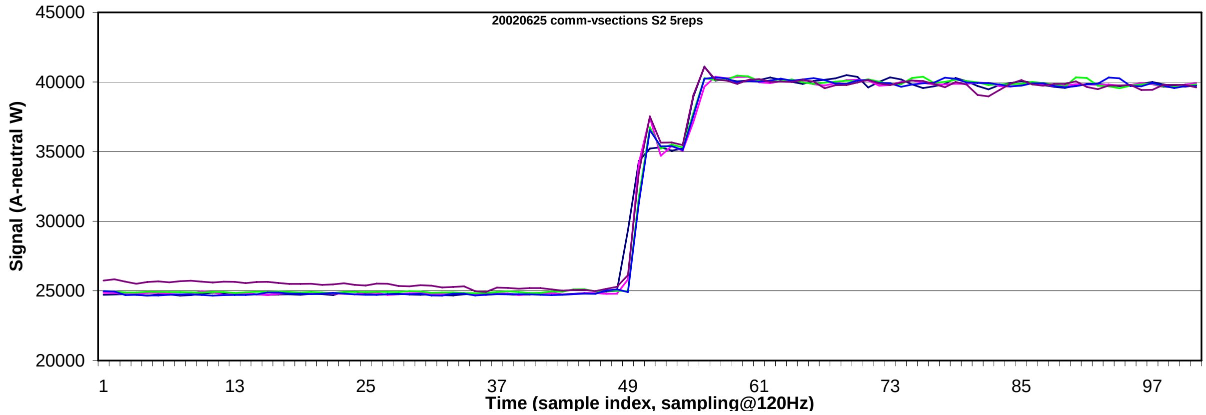

Figure E-8. Supply fan S2 inrush current transient.

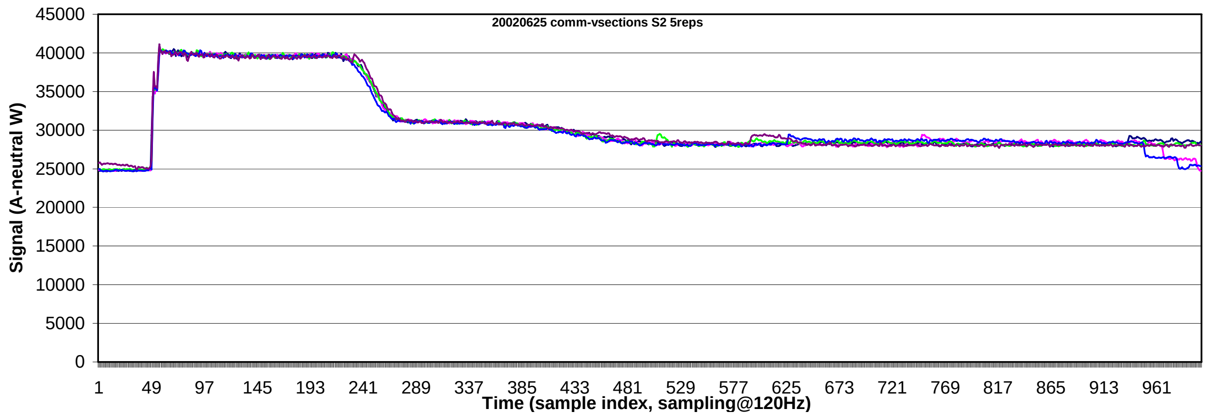

Figure E-9. Supply fan S2 rotor acceleration transient.

