PROPOSED GUIDELINES FOR THE DESIGN OF BUILDING ENCLOSURES AND LIGHTING SYSTEMS FOR USE IN CANADA IN PLACE OF SECTIONS 4 AND 9 OF ASHRAE STANDARD 90-75 ON ENERGY CONSERVATION IN NEW BUILDING DESIGN

by

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PREFACE

The National Research Council of Canada was asked to coordinate the preparation of a set of guidelines for the design of energy efficient buildings that could be used by all departments and agencies of the Government of Canada. An interdepartmental committee was formed to carry out this task; this committee decided that the guidelines should be in the form of annual energy budgets for various types of occupancies. Work is underway to prepare these guidelines.

It was recognized, however, that the development of a comprehensive set of energy budgets and methods for predicting and monitoring energy consumption in buildings would require a considerable period of time, so it was decided to produce a semi-prescriptive set of guidelines that could be used until the energy budget guidelines are ready for use. It was further decided that the interim guidelines should be based on ASHRAE Standard 90-75 for Energy Conservation in New Building Design, but with the requirements for the building envelope and lighting systems modified to suit Canadian conditions. This report presents the proposed modifications to the ASHRAE Standard.

In developing these modified requirements to the ASHRAE Standard the staff of the Division of Building Research of the NRC have had discussions with and advice from experts in other departments and agencies of the Government of Canada and private consultants. The guidelines reflect this input, but the final decisions on the proposed requirements were made by the author.

While these guidelines were being prepared it was decided that the NRC Associate Committee on the National Building Code was the appropriate body to be asked to subject the draft standard to the consensus process. The Associate Committee agreed and established a Standing Committee on Energy Conservation for this purpose. The material contained in this report is now being reviewed by this Committee and it is expected that the ACNBC will issue a draft Energy Conservation Code for review and comment based in part on this material, during the first half of 1977. These interim guidelines are being made available for limited circulation as an Internal Report of the Division of Building Research. They will be useful for the guidance of designers but it should be stressed that it is essential to submit such technical documents to the consensus process in order to ensure that all practical considerations are satisfied before they are widely implemented as design requirements.

Special appreciation is due to the generous cooperation of ASHRAE in permitting its publication to be used freely by Canadian Workers responsible for the preparation of Codes to suit Canadian needs.

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Ottawa
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THE BASIS FOR THE INTERIM GUIDELINES

The basic principle that has been followed in the development of these guidelines is that the measures should be consistent with low life-cycle cost. The aim is to reduce the amount of energy used to operate buildings, but any measure that increases the initial cost of the building must yield enough saving on operational costs to have a pay-back period that is less than the expected lifetime of the building. A second and equally important consideration has been to make the measures simple and convenient both for designers and regulatory officials. And finally the aim has been to make the requirements as rational as possible. Where there was conflict between simplicity and rationality, simplicity has been given priority.

Buildings have been separated into three different types on the basis of their ratio of envelope area to gross floor area. The reason for this way of categorizing is that heat loss is a function of the amount of exposed surface but heat gains from occupants, lights and equipment are related to floor area. Thus a building with a high ratio of exposed surface to floor area will have only a small part of its heat losses made up by heat produced from internal activities. Consequently it will be appropriate to require this type of building to have more thermal resistance in the shell than would be justifiable in a building with a low ratio of exposed surface to floor area.

All buildings that have more envelope area than gross floor area are classified as type 1. This category includes detached and row-type housing, all single-storey buildings regardless of size and other low-rise buildings of moderate size. Type 2 buildings are those with exposed surface areas ranging between 60 and 100 per cent of their gross floor area. Type 3 buildings are those that have exposed surface areas that are less than 60 per cent of gross floor area. This last category includes most large high-rise commercial buildings; most multistorey apartment buildings will fall into the intermediate category. This way of grouping buildings is certainly not perfect but it is simple to use and takes account of one very important parameter in building design.

The thermal resistance requirements for the walls and roof of type 1 buildings have been derived using the procedure outlined in Building Research Note 105 (1) and data on the incremental cost of achieving various thermal resistances for walls and roofs obtained from a private consultant who specializes in this field. (2) The requirements are less than the analysis indicates as "optimum" in order to allow for uncertainty in the data, and to make sure that the measures do not go beyond the point of minimum life-cycle cost. The requirements for type 2 and type 3 buildings are in turn based on those for type 1, but the higher proportion of the envelope heat loss that comes from lights and people in these types of buildings is taken into account.

The criteria for windows are somewhat arbitrary: they have been selected to conserve energy while still permitting reasonable amounts of glass in the enclosures of buildings. For example, type 1 buildings in the coldest parts of the country would be restricted to having less than 14 per cent of the wall area in double glazing, whereas in the mildest areas this could go up to 20 per cent. The amount of glazed areas could be increased, of course, by using triple or quadruple glazing. In type 3 commercial buildings, on the other hand, at least 28 per cent of the wall area could be double glazed even in the coldest regions.

