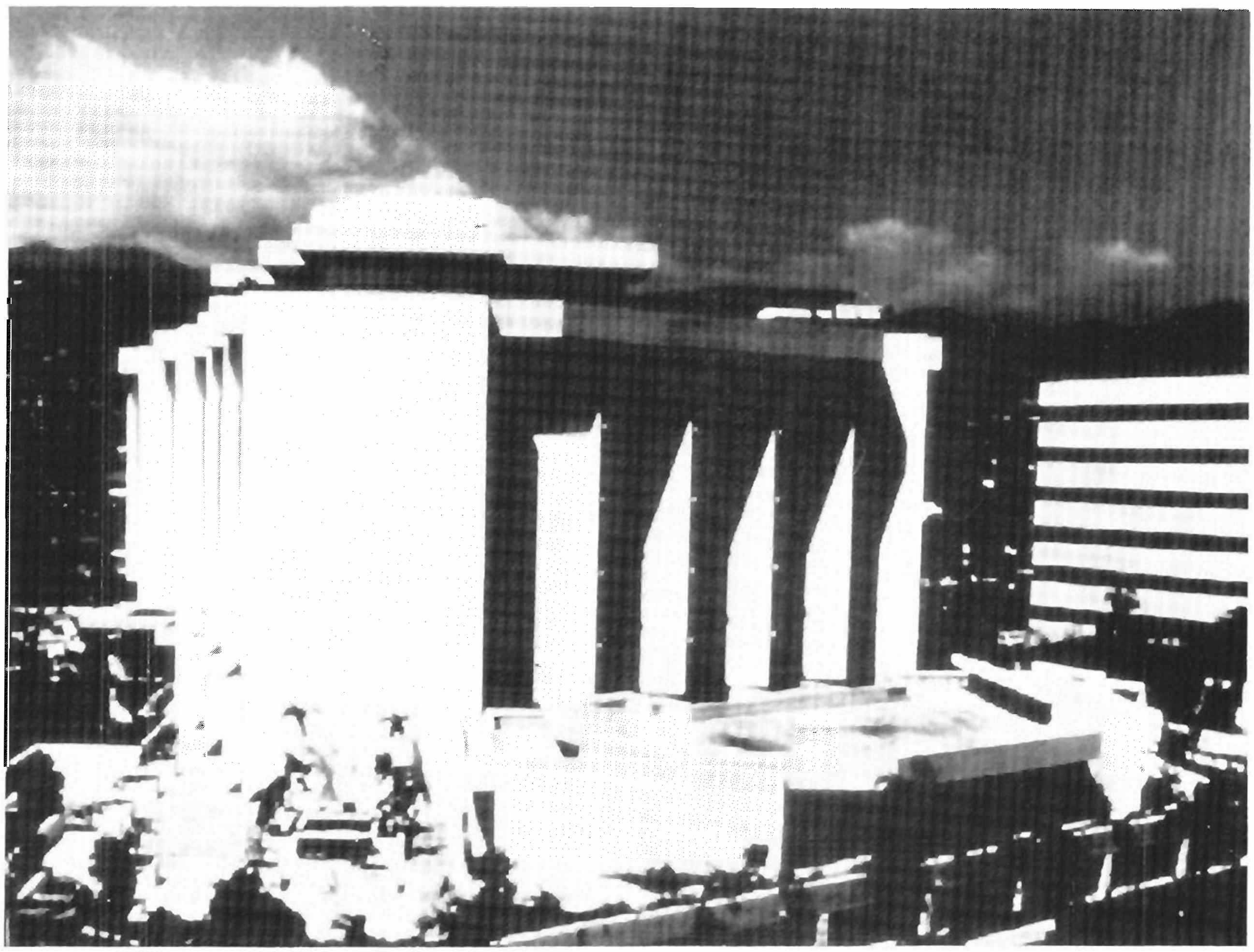
Jamaica Bureau of Standards

Jamaica National Building Code, Volume 2:

Energy Efficiency Building Code, Requirements and Guidelines, 1994

For New Buildings, Additions, and Retrofits
Except Low-Rise Residential Buildings



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Energy Sector Management Assistance Programme

ESMAP
Energy Sector Management Assistance Programme

JAMAICA NATIONAL BUILDING CODE
VOLUME 2

Energy Efficiency Building Code, Requirements and Guidelines, 1994 (EEBC-94)

For New Buildings, Additions, and Retrofits
Except Low-Rise Residential Buildings

Section 1: Requirements and
Section 2: Guidelines

Jamaica Bureau of Standards

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About the cover: The photograph shows the headquarters of the Petroleum Corporation of Jamaica (PCJ). This building was constructed during the mid-1980s as a demonstration of a very energy efficient building. It has been in operation for about seven years and has been measured to use only about 50 percent of the energy of typical office buildings in Jamaica.

JAMAICA NATIONAL BUILDING CODE
VOLUME 2

Energy Efficiency Building Code (EEBC-94)

Section 1: Requirements

December 1995

Jamaica Bureau of Standards

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ENERGY SECTOR MANAGEMENT ASSISTANCE PROGRAMME

JAMAICA ENERGY EFFICIENCY BUILDING CODE
(EEBC-94)
REQUIREMENTS FOR NEW BUILDINGS, ADDITIONS AND RETROFITS
EXCEPT LOW-RISE RESIDENTIAL BUILDINGS

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Note: Section 2: Guidelines, begins on page 45, immediately following the Requirements section. It contains its own complete contents, preface, and acknowledgments and Appendixes designated A through N, the last of which is a PC-compatible diskette with compliance spreadsheets and other data.

FOREWORD

The publication of the Energy Efficiency Building Code (EEBC) and Guidelines represents a formidable milestone in Jamaica's efforts to improve the efficiency of energy supply and use. These efforts have already resulted in savings of electricity and, hence, in the imported quantum of fuel for power generation. With Jamaica's growing demand for electricity, these energy savings will translate into reduction of scarce foreign exchange needed for fuel and electrical plant importation.

This document is the first volume of the National Building Code of Jamaica to be published. It is the culmination of a joint effort of the Jamaica Bureau of Standards, the Ministry of Public Utilities, Mining and Energy and Jamaican Architects and Engineers to develop the building Standards which are appropriate to our own climate as well as to our building designs and construction practices. At the same time, the EEBC reflects the current state of the art in international practice thereby ensuring that new buildings benefit fully from the current concepts and technologies.

We congratulate the contributors to the Energy Efficiency Building Code and Guidelines on the successful completion of their work. The EEBC Committee and Guidelines Working Group was comprised of a wide cross-section of professionals from the building industry as well as building owners, developers and financiers working in collaboration with international consultants. We are pleased to note that their work has been used as the basis of similar codes in other countries and we see this as one of Jamaica's contributions under Agenda 21 of the United Nations Conference on the Environment and Development for reducing global energy use.