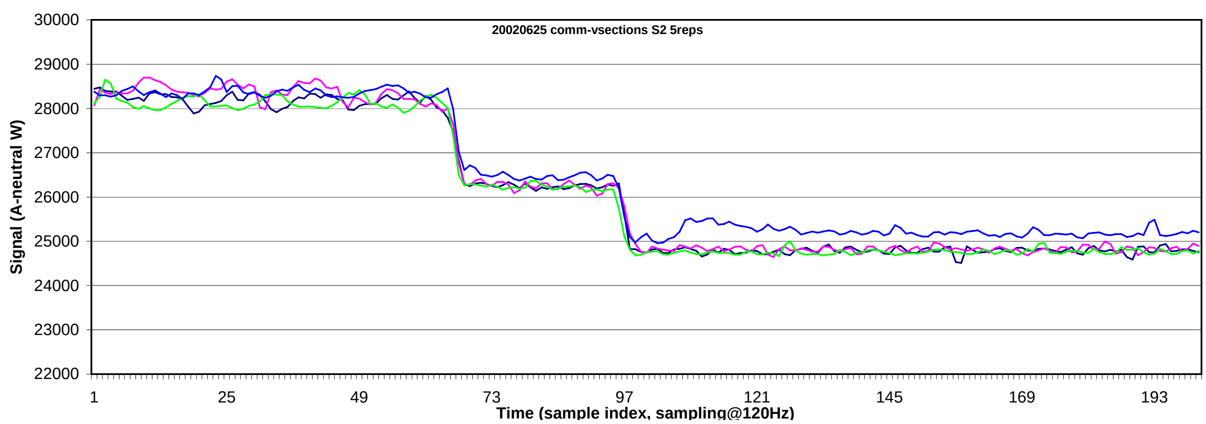

Figure E-10. Supply fan S2 off transient.

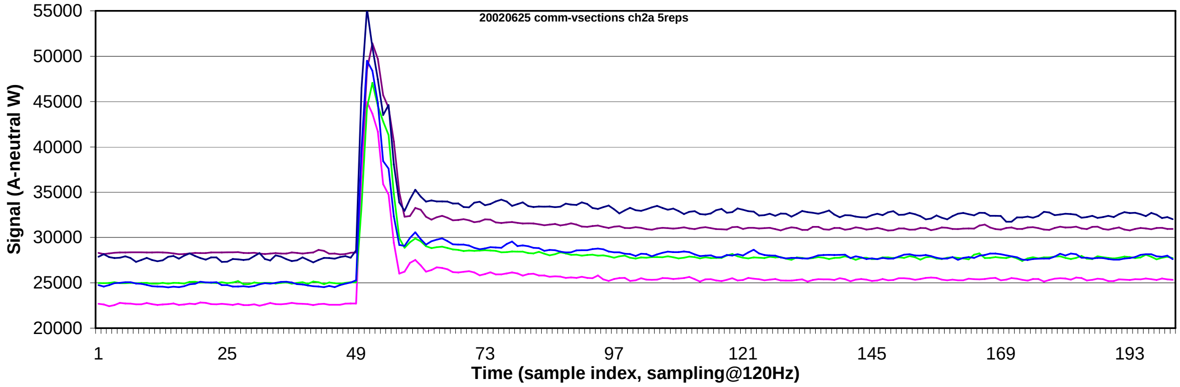

Figure E-11. Chiller 2 first motor start transient.

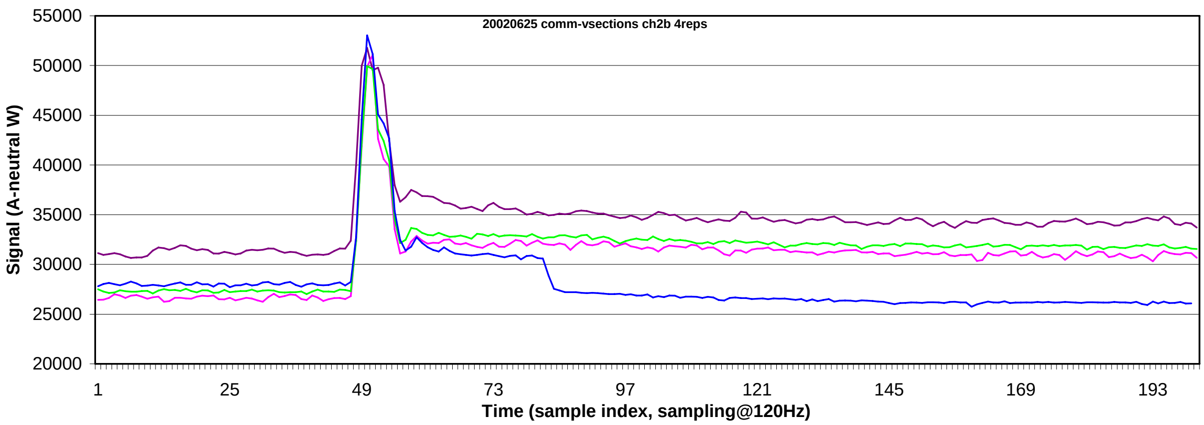

Figure E-12. Chiller 2 second motor start transient.