The requirements for lighting systems have been selected so that designers will be able to achieve lighting systems that meet the essential illumination needs of the occupants of a building. However, inefficient lamps and fixtures should not be used. The power budget for lighting systems represents a compromise between the ultimate in energy conservation and the ultimate in lighting. It is based on the judgement and experience of several lighting system designers.

REQUIREMENTS FOR ENCLOSURES AND LIGHTING SYSTEMS

This report is intended to be used in conjunction with ASHRAE Standard 90-75 on Energy Conservation in New Building Design.[3] The chapters in Standard 90-75 that deal with the exterior envelope requirements and lighting systems are not as stringent as has been judged appropriate for Canadian conditions, so modified versions of these two chapters have been prepared to meet these conditions. These chapters can be used as replacements for Sections 4 and 9 of Standard 90-75, or they can be used by themselves to limit the energy needed to operate heating and lighting systems in buildings.

CHAPTER 4: EXTERIOR ENVELOPE REQUIREMENTS

4.1 Scope

The criteria of this section establish the minimum requirements for thermal design of the exterior envelope of new buildings. The tables in this section are intended only for use in defining these criteria. In cases where a systems analysis approach to building design is desired, the requirements of Section 10 of this Standard shall apply.

4.2 General

4.2.1 The intent of this section is to provide minimum requirements for building envelope construction in the interests of energy conservation. These requirements are not intended to be, nor should they be construed as, the optimization of energy-conserving practices.

4.2.2 Classification of Buildings

Buildings shall be divided into three categories on the basis of the ratio of exposed envelope area to gross floor area of finished areas.

4.2.2.1 Type 1 buildings shall include all buildings where the total area of the exposed parts of the enclosure exceeds the total gross floor area of all the finished areas.

4.2.2.2 Type 2 buildings shall include all buildings where the total area of the exposed parts of the enclosure is between 0.6 and 1.0 times the total gross floor area of all the finished areas.

4.2.2.3 Type 3 buildings shall include all buildings where the total area of the exposed parts of the enclosure is less than 0.6 times the total gross floor area of all the finished areas.

4.2.3 The gross area of exterior walls consists of all opaque wall areas (including foundation walls, between-floor spandrels, peripheral edges of floors, etc.), window areas (including sash), and door areas, where such surfaces are exposed to outdoor air and enclose a heated space (including interstitial areas between two such spaces).

4.2.4 A roof assembly shall be considered as all components of the roof/ceiling envelope through which heat flows, thereby creating a building transmission heat loss or gain, where such an assembly is exposed to outdoor air and encloses a heated space.

4.2.4.1 The gross area of a roof assembly consists of the total area of the interior surface of such assembly, including skylights exposed to the heated space.

4.2.4.2 Where return-air ceiling plenums are employed, the roof/ceiling assembly shall:

a) for thermal transmittance purposes, not include the ceiling nor the plenum space as part of the assembly, and

b) for gross area purposes, be based upon the interior face of the upper surface of the plenum space.

4.2.5 The R value of any assembly such as roof/ceiling, wall or floor may be lower than the value specified in the various sections of this standard, provided that the R value for some other assembly exceeds its minimum required value by enough to make the total heat loss through the building enclosure equal to or less than it would have been if all the specified R values had been adhered to.

4.2.5.1 The R value for any assembly such as roof/ceiling, wall or floor shall be calculated using the procedures given in the ASHRAE Handbook of Fundamentals and data supported by laboratory test reports that are acceptable to the authority having jurisdiction.

4.3 Criteria for Thermal Resistance

4.3.1 Walls

The opaque walls that are exposed to outside conditions or to unheated adjacent spaces of any building within the scope of this Standard as set out in Section 2 shall have a thermal resistance that equals or exceeds the values given in Table I.

TABLE I THERMAL RESISTANCE (R) FOR OPAQUE WALLS

Building Type \ Celsius Heating Degree-Days	Fewer than 3500	Between 3500 and 5000	Between 5000 and 6500	More than 6500
Type 1	2.5* (14.2)**	3.0 (17.0)	3.4 (19.3)	3.7 (21.0)
Type 2	2.0 (11.4)	2.5 (14.2)	3.0 (17.0)	3.4 (19.3)
Type 3	1.5 (8.5)	2.0 (11.4)	2.5 (14.2)	3.0 (17.0)

* R values have units m^2 K/W
** Values in parentheses are equivalents in ft^2 hr F/Btu

4.3.2 Roof/ceiling

The roof/ceiling of any building that is within the scope of this Standard and that must be of non-combustible construction shall have a thermal resistance that equals or exceeds the values given in Table II; the roof/ceiling in other buildings where combustible construction is permitted shall have a thermal resistance that equals or exceeds the values given in Table III.