Finally, we would like to thank the Canadian International Development Agency for financing the preparation of the EEBC and the UNDP/World Bank Energy Sector Management Assistance Programme (ESMAP) for its support.

Artnel Henry
Executive Director
Jamaica Bureau of Standards

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Permanent Secretary
Ministry of Public Utilities
Mining and Energy

PREFACE

Need and Benefits

Electricity, generated by the Jamaica Public Service Company, accounts for the major portion of energy used in Jamaica, with lesser contribution from Diesel Oil and Liquid Petroleum Gas. Imported oil is the major energy source for electric generation, creating a serious balance of trade deficit, and an economic hardship for the country. Electricity is the main source of energy for buildings, and provides air-conditioning, lighting, power, service hot water, and to a lesser extent, heating.

This code is tailored especially for Jamaica, taking into account climate, building materials and construction practices, mechanical and electrical equipment and systems appropriate and cost effective for Jamaica. At the same time, this code is based on energy efficiency experience in the USA and elsewhere where energy codes and standards have been used. This code can lead to a significant reduction in energy use and required electrical generating capacity and can produce long term economic and social benefits to Jamaica.

The code serves to acquaint architects, engineers, and contractors with design methods to conserve energy. It will help educate the public and private sectors, responsible for design, construction and operation of buildings, with the economic benefits of energy conscious practices, and lead to a new energy conscious ethic.

Structure and Content of the Code

This code incorporates key technical content and requirements from the latest versions of ASHRAE and other standards, which are complex second or third generation standards. However, this code uses an innovative format and structure that is intended to permit the code to be short and easy to use. The text of the code is kept short by including only the basic and prescriptive requirements. This permits a first-time reader or user to quickly grasp the code requirements and the compliance options.

All other reference materials are moved into a series of appendices that are referenced in the code. These appendices are prepared as a separate, companion volume to the EEBC requirements volume. The reference materials include: design guidance, case studies, test methods, reference data, calculation methods, compliance examples for building system performance and whole-building alternative compliance methods, which are more flexible, but also more complex. This approach permits a sophisticated user of this code to refer to the appropriate appendix to use a number of valuable, but more complicated, items that would otherwise clutter the text of the code itself. Thus, the flexibility and complexity needed by a sophisticated user is provided, but *every* user is not required to wade through the complexity.

Background of Development

In 1983, the Jamaica Ministry of Mining, Energy and Tourism, cognizant of the need to conserve energy in all sectors of the economy, including buildings, supported design input for a very energy efficient design for the Petroleum Corporation of Jamaica's new headquarters building. The Ministry also sponsored the preparation of interim construction standards for buildings in Jamaica. The construction standards included recommendations and interim provisions for an energy efficiency building code. The Ministry then requested the Jamaica Bureau of Standards (JBS) to prepare a draft energy code that would be based upon the 1983 standards and other documents and would include new criteria applicable to Jamaica. JBS established an Energy Efficiency Building Code Committee, with authority to develop a new energy code.

In 1988, under the guidance of the JBS Energy Efficiency Building Code Committee, a draft of this Jamaica Energy Efficiency Building Code (EEBC) was prepared by Fred. S. Dubin, P.E., international consultant, assisted by Ruth Mcleod, and Stephen Hodges, Construction Resource and Development Centre Ltd .

In 1990, a final draft of the code — EEBC-90 — was prepared by Joseph J. Deringer, AIA, The Deringer Group, Berkeley, CA, USA. This final draft included a reformatting of the 1988 draft with the intent to facilitate ease of compliance with the code.

The EEBC-90 code was approved in early 1991 by the council of the Bureau of Standards as to both format and content. However, the approval was with one qualification; that in keeping with the plans of Jamaica to convert to metric units, the code be converted to metric units. The EEBC-90 code was used voluntarily for compliance by the private sector and was made mandatory for government buildings in early 1991.

During 1991, a public comment period occurred for review of EEBC-90. This included a series of workshops which were given to the Jamaican building community, to explain in detail the provisions in the EEBC-90 code and how compliance could be achieved. Some 200 copies of the EEBC-90 text were distributed as part of this information dissemination and education effort. A number of comments were made with the intent to improve and to simplify the EEBC-90 code. These comments are incorporated into a revised version in October 1992, EEBC-92. In addition, this EEBC-92 version contains joint metric (inch-pound) units. The use of joint units was intended to provide an educational service as well as a transition to metric units. This current version of the EEBC code in March 1994, EEBC-94, is entirely in metric units, as is consistent with the overall metrication plan for Jamaica.

In addition, a detailed analysis was conducted of the energy, financial, and economic impacts of the requirements in the EEBC on the stock of Jamaican buildings. This work has resulted in a report by J. Cumper and S. Marston of Enertech, Ltd, Kingston, that details the results.

Request for Input

The JBS Energy Efficiency Building Code Committee welcomes comments and suggestions regarding this code. Such input will be considered as part of a planned review and revision process that is intended to result in periodic updates to this code.

Any interested party at any time may submit a request for a change or addition to the Chairman, EEBC Committee, Jamaica Bureau of Standards. The request should be accompanied by a statement of reason for the requested change and by specifics of an alternate proposal.

Sources

This draft draws heavily on the latest versions of ASHRAE/IES Standard 90.1-1989, "Energy Efficient Design of New Buildings Except New Low-Rise Residential Buildings" (and its various drafts and addenda as available at the time when the EEBC was written). Further information about this and other ASHRAE standards and reference materials (such as the Handbook of Fundamentals), may be obtained from ASHRAE Publications, 1791 Tullie Circle, NE, Atlanta, GA 30329 USA, telephone (404) 636-8400, fax: (404) 321-5478.

Also, in preparing this code, a number of existing and developing codes listed hereafter were reviewed. Test runs for Malaysia, using DOE-2.1C Computer program, to provide validation for the Malaysia code, were reviewed and provided background for quantitative values developed for this Jamaica code.