Appendix F: ISD K20 Channel List

Four digital channels were added to monitor valve status (open or closed) of the low- and high-fire burners on each of two boilers. They were programmed to record duration of firing during each 1-minute logging interval. The current logger configuration table follows.

```
RECORDER_TYPE
DESCRIP: ISD hvac
  MODEL: K20-6
 SERIAL: 10035

RECORDER_INFO
   PSID: 2
    MIN: 1
 PSDESC:
  RINGS: 2
 CUTOFF: 0
OPTIONA: 0
OPTIONB: 0
```

K20_CT_TABLE

CH	DESCRIP	AMPS	VH	VL	VMULT	VLT	AMP	DLT	PW
0	Supply Fan	150.0	A1	N1	1.0	ON	ON	OFF	0
1	Chiller 1B+2B	300.0	A1	N1	1.0	OFF	ON	OFF	1
2	Ch Water Pumps	25.00	A1	N1	1.0	OFF	ON	OFF	2
3	Cnd Water Pumps	50.00	A1	N1	1.0	OFF	ON	OFF	3
4	Chiller 1A+2A	300.0	A1	N1	1.0	OFF	ON	OFF	4
5	Return Fan	50.00	A1	N1	1.0	OFF	ON	OFF	5
6	TFan,Compr/dryer	10.00	A1	N1	1.0	OFF	ON	OFF	6
7	HWPumps5+6	10.00	A1	N1	1.0	OFF	ON	OFF	7
8	LAC	150.0	A1	N1	1.0	OFF	ON	OFF	8
9	DSA	300.0	A1	N1	1.0	OFF	ON	OFF	9
10	MCAB	100.0	A1	N1	1.0	OFF	ON	OFF	10
11	Lift	150.0	A1	N1	1.0	OFF	ON	OFF	11
12	DEA	150.0	A1	N1	1.0	OFF	ON	OFF	12
13	LAG	50.00	A1	N1	1.0	OFF	ON	OFF	13
14	HVAC total	600.0	A1	N1	1.0	OFF	ON	OFF	14
15	Main total	1500.	A1	N1	1.0	OFF	ON	OFF	15

K20_PW_TABLE

PW	DESCRIP	KW	KWH	KVA	KVH
0	Supply Fan	ON	OFF	OFF	OFF
1	Chiller 1B, 2B	ON	OFF	OFF	OFF
2	Ch Water Pumps	ON	OFF	OFF	OFF
3	Cnd Water Pumps	ON	OFF	OFF	OFF
4	Chiller 1A, 2A	ON	OFF	OFF	OFF
5	Return Fan	ON	OFF	OFF	OFF
6	Xfer F, Ctrl AC	ON	OFF	OFF	OFF
7	HWPump5+6	ON	OFF	OFF	OFF
8	LAC	ON	OFF	OFF	OFF
9	DSA	ON	OFF	OFF	OFF
10	MCAB	ON	OFF	OFF	OFF
11	Lift1+2	ON	OFF	OFF	OFF
12	DEA	ON	OFF	OFF	OFF
13	LAG	ON	OFF	OFF	OFF
14	HVAC total	ON	ON	ON	OFF
15	Main total	ON	ON	ON	OFF