4.3.3 Floors

4.3.3.1 Unheated spaces are spaces that are not within the scope of this Standard by virtue of paragraph 2.1.2 (i.e., spaces that do not need to have any thermal resistance in their exterior walls).

TABLE II THERMAL RESISTANCE (R) FOR ROOF/CEILING AND FLOORS OVER UNHEATED SPACES (NON-COMBUSTIBLE CONSTRUCTIONS)

Building Type \ Celsius Heating Degree-Days	Fewer than 3500	Between 3500 and 5000	Between 5000 and 6500	More than 6500
Type 1	2.4* (13.6)**	2.8 (15.9)	3.2 (18.2)	3.5 (19.9)
Type 2	2.0 (11.4)	2.4 (13.6)	2.8 (15.9)	3.2 (18.2)
Type 3	1.5 (8.5)	2.0 (11.4)	2.4 (13.6)	2.8 (15.9)

TABLE III THERMAL RESISTANCE (R) FOR ROOF/CEILING (COMBUSTIBLE CONSTRUCTIONS)

Building Type \ Celsius Heating Degree-Days	Fewer than 3500	Between 3500 and 5000	Between 5000 and 6500	More than 6500
Type 1	4.9* (27.8)**	5.7 (32.3)	6.4 (36.3)	7.0 (39.7)
Type 2	4.0 (22.7)	4.9 (27.8)	5.7 (32.3)	6.4 (36.3)
Type 3	3.0 (17.0)	4.0 (22.7)	4.9 (27.8)	5.7 (32.3)

* R values have units m^2 K/W

** Values in parentheses are equivalents in ft^2 hr F/Btu

4.3.3.2 Floors over unheated spaces in any building that is within the scope of this Standard and that must be of non-combustible construction shall have a thermal resistance that equals or exceeds the values given in Table II; in other buildings where combustible construction is permitted floors over unheated spaces shall have a thermal resistance equal to or exceeding the values given in Table IV.

4.3.3.3 The thermal resistance of the insulation around the perimeter of a heated slab-on-grade floor shall equal or exceed the values given in Table V; for an unheated slab-on-grade floor the thermal

TABLE IV THERMAL RESISTANCE (R) FOR FLOORS OVER UNHEATED SPACES (COMBUSTIBLE CONSTRUCTIONS)

Celsius Heating Degree-Days / Building Type	Fewer than 3500	Between 3500 and 5000	Between 5000 and 6500	More than 6500
Type 1	4.7* (26.7)**	4.7 (26.7)	4.7 (26.7)	4.7 (26.7)
Type 2	4.0 (22.7)	4.7 (26.7)	4.7 (26.7)	4.7 (26.7)
Type 3	3.0 (17.0)	4.0 (22.7)	4.7 (26.7)	4.7 (26.7)

TABLE V THERMAL RESISTANCE (R) AROUND PERIMETER OF HEATED SLAB-ON-GRADE FLOORS

Celsius Heating Degree-Days / Building Type	Fewer than 3500	Between 3500 and 5000	Between 5000 and 6500	More than 6500
Type 1	1.3* (7.4)**	1.7 (9.6)	2.1 (11.9)	2.5 (14.2)
Type 2	0.8 (4.5)	1.3 (7.4)	1.7 (9.6)	2.1 (11.9)
Type 3	0.8 (4.5)	0.8 (4.5)	1.3 (7.4)	1.7 (9.6)

* R values have units m^2 K/W

** Values in parentheses are equivalents in ft^2 hr F/Btu

resistance of the perimeter insulation shall equal or exceed the values given in Table VI. The insulation shall extend downward from the top of the slab for a distance of not less than 0.6 m (2 ft), or downward to the bottom of the slab and then horizontally outward for a total distance of not less than 0.6 m.

4.3.4 Walls Below Grade Level

Any space that is within the scope of this Standard and has walls that are in contact with the surrounding ground shall have the walls insulated to not less than 0.6 m (2 ft) below the grade level, or to the basement floor level. The total thermal resistance between inside air and the surrounding ground shall equal or exceed the values required for unheated slab-on-grade floors as set out in Table VI.

4.3.5 Windows

The sum of the quotients of the areas of the glazed parts of the enclosure divided by their respective R-values shall not exceed 1.6 times the quotient of the gross floor area divided by the minimum R-value for walls for the building type and climate region as given in Table I.

4.3.6 Doors

Where no storm door is provided all openings in exterior doors shall be double-glazed, and the opaque parts of the door shall have a thermal resistance of at least 0.7 m^2 K/W (4 ft^2 hr F/Btu).