Codes and related documents reviewed include:

1. ASHRAE/IES Standard 90.1-1989, "Energy Efficient Design of New Buildings Except New Low-Rise Residential Buildings," 1989, and ASHRAE/IES Proposed Standard 90.1P, 2nd Public review Draft, Aug. 22, 1986.
2. State of Florida "Energy Efficiency Code for Building Construction," Jan. 1987 and Jan 1989 versions.
3. US DOE Voluntary Interim Standards, 1987, and Proposed Rulemaking, 1989.
4. California - Title 24, December 1986 and 1988 versions.
5. Busch, J.F. and J.J. Deringer, "A Building Envelope Standard for Malaysia," ASHRAE Far East Conference, Singapore, 1987.
3. Deringer, J.J. and J.D. Hall, "A Draft Model Energy Standard for Thailand, 1987," includes
- Appendix A: Suggested Submission Requirements
- Appendix B: Sample Calculations

   Based upon ASHRAE/IES Proposed Standard 90.1P, Second Public review Draft (1986), and the Malaysia draft standard (1986).
6. New York State Energy Efficiency Code, 1987.
7. Northwest Power Planning Council, "Model Conservation Standards Code", Feb. 1985.
8. Northwest Power Planning Council, Comparison of Five Major Energy Codes, 1987.
9. Washington State Energy Code, Feb. 1985.
10. Singapore Handbook - Energy Conservation in Buildings and Building Services, 1979.
11. Energy Conservation Standards for Jamaica, F. Dubin, 1984.
12. Tennessee Valley Authority, Energy Design Guidelines Manual, 1985.
13. Jamaica Bureau of Standards, "Energy Conservation Code Addendum to National Building Code - Jamaica," first draft, 1985.
14. Construction Manual - Energy Conservation for Building in Jamaica, Dubin-Bloome Associates, April, 1983.

ACKNOWLEDGMENTS

This code was prepared by the consultants in collaboration with the Jamaica Bureau of Standards Energy Efficiency Building Code (EEBC) Committee with extensive efforts by their sub-committees and the assistance and co-operation of many individuals and Jamaica agencies.

JBS Energy Efficiency Building Code Committee Members:

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Mr. Roddy Ashby
Miss Grace Ashley
Mr. Milton Baker
Mr. Clive O.B. Broomfield
Mr. Richard Chambers
Mr. Dennis Chung
Mr. Roosevelt DaCosta
Mr. Marvin Goodman
Mr. Claon Rowe
Mr. H.G. Sinclair

Contribution of Consultants

A draft of this Jamaica Energy Efficiency Building Code (EEBC) was prepared in 1988 under the authority of the Energy Efficiency Building Code Committee of the JBS, by Fred. S. Dubin , P.E., Dubin-Bloome Associates, PC, East Norwalk, Ct, USA, international consultant, assisted by Jamaican consultants Ruth Mcleod, and Stephen Hodges, Construction Resource and Development Centre Ltd. The EEBC-90 draft was prepared in November, 1990 by Joseph J. Deringer, AIA, The Deringer Group, Berkeley, CA, USA. EEBC-90 consisted of reformatting the 1988 draft to facilitate ease of code compliance. This current version of the code — EEBC-94 — was prepared in March, 1994, by Joseph J. Deringer, with substantial inputs from an extended public review of EEBC draft versions EEBC-90 and EEBC-92, from the EEBC committee members, and from Jamaican consultants including John Cumper, Donat Dundas, Paul Hay, Nadine Isaacs, Steve Marston, Keith Walters, and Ken Wedderburn.

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(b) Agencies and individuals who provided a rich source of technical material from existing Codes in the United States and elsewhere, including American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE), U.S. Department of Energy (US DOE), U.S. Agency for International Development (US AID); Tennessee Valley Authority (TVA); Bonneville Power Authority (BPA), States of California, Florida, Washington, Oregon, Massachusetts, New York, Tennessee.

1. PURPOSE

1.1 Energy, Comfort, and Productivity. Encourage the design of new buildings and the retrofit of existing buildings so that they may be constructed, operated and maintained in a manner that reduces the use of energy without constraining the building function, nor the comfort or productivity of the occupants and with appropriate regard for cost considerations.

1.2 Minimum Standards and Criteria. Provide minimum standards and criteria for energy conserving design of new buildings and major retrofits.

1.3 Recommended Practices. Provide guidance for energy conserving design that demonstrates good professional judgment and exceeds minimum standards and criteria. (Refer to the Appendices to this code).

1.4 Calculation Methods and Tools. Provide calculation methods, compliance forms, and tools for determining compliance with these criteria and minimum standards. The tools include both manual and microcomputer-based calculation procedures.

2. SCOPE

This code sets forth requirements and recommended guidelines for the effective use of energy in the design of buildings intended for human occupancy.

2.1 Building Systems Covered. The requirements and guidelines apply to the building exterior envelopes and to energy systems, equipment and auxiliaries for lighting, ventilating, air-conditioning, service water heating, and energy managing.

2.2 Application. This code applies to all buildings or portions of buildings that provide facilities or shelter for human occupancy, and use energy primarily to provide human comfort; except single family residential buildings and multifamily residential buildings of three or fewer stories above grade.

2.3 ***Exemptions:*** This code does not apply to:

a) those areas of buildings intended primarily for manufacturing or commercial or industrial processing.
b) buildings or separately enclosed identifiable areas having any combination of lighting, ventilating, air-conditioning, or service water heating systems whose combined peak design rate of energy usage is less than 11 W/m^2 of gross floor area.
c) buildings of fewer than 93 square metres of gross floor area.
d) seasonally occupied agricultural buildings.
e) those areas of buildings intended primarily for product storage, for which mechanical air-conditioning is not used.
f) Qualified historical buildings, which have been specifically designated as historically significant by a parish or local governing body, or listed in "The National Register of Historical Places" or which have been determined to be eligible for listing. Reasonable alternative energy efficient practices shall be used for such qualified historical buildings.

Where specifically noted in this code, certain other buildings or elements of buildings may also be exempt.

2.4 New Buildings. All new buildings shall be designed to comply with the requirements of this code.

2.5 Existing Buildings

2.5.1 Additions. Additions to existing buildings shall be considered new building construction, and that portion of the building being added shall meet the requirements of this code.

2.5.2 Renovated Buildings. Buildings being renovated shall meet the requirements of this code, for those energy-related components being retrofitted or replaced.

"Renovated building" means a building undergoing alteration that varies or changes exterior envelope conditions, fenestration, lighting systems, ventilation systems, air-conditioning systems, or service water heating systems, provided that the estimated cost of the renovation exceeds 30 percent of the assessed value of the structure.

Exceptions: Alterations or repairs which do not fully comply with the requirements of this code are permitted if:

a) full compliance is determined to be physically impossible and/or economically impractical.
b) the alteration or repair improves the energy efficiency of the building.
c) the alteration is energy efficient and is necessary for the health, safety and welfare of the general public.

2.5.3 Replacement of Key Energy-Using Equipment. Lighting, electrical, and water heating systems and equipment being replaced in an existing building shall meet the applicable requirements of Sections 5, 6 and 9 of this code, respectively. Ventilating and air-conditioning (VAC) systems and equipment being replaced in an existing building shall meet the applicable component requirements of Sections 7 and 8 of this code.

2.5.4 Change of Occupancy. If any change in the character of occupancy for a building or portion of a building requires an increase in the demand for either fossil fuel or electrical energy, then that portion of the building shall be renovated to meet the requirements of this code.