K20_AN_TABLE

CH	DESCRIP	TYPE	SCALE	OFFSET	UNITS	SNAP	TSR	TYP	LCH	INV
0	Treturn	385RTD	1.0	0.0	degF	OFF	ON	NA	0	OFF
1	RHreturn	VOLTS	1.0	0.0	volt	OFF	ON	NA	0	OFF
2	rhoVreturn	VOLTS	1.0	0.0	volt	OFF	ON	NA	0	OFF
3	ThotDeck	385RTD	1.0	0.0	degF	OFF	ON	NA	0	OFF
4	rhoVhotDeck	VOLTS	1.0	0.0	volt	OFF	ON	NA	0	OFF
5	TcoldDeck	385RTD	1.0	0.0	degF	OFF	ON	NA	0	OFF
6	RHcoldDeck	VOLTS	1.0	0.0	volt	OFF	ON	NA	0	OFF
7	rhoVcoldDeck	VOLTS	1.0	0.0	volt	OFF	ON	NA	0	OFF

```
 8  Tmixed           385RTD 1.0    0.0    degF      OFF  ON  NA  0   OFF
 9  RHmixed          VOLTS  1.0    0.0    volt      OFF  ON  NA  0   OFF
 10 rhoVmixed        VOLTS  1.0    0.0    volt      OFF  ON  NA  0   OFF
 11 PvSupply         VOLTS  1.0    0.0    volt      OFF  ON  NA  0   OFF
 12 PvReturn         VOLTS  1.0    0.0    volt      OFF  ON  NA  0   OFF
 13 dThotDeck        VOLTS  1.0    0.0    volt      OFF  ON  NA  0   OFF
 14 dTcoldDeck       VOLTS  1.0    0.0    volt      OFF  ON  NA  0   OFF
 15                  UNUSED 1.0    0.0              OFF  OFF NA  0   OFF

//0 W3 Brn
//1 W3 Red
//2 W3 Yel
//3 W1 Brn
//4 W1 Red
//5 W1 Yel
//6 W1 Grn
//7 W1 Blu
//8 W2 Yel
//9 W2 Grn
//10 W2 Blu
//11 W2 Brn
//12 W2 Red
//13 Red-Blk G=1000 nominal (check this); Vsc=2.48V
//14 Wht-Grn G=1224; Vsc= (check this)
//15 W2 Wht K20 28Vdc power to AutoTran fan inlet pressure sensors
//note each RH,rhoV probe has dedicated 12vdc (14.8V actual) pwr sply (one shared H/C decks)

K20_DI_TABLE
|CH|DESCRIP         |SCALE |OFFSET|UNITS   |METHOD|TSR|
-------------------------------------------------------
 0  B1-LOW           1.0    0.0            RTIME  ON
 1  B1-HIGH          1.0    0.0            RTIME  ON
 2  B2-LOW           1.0    0.0            RTIME  ON
 3  B2-HIGH          1.0    0.0            RTIME  ON
 4                   1.0    0.0            COUNT  OFF
 5                   1.0    0.0            COUNT  OFF
 6                   1.0    0.0            COUNT  OFF
 7                   1.0    0.0            COUNT  OFF
 8                   1.0    0.0            COUNT  OFF
 9                   1.0    0.0            COUNT  OFF
 10                  1.0    0.0            COUNT  OFF
 11                  1.0    0.0            COUNT  OFF
 12                  1.0    0.0            COUNT  OFF
 13                  1.0    0.0            COUNT  OFF
 14                  1.0    0.0            COUNT  OFF
 15                  1.0    0.0            COUNT  OFF
```