TABLE VI THERMAL RESISTANCE (R) AROUND PERIMETER OF UNHEATED SLAB-ON-GRADE FLOORS

Building Type \ Celsius Heating Degree-Days	Fewer than 3500	Between 3500 and 5000	Between 5000 and 6500	More than 6500
Type 1	0.8* (4.5)**	1.3 (7.4)	1.7 (9.6)	2.1 (11.9)
Type 2	0.8 (4.5)	0.8 (4.5)	1.3 (7.4)	1.7 (9.6)
Type 3	0.8 (4.5)	0.8 (4.5)	0.8 (4.5)	1.3 (7.4)

* R values have units m^2 K/W

** Values in parentheses are equivalents in ft^2 hr F/Btu

4.4 Air Leakage

4.4.1 The requirements of this section are limited to doors and windows separating outside ambient conditions or unheated spaces from heated interior spaces; they do not apply to separations between heated spaces.

4.4.2 Compliance with the criteria for air leakage shall be determined by ASTM E283-73, Standard Method of Test for Rate of Air Leakage through Exterior Windows, Curtain Walls and Doors, at a pressure differential of 75 Pa, which is equivalent to the effect of a wind velocity of 11 m/s (25 mph).

4.4.3 The rate of air leakage shall not exceed the values given in Table VII when components are tested in accordance with paragraph 4.4.2.

TABLE VII CRITERIA FOR AIR LEAKAGE OF DOORS AND WINDOWS

Component	Maximum Allowable Rate of Air Leakage, dm^3/s
Windows	0.77 per metre of sash crack
Sliding glass doors (residential patio type)	2.5 per square metre of door area
Entrance swinging doors for residential use	6.35 per square metre of door area
Swinging, revolving or sliding doors for other than residential use	17 per metre of door crack

4.4.5 Caulking and Sealants

Exterior joints around windows and door frames, between wall cavities and window and door frames, between wall and foundation, between wall and roof, between wall panels, at penetrations or utility services through walls, floors and roofs, and all other openings in the exterior envelope shall be caulked, gasketed, weatherstripped, or otherwise sealed.

References

1. Stephenson, D.G. Determining the Optimum Thermal Resistance for Walls and Roofs, Building Research Note #105, Division of Building Research, National Research Council of Canada, January 1976.

2. Residential Construction Costs Entailed for Higher Levels of Thermal Resistance, Special Report prepared by Scanada Consultants Ltd. for Division of Building Research, NRC, September 1976.

3. ASHRAE Standard 90-75. Energy Conservation in New Building Design. The Am. Soc. of Heating Refrigerating and Air-Conditioning Engrs. Inc. 345 East 47th Street, New York, NY 10017, 1975. Price $10.00.

CHAPTER 9: LIGHTING SYSTEMS

9.1 General

A lighting power budget is the upper limit of power to be available to provide the lighting needs of the building. The illumination in any space within a building shall be based on the use for which the space is intended and on efficient utilization of energy. The actual illumination design should follow the procedures recommended by the Illuminating Engineering Society in the 5th Edition of the I.E.S. Lighting Handbook to as great an extent as is possible without exceeding the allowable lighting power budget.

9.1.1 Purpose

To institute energy conserving lighting design practices while allowing the maximum freedom of design, including the use of inefficient lamps to achieve special effects, provided the total power demand does not exceed the specified lighting power budget.

9.2 Illumination Levels

9.2.1 Task Lighting

In most cases, the levels of illumination listed in the I.E.S. Lighting Handbook, Figure 9-80, are for specific tasks. In some cases, however, the levels of illumination are listed for locations (e.g., auditoria) and these levels shall be considered average levels.

9.2.2 General Lighting

In areas surrounding task locations the average level of illumination shall be not more than 1/3 the level for the tasks performed in the area. Where more than one task level occurs in a space, the general level shall be not more than 1/3 the average of the task levels.

9.2.3 Non-critical General Lighting

In circulation and seating areas, and other seldom occupied spaces or those in which no critical visual tasks occur, the average level of illumination shall not exceed 1/3 of the average general lighting in the adjacent task spaces.

9.3 Lighting Power Budget

The maximum connected load for lighting shall not exceed 24 W/m^2 (2.24 W/ft^2) based on net usable floor area of the building.

9.4 Usage

Energy used for lighting purposes is a product of the lighting load and the hours of usage. Therefore, circuiting and switching (or non-resistive dimming) shall be provided so that:

1. Lighting in task areas larger than 10 m^2 (107 ft^2) can be reduced by at least 50 per cent when the task is not being performed.

2. In any space requiring two or more branch circuits for lighting, switching shall be provided for each circuit or for portions of each circuit, so that a portion of the lighting system adequate for custodial or maintenance purposes or for effective complementary use of natural and artificial lighting may be operated without switching on/off all the lighting in that space.