2.5.5 Operations and Maintenance (O&M). Proper O&M can contribute substantially to building energy efficiency. Recommendations for effective O&M are contained in Appendix J.

3. COMPLIANCE

3.1 Purpose. The purpose of this section is to illustrate the methods by which compliance with this code can be demonstrated.

3.2 Scope. This section applies to all buildings for which compliance with this code is claimed.

3.3 General. This code provides different paths by which compliance can be determined, as shown in Figure 3-1.

The Prescriptive Requirements may be used when the minimum amount of effort to determine compliance is desired. System Performance Requirements are available for the building envelope (Section 4) and lighting (Section 5) portions of this code. These requirements should be used when more innovative design or flexibility is desired.

The Building Energy Budget or Energy Cost Budget Methods (Section 12) should be used when the most innovative design concepts are being considered or when the proposed design fails to meet either the Prescriptive or System Performance Requirements of this code while meeting the Basic Requirements.

3.4 Requirements

3.4.1 Basic Requirements. All building designs shall meet the basic requirements specified in sections 4.4, 5.4, 6.4, 7.4, 8.4, 9.4, 10.4, and 11.4 of this code.

3.4.2 Additional Requirements - Prescriptive Criteria or System Performance Criteria or Both. Either the requirements of 3.4.2 or of 3.4.3 shall be met.

3.4.2.1 The building envelope design shall meet either the Prescriptive requirements of 4.5 or the System Performance requirements of 4.6.

3.4.2.2 The lighting design shall meet either the Prescriptive requirements of 5.5 or the System Performance requirements of 5.6.

3.4.2.3 The ventilating, and air-conditioning systems design shall meet the Prescriptive requirements of 7.5.

3.4.2.4 The service water heating systems and equipment design shall meet the Prescriptive requirements of 9.5.

3.4.3 Building Energy Cost Budget Method. The Building Energy Cost Budget method (Section 12) may be used for compliance instead of the Prescriptive and/or System Performance Criteria of 3.4.2. If the Building Energy Cost Budget method is used, the building design shall meet the criteria of Section 12. Buildings with gross conditioned floor area greater than 4,000 m^2 may comply using either the Building Energy Cost Budget method in Section 12 or the provisions of 3.4.2.

The Building Energy Budget method described in Appendix C may also be used. If the Building Energy Budget method is used, the building design shall conform with the criteria and procedures specified in Appendix C.

3.4.4 Compliance Forms. One of three sets of compliance forms contained in Appendix M shall be used to document compliance:

a) For buildings with gross conditioned floor area greater than 4,000 m^2, compliance form WBEB-1 shall be used.
b) For buildings with gross conditioned floor area equal to or less than 4,000 m^2, a set of 10 compliance forms shall be used.
c) For buildings with gross conditioned floor area equal to or less than 1,000 m^2, a shorter set of 5 compliance forms for small buildings may be used.

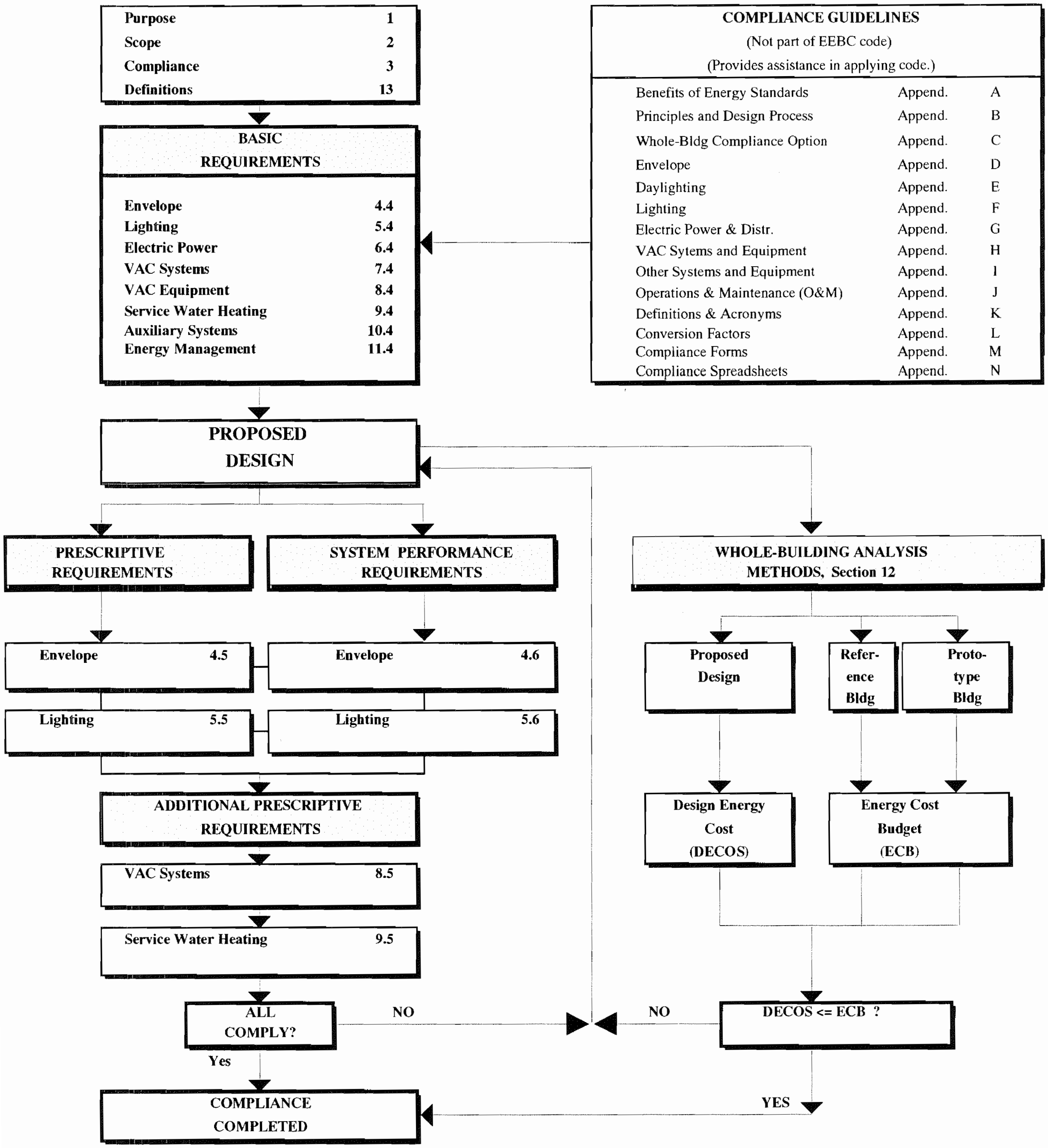


FIG. 3-1: Alternate Methods of Achieving Compliance

4 BUILDING ENVELOPE

4.1 Purpose. This section sets forth basic, prescriptive, and system performance requirements for the energy performance of building envelopes. This section also provides credits for the use of daylighting in conjunction with automatic electric lighting controls.