Appendix G: Children's Court K20 Channel List

A thermopile was installed to measure the supply-return temperature difference. Six "hot" junctions are arrayed vertically in the ~15'H x 6'W return channel and six "cold" junctions are arrayed just downstream of the ~12'H x 6'W supply duct entrance/acoustic baffle. A thermopile amplifier/voltage shifter (2.448Vout for shorted input) with its gain configured to 670 was installed on channel AN6. Channel AN7 is still logged but has no input (will be shorted on next trip). A supply fan inlet pressure tap was installed (AN8) but the pressure transducer was found defective and will have to be replaced on the next site visit. Six digital channels were added to monitor valve status (open or closed) of the low- and high-fire burners on each of three boilers. The logger configuration table follows.

```
RECORDER_TYPE
DESCRIP: LA County Children's Court HVAC
  MODEL: K20-6
 SERIAL: 10034

RECORDER_INFO
   PSID: 2
    MIN: 1
 PSDESC:
  RINGS: 2
 CUTOFF: 0
OPTIONA: 0
OPTIONB: 0

K20_CT_TABLE
|CH|DESCRIP          |AMPS |VH|VL|VMULT |VLT|AMP|DLT|PW|
-------------------------------------------------------
 0  SupplyFan1        250.0 A2 N2 1.0    ON  ON  OFF 0
 1  CTowerFan2        50.00 A2 N2 1.0    OFF ON  OFF 1
 2  HWpump7           25.00 A2 N2 1.0    OFF ON  OFF 2
 3  F1 F2 EF5         25.00 A2 N2 1.0    OFF ON  OFF 3
 4  CTowerFan1        50.00 A2 N2 1.0    OFF ON  OFF 4
 5  EF1 EF2 EF3       25.00 A2 N2 1.0    OFF ON  OFF 5
 6  CndWpump3 4       150.0 A2 N2 1.0    OFF ON  OFF 6
 7  ReturnFan1 2      150.0 A2 N2 1.0    OFF ON  OFF 7
 8  SupplyFan2        250.0 A2 N2 1.0    OFF ON  OFF 8
 9  HWpump5 6         25.00 A2 N2 1.0    OFF ON  OFF 9
 10 ChWpump1 2        75.00 A2 N2 1.0    OFF ON  OFF 10
 11 MCP feed          2000. A2 N2 1.0    OFF ON  OFF 11
 12 Chiller1          500.0 A2 N2 1.0    OFF ON  OFF 12
 13 Chiller2          500.0 A2 N2 1.0    OFF ON  OFF 13
 14                   0.0   A2 N2 1.0    OFF OFF OFF 14
 15                   0.0   A2 N2 1.0    OFF OFF OFF 15

K20_PW_TABLE
|PW|DESCRIP          |KW |KWH|KVA|KVH|
-------------------------------------
 0  Ch0               ON  OFF OFF OFF
 1  Ch1               ON  OFF OFF OFF
 2  ch2               ON  OFF OFF OFF
 3  ch3               ON  OFF OFF OFF
 4  ch4               ON  OFF OFF OFF
 5  ch5               ON  OFF OFF OFF
 6  ch6               ON  OFF OFF OFF
 7  ch7               ON  OFF OFF OFF
 8  ch8               ON  OFF OFF OFF
 9  ch9               ON  OFF OFF OFF
 10 ch10              ON  OFF OFF OFF
 11 ch11              ON  ON  ON  OFF
 12 ch12              ON  OFF OFF OFF
 13 ch13              ON  OFF OFF OFF
 14 ch14              OFF OFF OFF OFF
 15 ch15              OFF OFF OFF OFF
```

K20_AN_TABLE

CH	DESCRIP	TYPE	SCALE	OFFSET	UNITS	SNAP	TSR	TYP	LCH	INV
0	Tra	385RTD	1.0	0.0	degF	OFF	ON	NA	0	OFF
1	Tmixed	385RTD	1.0	0.0	degF	OFF	ON	NA	0	OFF
2	Tsa	385RTD	1.0	0.0	degF	OFF	ON	NA	0	OFF
3	RHra	VOLTS	1.0	0.0		OFF	ON	NA	0	OFF
4	RHmixed	VOLTS	1.0	0.0		OFF	ON	NA	0	OFF
5	RHsa	VOLTS	1.0	0.0		OFF	ON	NA	0	OFF
6	TraTsa	VOLTS	1.0	0.0		OFF	ON	NA	0	OFF
7	TsaTra	VOLTS	1.0	0.0		OFF	ON	NA	0	OFF
8	dPsaFan	VOLTS	1.0	0.0		OFF	ON	NA	0	OFF
9	dPraFan	VOLTS	1.0	0.0		OFF	ON	NA	0	OFF
10	coilDrainS	VOLTS	1.0	0.0		OFF	ON	NA	0	OFF
11	coilDrainN	VOLTS	1.0	0.0		OFF	ON	NA	0	OFF
12		UNUSED	1.0	0.0		OFF	OFF	NA	0	OFF
13		UNUSED	1.0	0.0		OFF	OFF	NA	0	OFF
14		UNUSED	1.0	0.0		OFF	OFF	NA	0	OFF
15		UNUSED	1.0	0.0		OFF	OFF	NA	0	OFF