4.2 Scope. This section applies to air-conditioned buildings with a total cooling load of 35 kW or greater. In addition, the roof and wall requirements of sections 4.5 and 4.6 are recommended for consideration in non-air-conditioned buildings, to improve comfort conditions.

4.3 General. For compliance to be achieved, compliance with the Basic Requirements listed in section 4.4 is mandatory under all compliance paths. In addition, to comply with the envelope requirements, one of the following sets of requirements must be met or exceeded:

a) the Prescriptive Requirements of 4.5, or

b) the System Performance Requirements of 4.6.

The envelope requirements are sensitive to the range of climate variation in Jamaica. Three climate zones have been designated, as shown in Figure 4-1.

4.4 Basic Requirements - Air Leakage. This section specifies minimum air leakage requirements for buildings that are mechanically cooled. Also, Appendix D contains additional recommended criteria, standards and procedures for good practice.

4.4.1 Caulking and Weatherstripping. Effective means of caulking and weatherstripping shall be used to seal all penetrations through the exterior surfaces of the building. Such penetrations or joints include the following:

a) around window or door frames

b) between wall and foundation

c) between wall and roof

d) through wall panels and top and bottom plates in exterior walls

e) at penetrations of utility services or other service openings through walls, floors, and roofs

f) between wall panels particularly at corners and changes in orientation

g) between wall and floor where floor penetrates wall

h) around penetrations of chimneys, flue vents, or attic hatches.

4.4.2 Windows. Windows enclosing conditioned spaces shall be designed to meet one of the following standards for air leakage:

a) ANSI/AAMA 101-1985 Aluminum Prime Windows.

b) ASTM D 4099-83, Poly Vinyl Chloride (PVC) Prime Windows.

c) ANSI/NWMA I.S. 2-80 Wood Window Units (Improved Performance Rating Only).

Manufacturers shall provide documentation certifying compliance with these criteria.

4.4.3 Swinging, Revolving or Sliding Doors. These types of doors shall be used at all entrances and they shall be designed to limit air leakage.

When spaces have regular high volume traffic through the building envelope such as retail store entrances and loading bays, estimates of air leakage for VAC system design shall be based on air exchange by traffic flow.

To reduce infiltration due to stack-effect draft in multi-story buildings, the use of vestibules or revolving doors on all primary entries and exits should be considered.

Door manufacturers shall provide documentation certifying compliance with these criteria.

4.4.3.1 Sliding Doors. These doors shall meet one of the following standards for air leakage:

a) ANSI/AAMA 101-1985 Aluminum Sliding Glass Doors.

b) ANSI/NWMA I.S.3-83 Wood Sliding Patio Doors.

4.4.3.2 Swinging or Revolving Doors. Commercial entrance swinging or revolving doors shall limit air leakage to a rate not to exceed 6.35 $L/s{\cdot}m^2$ of door area, when tested at standard test conditions in accordance with ASTM E283-84.

Residential swinging doors shall limit air leakage to a rate not to exceed 2.54 $L/s{\cdot}m^2$ of door area when tested at standard test conditions in accordance with ASTM E283-84.

Exception: Air curtains may be used in very high volume entrances only when revolving or self-enclosing sliding doors are not appropriate.

4.4.4 Skylights. The infiltration coefficient of skylights shall be less than or equal to 0.254 $L/s{\cdot}m^2$.

4.5 Prescriptive Requirements for Exterior Walls and Roofs. These prescriptive wall and roof requirements apply only to buildings with gross conditioned floor less than 4,000 m^2. Larger buildings shall use either the wall and roof system performance compliance methods in 4.6, or the whole-building energy cost budget compliance method in section 12.

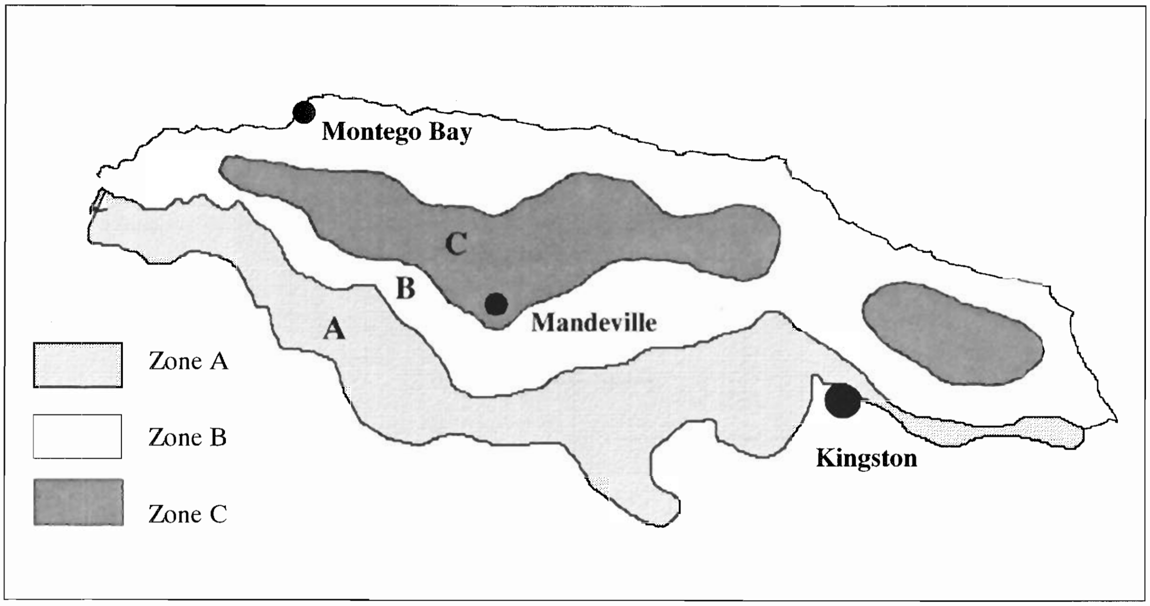


Figure 4-1: Jamaica - Climate Zones

4.5.1 Exterior Walls. Compliance is achieved if the exterior walls of building envelopes meet the appropriate set of prescriptive wall requirements listed in Tables 4-1 and 4-2. Each table contains five columns of options, to provide flexibility in achieving compliance.

To comply, first select the appropriate table for the predominant function of the building under consideration. Use Table 4-1 for office buildings, and Table 4-2 for all other building types.

Second, select one of the set of rows in the table, based upon the overall window-to-wall ratio (WWR) for the building envelope. Third, within the set of rows selected within the table, compliance is obtained by meeting or exceeding all requirements within any one of the five columns.