//0 Minco kevlar adhesive-backed W3 red
//1 Minco kevlar adhesive-backed W3 yel
//2 Minco kevlar adhesive-backed W3 wht
//3 HyCal/HWell HIH-3610-001 W3 grn
//4 HyCal/HWell HIH-3610-001 W3 blu
//5 HyCal/HWell HIH-3610-001 W3 brn
//6 6-pair tp.T; gain=670; zero=2.4476V; W4blue coax
//7 not connected
//8 AutoTran 851D-00; 0-5v = 0-1"WC; W4 ?
//9 not connected
//10 not connected
//11 not connected
//note W4 white is 5Vdc to RH; W4 blk is 16Vdc to AutoTran

K20_DI_TABLE

CH	DESCRIP	SCALE	OFFSET	UNITS	METHOD	TSR
0	B1-LOW	1.0	0.0		RTIME	ON
1	B1-HI	1.0	0.0		RTIME	ON
2	B2-LOW	1.0	0.0		RTIME	ON
3	B2-HI	1.0	0.0		RTIME	ON
4	B3-LOW	1.0	0.0		RTIME	ON
5	B3-HI	1.0	0.0		RTIME	ON
6		1.0	0.0		COUNT	OFF
7		1.0	0.0		COUNT	OFF
8		1.0	0.0		COUNT	OFF
9		1.0	0.0		COUNT	OFF
10		1.0	0.0		COUNT	OFF
11		1.0	0.0		COUNT	OFF
12		1.0	0.0		COUNT	OFF
13		1.0	0.0		COUNT	OFF
14		1.0	0.0		COUNT	OFF
15		1.0	0.0		COUNT	OFF

//W5 blue/wht contact to K20-gnd
//W5 orng/wht contact to K20-gnd
//W5 orng contact to K20-gnd
//W6 orng contact to K20-gnd
//W6 blue/wht contact to K20-gnd
//W6 orng/wht contact to K20-gnd

Appendix H: Communications Building K20 Channel List

A met-station was installed above the electrical room on a guyed pole 21 feet above the parapet. The station currently hosts two LiCor PY200 silicon cell pyranometers (one facing up, one facing down), two RTDs (Minco S247-PF06B, one in a Gill passive radiation shield, one unshielded), and a HyCal HIH-3610 RH sensor attached to the shielded RTD. A trans-impedance (33mV per uA) amplifier was installed for each pyranometer. These amps use a single positive supply so their outputs cannot track all the way down to zero input. The output is 13.7mV (equivalent to about 4 Wm^{-2} or 0.25% of FS) with zero input. Such small signals are rarely, if ever, observed between sunrise and sunset. Five additional channels were configured to accommodate future met-station instruments: barometer, shadow-band pyranometer, wind speed and direction. A digital channel was configured to monitor the building's lone, 1-stage boiler, but it has not been connected. The logger configuration table follows.

```
RECORDER_TYPE
DESCRIP: CEC/LA/Comm Main Service and Met Station
  MODEL: K20-6
 SERIAL: 10037

RECORDER_INFO
   PSID: 2
    MIN: 1
 PSDESC:
  RINGS: 2
 CUTOFF: 0
OPTIONA: 0
OPTIONB: 0

K20_CT_TABLE
|CH|DESCRIP          |AMPS |VH|VL|VMULT |VLT|AMP|DLT|PW|
-------------------------------------------------------
 0  MCCE             100.0 A1 N1 1.0    ON  ON  OFF 0
 1  Tin,EOC,Trailers 250.0 A1 N1 1.0    OFF ON  OFF 1
 2  DistribMPA       300.0 A1 N1 1.0    OFF ON  OFF 2
 3  Fire,LazerVillag 125.0 A1 N1 1.0    OFF ON  OFF 3
 4  panelELA         50.00 A1 N1 1.0    OFF ON  OFF 4
 5  WH1,Ex,genRm,gas 15.00 A1 N1 1.0    OFF ON  OFF 5
 6  panelMLA         150.0 A1 N1 1.0    OFF ON  OFF 6
 7  ACC-2            250.0 A1 N1 1.0    OFF ON  OFF 7
 8  Trailers(frntBld 125.0 A1 N1 1.0    OFF ON  OFF 8
 9  ACC-1            250.0 A1 N1 1.0    OFF ON  OFF 9
 10 AirCompressor    15.00 A1 N1 1.0    OFF ON  OFF 10
 11 Trailer          75.00 A1 N1 0.4333 OFF ON  OFF 11
 12                  100.0 A1 N1 1.0    OFF OFF OFF 12
 13 DistribMPB       300.0 A1 N1 1.0    OFF ON  OFF 13
 14 panelPL          50.00 A1 N1 1.0    OFF ON  OFF 14
 15 BldgFeed         1200. A1 N1 1.0    OFF ON  OFF 15

K20_PW_TABLE
|PW|DESCRIP          |KW |KWH|KVA|KVH|
------------------------------------
 0  MCCE             ON  OFF OFF OFF
 1  Tin,EOC,Trailers ON  OFF OFF OFF
 2  DistribMPA       ON  OFF OFF OFF
 3  Fire,LazerVillag ON  OFF OFF OFF
 4  panelELA         ON  OFF OFF OFF
 5  WH1,Ex,genRm,gas ON  OFF OFF OFF
 6  panelMLA         ON  OFF OFF OFF
 7  ACC-2            ON  OFF OFF OFF
 8  Trailers(frntBld ON  OFF OFF OFF
 9  ACC-1            ON  OFF OFF OFF
 10 AirCompressor    ON  OFF OFF OFF
 11 Trailer          ON  OFF OFF OFF
 12                  OFF OFF OFF OFF
```