Climate adjustment: The requirements in Tables 4-1 and 4-2 have been determined for climate zone A (e.g., Kingston). If the building location is in climate Zone B, then the minimum percent of window area that is externally shaded may be reduced by 5% from those listed in the tables. If the building location is in climate Zone C, then the minimum percent of window area that is externally shaded may be reduced by 10% from those listed in the tables. If further or different adjustments for climate are desired, then the system performance compliance in 4.6.1 may be used.

4.5.2 Roofs. Compliance is achieved if the roof meets one of the sets of prescriptive roof requirements listed in Table 4-3. Within the table, select the column of requirements that best matches the roof construction characteristics. The roof design must meet or exceed all of the requirements contained in the column selected.

Climate adjustment: The requirements in Table 4-3 have been determined for climate zone A (e.g., Kingston). If the building location is in climate Zone B, then the maximum U-values may be increased by 5% from those listed in the table. If the building location is in climate Zone C, then the maximum U-values may be increased by 10% from those listed in the table. If further or different adjustments for climate are desired, then the roof system performance compliance procedures in 4.6.2 may be used.

Table 4-1 EXTERNAL WALL PRESCRIPTIVE REQUIREMENTS

Building Type: SMALL OFFICE

Gross Floor Area less than 4,000 sq. metres

Requirement: OTTVw of design shall be <= 61.7 W/m2

OPAQUE WALL

U-Value, W/sq.m.-K (Max.)	3.01	<--- For example, 150 mm conc. block with 12 mm rendering both sides, 1 core filled with conc. (no insulating fill)
Solar Absorptivity Coefficient (Ac) (Min.)	Ac = 0.7	<--- For example, light or white color

WWR	Fenestration Features	FENESTRATION OPTIONS 1	2	3	4	5
Less than or equal to 0.10	Percent of Window Ext. Shaded (Min.)	65%	40%	30%	20%	0%
	Glass Type (SCg of glass)	Clear (0.95)	Tinted (0.73)	Tinted (0.73)	Refl (0.60)	Refl (0.60)
	Internal Shading Devices (Max. SCx)	M. Blinds (0.74)	M. Blinds (0.57)	L. Blinds (0.53)	M. Blinds (0.50)	L. Blinds (0.46)
	Number of Panes (Min.)	1	1	1	1	1
	U-Value, W/(m2-K) (Max.)	4.60	4.60	4.60	4.60	4.60
	Automatic daylight controls on elect. lights	NO	NO	NO	NO	NO
From 0.11 to 0.20	Percent of Window Ext. Shaded (Min.)	90%	80%	65%	40%	0%
	Glass Type (SCg of glass)	Tinted (0.73)	Refl (0.60)	Refl (0.50)	Refl (0.40)	Tinted (0.73)
	Internal Shading Devices (Max. SCx)	L. Blinds (0.53)	L. Blinds (0.44)	L. Blinds (0.38)	L. Blinds (0.29)	L. Blinds (0.53)
	Number of Panes (Min.)	1	1	1	1	1
	U-Value, W/(m2-K) (Max.)	4.60	4.60	4.60	4.60	4.60
	Automatic daylight controls on elect. lights	NO	NO	NO	NO	YES
From 0.21 to 0.30	Percent of Window Ext. Shaded (Min.)	100%	80%	80%	70%	50%
	Glass Type (SCg of glass)	Refl (0.60)	Refl (0.40)	Tinted (0.58)	Refl (0.40)	Tinted (0.73)
	Internal Shading Devices (Max. SCx)	L. Blinds (0.44)	L. Blinds (0.29)	L. Blinds (0.36)	M. Blinds (0.34)	L. Blinds (0.53)
	Number of Panes (Min.)	1	1	2	2	1
	U-Value, W/(m2-K) (Max.)	4.60	4.60	2.95	2.95	4.60
	Automatic daylight controls on elect. lights	NO	NO	NO	NO	YES
From 0.31 to 0.40	Percent of Window Ext. Shaded (Min.)	100%	85%	50%	25%	10%
	Glass Type (SCg of glass)	Refl (0.40)	Refl (0.40)	Refl (0.50)	Refl (0.40)	Refl (0.40)
	Internal Shading Devices (Max. SCx)	M. Blinds (0.34)	M. Blinds (0.34)	M. Blinds (0.42)	M. Blinds (0.33)	M. Blinds (0.34)
	Number of Panes (Min.)	1	2	1	1	2
	U-Value, W/(m2-K) (Max.)	4.60	2.95	4.60	4.60	2.95
	Automatic daylight controls on elect. lights	NO	NO	YES	YES	YES
From 0.41 to 0.50	Percent of Window Ext. Shaded (Min.)	100%	50%	40%	35%	30%
	Glass Type (SCg of glass)	Tint (0.58)	Tint (0.58)	Tint (0.58)	Refl (0.40)	Refl (0.40)
	Internal Shading Devices (Max. SCx)	L. Blinds (0.36)	M. Blinds (0.39)	L. Blinds (0.36)	M. Blinds (0.34)	L. Blinds (0.29)
	Number of Panes (Min.)	2	2	2	2	2
	U-Value, W/(m2-K) (Max.)	2.95	2.95	2.95	2.95	2.95
	Automatic daylight controls on elect. lights	NO	NO	YES	YES	YES

Notes:

1 Calculations use EEBC-94 Eq. (4-1) and (4-2). For WWR > 0.50, use the System Performance compliance method in EEBC 4.6.1.

3 Percent of window that is externally shaded from 8 am to 5 pm, April 21 through October 21.

4 Double pane low-e glazings are very effective, especially in conjunction with daylighting controls.

5 Wall construction always 152 mm block, 2 of every 4 cores filled w/concrete, unless otherwise specified

6 SCg = Shading coefficient of the glass only. Alternate glazings with equivalent or lower SCg may be used.

7 Internal Shading Devices: Venetian blinds, shades, or equivalent. SCx = combined effective shading coefficient of both the glass and the internal shading device. Other devices with equivalent or lower SCx may be used. See Table D-5 in Appendix D of the Guidelines for typical SCx values and comparable SCg values.

8 Tables 29, 35, and 36, 1985 ASHRAE Handbook of Fundamental, Chapter 27, were used as basis for fenestration input values.

9 U-Values for glazings are Summer values and include shades if applicable (from Chapter 27, Table 13, 1985 H of F)

Table 4-2 EXTERNAL WALL PRESCRIPTIVE REQUIREMENTS ALL BUILDING TYPES (except Offices)

Requirement: OTTVw of design shall be <= 55.1 W/m2

OPAQUE WALL

U-Value, W/m2-K	(Max.)	3.01	<--- For example, 150 mm conc. block with 12 mm rendering both sides, 1 core filled with conc. (no insulating fill)
Solar Absorptivity Coef. (Ac)	(Min.)	Ac = 0.7	<--- For example, light or white color

WWR	Fenestration Features		FENESTRATION OPTIONS 1	2	3	4	5
Less than or equal to 0.10	Percent of Window Ext. Shaded	(Min.)	90%	75%	70%	45%	10%
	Glass Type	(SCg of glass)	Clear (0.95)	Tinted (0.73)	Refl (0.60)	Refl (0.50)	Refl (0.40)
	Internal Shading Devices	(Max. SCx)	L Blinds (0.67)	L Blinds (0.53)	M. Blinds (0.50)	L Blinds (0.38)	L Blinds (0.30)
	Number of Panes	(Min.)	1	1	1	1	1
	U-Value, W/(m2-K)	(Max.)	4.60	4.60	4.60	4.60	4.60
	Automatic daylight controls on elect. lights		NO	NO	NO	NO	NO
From 0.11 to 0.20	Percent of Window Ext. Shaded	(Min.)	100%	80%	70%	30%	0%
	Glass Type	(SCg of glass)	Refl (0.50)	Refl (0.40)	Refl (0.40)	Tinted (0.73)	Refl (0.50)
	Internal Shading Devices	(Max. SCx)	L Blinds (0.38)	L Blinds (0.29)	L Blinds (0.33)	L Blinds (0.53)	M. Blinds (0.42)
	Number of Panes	(Min.)	1	1	2	1	1
	U-Value, W/(m2-K)	(Max.)	4.60	4.60	2.95	4.60	4.60
	Automatic daylight controls on elect. lights		NO	NO	NO	YES	YES
From 0.21 to 0.30	Percent of Window Ext. Shaded	(Min.)	100%	90%	70%	40%	0%
	Glass Type	(SCg of glass)	Tinted (0.58)	Refl (0.40)	Tinted (0.73)	Refl (0.50)	Refl (0.40)
	Internal Shading Devices	(Max. SCx)	M. Blinds (0.39)	L Blinds (0.33)	L Blinds (0.53)	L Blinds (0.38)	L Blinds (0.29)
	Number of Panes	(Min.)	2	2	1	1	1
	U-Value, W/(m2-K)	(Max.)	2.95	2.95	4.60	4.60	4.60
	Automatic daylight controls on elect. lights		NO	NO	YES	YES	YES

Notes:

1 For WWR > 0.50, use the Wall System Performance compliance method in EEBC 4.6.1.

2 Calculations use Equations 4-1 and 4--2 of the EEBC-94

3 Percent of window externally shaded: the percent of window surface area that is in shade from 8 am to 5 pm, from April 21 through October 21.

4 Double pane low-e glazings are very effective, especially in conjunction with daylighting controls.

5 Wall construction always 152 mm block, 2 of every 4 cores filled w/concrete, unless otherwise specified

6 SCg = Shading coefficient of the glass only. Alternate glazings with equivalent or lower SCg may be used.

7 Internal Shading Devices: Venetian blinds, shades, or equivalent. SCx = combined effective shading coefficient of both the glass and the internal shading device. Other devices with equivalent or lower SCx may be used. See Table D-5 in Appendix D of the Guidelines for typical SCx values and comparable SCg values.

8 Tables 29, 35, and 36, 1985 ASHRAE Handbook of Fundamental, Chapter 27, were used as basis for calculations.

9 U-Values for glazings are Summer values and include shades if applicable (from Chapter 27, Table 13, 1985 Hof F)

Table 4-3: **PRESCRIPTIVE REQUIREMENTS FOR ROOFS**

Requirement: OTTVr of design shall be <= 20.0 W/sq.m

		OPTIONS					
		1	2	3	4	5	6
Opaque Portion of Roof		**Concrete Deck**		**Pitched Frame**		**Metal Deck**	
U-Value, W/m.sq.-K	(Max.)	1.08	0.91	0.74	0.62	0.74	0.57
Weight, kg/sq.m	(Min.)	371	371	58	58	34	34
Solar Absorptivity Coefficient (Ac)	(Min.)	0.70	1.00	0.75	1.00	0.70	1.00

NOTES:

1 U-Values listed for each type of opaque roof construction are approximately for:
Added R-Value = 0.7 in columns 1, 3, and 5.
Added R-Value = 1.4 in columns 2, 4, and 6.

2 Example Solar Absorptivity Coefficients: Asphalt, Dark Roof = 1.00. Gravel = 0.70. Light pebbles= .50
Mildew resistant white = .42

3 Skylights: Section 4.7.2 and Table 4-4 may be used in conjunction with this table to include up to indicated pecentages of skylight areas, if daylighting controls are used as specified.

4.6 System Performance Requirements for External Walls and Roofs

4.6.1 Wall System Performance Requirements. The prescriptive exterior wall requirements of 4.5.1 have limited compliance flexibility. If additional compliance flexibility is desired, then the system performance compliance procedure described below may be used in place of the wall prescriptive requirements.

4.6.1.1 Wall $OTTV_w$ Requirements. The Overall Thermal Transfer Value (OTTVw) for the exterior walls of a building shall not exceed the following values:

a) 67.7 W/m^2 for large office buildings, with gross conditioned floor area equal to or greater than 4,000 m^2.

b) 61.7 W/m^2 for smaller office buildings, with gross conditioned floor area less than 4,000 m^2.

c) 55.1 W/m^2 for all other buildings.

4.6.1.2 Compliance: Calculating the $OTTV_i$ for an Individual Wall. The Overall Thermal Transfer Value (OTTVi) for each exterior wall section that has a different orientation shall be determined by:

$$OTTV_i = (TD_{eq}-DT) \times CF \times A_c \times U_w \times (1-WWR) + DT \times U_w \times (1-WWR) + SF \times CF \times SC \times WWR + DT \times U_f \times WWR \qquad \text{Eq (4-1)}$$

where,

$OTTV_i$ = Overall thermal transmittance value for the ith specific wall orientation being considered, W/m^2.

A_c = Coefficient of solar absorptance for the surface of the opaque wall.

U_w = Thermal transmittance of the opaque wall, W/m^{2}K.

WWR = Window-to-wall area ratio for the gross exterior wall being considered.

TD_{eq} = Equivalent indoor-outdoor temperature difference, in °C, which incorporates the effects of solar gains into the opaque wall. Can vary by location and climate zone.

DT = Temperature difference, in °C, between indoor temperature and outdoor temperature. Can vary by location and climate zone.

U_f = Thermal transmittance of fenestration system in W/m$^2\cdot$K.

SC = Shading coefficient of the fenestration system.

SF = Average hourly value of the solar energy incident on the windows, 372 W/m^2.