13	DistribMPB	ON	OFF	OFF	OFF
14	panelPL	ON	OFF	OFF	OFF
15	BldgFeed	ON	ON	ON	OFF

K20_AN_TABLE

CH	DESCRIP	TYPE	SCALE	OFFSET	UNITS	SNAP	TSR	TYP	LCH	INV
0	OATbare	385RTD	1.0	0.0	degF	OFF	ON	NA	0	OFF
1	RHshielded	VOLTS	1.0	0.0		OFF	ON	NA	0	OFF
2	OATshielded	385RTD	1.0	0.0	degF	OFF	ON	NA	0	OFF
3	SOLRADsky	VOLTS	1.0	0.0		OFF	ON	NA	0	OFF
4	SOLRADgnd	VOLTS	1.0	0.0		OFF	ON	NA	0	OFF
5	SOLRADsband	VOLTS	1.0	0.0		OFF	ON	NA	0	OFF
6	SOLRADsbref	VOLTS	1.0	0.0		OFF	ON	NA	0	OFF
7	Barom	VOLTS	1.0	0.0		OFF	ON	NA	0	OFF
8	Wspd	VOLTS	1.0	0.0		OFF	ON	NA	0	OFF
9	Wdir	VOLTS	1.0	0.0		OFF	ON	NA	0	OFF
10		VOLTS	1.0	0.0		OFF	OFF	NA	0	OFF
11		VOLTS	1.0	0.0		OFF	OFF	NA	0	OFF
12		VOLTS	1.0	0.0		OFF	OFF	NA	0	OFF
13		VOLTS	1.0	0.0		OFF	OFF	NA	0	OFF
14		VOLTS	1.0	0.0		OFF	OFF	NA	0	OFF
15		VOLTS	1.0	0.0		OFF	OFF	NA	0	OFF

K20_DI_TABLE

CH	DESCRIP	SCALE	OFFSET	UNITS	METHOD	TSR
0	Boiler1	1.0	0.0		RTIME	ON
1		1.0	0.0		COUNT	OFF
2		1.0	0.0		COUNT	OFF
3		1.0	0.0		COUNT	OFF
4		1.0	0.0		COUNT	OFF
5		1.0	0.0		COUNT	OFF
6		1.0	0.0		COUNT	OFF
7		1.0	0.0		COUNT	OFF
8		1.0	0.0		COUNT	OFF
9		1.0	0.0		COUNT	OFF
10		1.0	0.0		COUNT	OFF
11		1.0	0.0		COUNT	OFF
12		1.0	0.0		COUNT	OFF
13		1.0	0.0		COUNT	OFF
14		1.0	0.0		COUNT	OFF
15		1.0	0.0		COUNT	OFF