CF = Correction factor to account for the variation in the available solar, due to the orientation of the wall, for the wall section being considered.

4.6.1.3 Compliance: Calculating the $OTTV_w$ for all Walls of a Building. The Overall Thermal Transfer Value ($OTTV_w$) for the total exterior gross wall area of the building is a weighted average of the $OTTV_i$'s computed for the individual walls. The $OTTV_w$ shall be determined by:

$$OTTV_w = (Ao_1 \times OTTV_1 + Ao_2 \times OTTV_2 + ... + Ao_i \times OTTV_i) / (Ao_1 + Ao_2 + ... + Ao_i) \quad \text{Eq (4-2)}$$

where

Ao_i = Gross wall area for the i^{th} exterior wall section in m^2.

$OTTV_i$ = Overall thermal transfer value for the i^{th} wall section, from Eq. (4-1).

Examples of wall compliance values and details of the wall compliance calculation procedures for the System Performance path are contained in Appendix D. Also, microcomputer spreadsheets are available to facilitate compliance.

4.6.2 Roof System Performance Criteria. If more flexibility is desired in complying with the roof thermal performance criteria than is available using the prescriptive criteria of section 4.5.2, then this roof system performance procedure may be used in place of the prescriptive roof requirements.

4.6.2.1 Roof $OTTV_r$ Requirements. The Overall Thermal Transfer Value ($OTTV_r$) for the gross area of the roof shall not exceed 20 W/m^2.

4.6.2.2 Roof $OTTV_r$ Compliance. For a roof without skylights, compliance with the Roof Overall Thermal Transfer Value ($OTTV_r$) shall be determined by:

$$OTTV_r = Ac \times U_r \times (TD_{eqr} - DT) + U_r \times DT \quad \text{Eq (4-3)}$$

For a roof with skylights, ($OTTV_r$) shall be determined by:

$$OTTV_r = Ac \times U_r \times (TD_{eqr} - DT) \times (1-SRR) + U_r \times DT \times (1-SRR) + SF \times SC_s \times SRR + U_s \times DT \times SRR \quad \text{Eq (4-4)}$$

where

$OTTV_r$ = Overall thermal transmittance value for the roof assembly in W/m^2.

Ac = Coefficient for solar absorptance of the opaque portion of the roof.

U_r = Thermal transmittance of the roof assembly, including both above and below deck insulation, in $W/m^2 \cdot K$.

TD_{eqr} = Equivalent indoor-outdoor temperature difference, in °C, which incorporates the effects of solar gains into the roof being considered.

SRR = Skylight-to-roof area ratio.

SF = Solar factor, for horizontal surfaces, average hourly value of the solar energy incident on the skylights, 435 W/m^2.

Examples of roof compliance values and details of the roof compliance calculation procedures for the System Performance path are contained in Appendix D. Also, microcomputer spreadsheets are available to facilitate compliance.

4.7 Daylighting credits

4.7.1 Daylighting Credits for Walls with Vertical Glazing. If the following conditions are met for any exterior wall portion, then the $OTTV_i$ of the building design, for that portion of the wall, may be reduced:

a) automatic daylight controls are provided for the electric lighting system within 5.0 m of the exterior wall.

b) the effective aperture (WWR x VLT) of the wall at least 0.10.

The $OTTV_i$ is calculated in 4.6 using equation (4-1), and the reduced $OTTV_i$ value is then used to evaluate equation (4-2). If the Lighting Power Control Credit for daylighting is *not* claimed in section 5.4.3, then the applicable portion of $OTTV_i$ may be reduced by 30%. If the Lighting Power Control Credit for daylighting *is* claimed in section 5.4.3, then the applicable portion of $OTTV_i$ may be reduced by 7.5%.

4.7.2 Daylight Credits For Skylights. Skylights used in conjunction with automatic lighting controls for daylighting can significantly reduce the lighting energy consumption thereby more than offsetting the increase in envelope heat transfer.

When determining building roof compliance by either the prescriptive method of 4.5.2 or the system performance method of 4.6.2, a daylight credit is provided for skylights used in conjunction with automatic controls for electric lighting. Skylights for which daylight credit is taken may be excluded from the calculations of the overall thermal transmittance value of the roof assembly (U_{or}) if the following two conditions are met:

a) Skylit areas, including framing, as a percentage of the roof area do not exceed the values specified in Table 4-4 where Visible Light Transmittance (VLT) is the transmittance of a particular glazing material over the visible portion of the solar spectrum. Climate zones may be determined from Figure 4-1. Skylight areas shall be interpolated only between the listed visible light transmittance values of 0.75 and 0.50.

b) All electric lighting fixtures within daylighted areas under skylights are controlled by automatic daylighting controls. Daylighted areas under skylights shall be defined as the daylight area beneath each skylight whose dimension in each direction (centered on the skylight) is equal to the skylight dimension in that direction plus the dimension of the floor to ceiling height.

4.7.2.1 Skylit areas in Table 4-4 may be increased by 50% if an external shading device is used that blocks over 50% of the solar heat gain during the peak cooling design condition.

4.7.2.2 Areas for vertical glazing in clerestories and roof monitors shall be included in the wall fenestration calculation.

4.7.2.3 For shell buildings the permitted skylight area from Table 4-4 be based on a light level of 300 lux and a lighting unit power density (UPD) of less than 10.8 W/m^2.

4.7.2.4 For speculative buildings, the permitted skylight area from Table 4-4 shall be based on an appropriate unit lighting power density from Table 5-7, in W/m^2 and an illuminance level, in lux, as follows:

UPD <= 10.8	Use 300 lux
10.8 < UPD <= 21.5	Use 500 lux
UPD > 21.5	Use 700 lux

Table 4-4

Maximum Percent Skylight Area

Climate Zone	VLT Level	Light Level (lux)	Range of Lighting Power Density (W/m^2) <10.8	10.8-16.1	17.2-21.5	>21.5
A		300	2.2	2.8	3.4	4.0
&	0.75	500	2.3	3.1	3.9	4.7
B		700	2.9	4.1	5.3	6.5
A		300	3.3	4.2	5.1	6.0
&	0.50	500	3.6	4.8	6.0	7.2
B		700	4.2	6.0	7.8	9.6
		300	2.3	3.4	4.5	5.6
C	0.75	500	2.5	4.0	5.5	7.0
		700	2.8	4.6	6.4	8.2
		300	3.6	5.1	6.6	8.1
C	0.50	500	3.9	6.0	8.1	10.2
		700	4.2	6.9	9.6	12.3

5 LIGHTING

5.1 Purpose. This section specifies minimum requirements for lighting systems and controls.

5.2 Scope of Lighting Requirements.

5.2.1 The rooms, spaces and areas covered by this section include:

a) interior spaces of buildings.

b) building exterior areas such as entrances, exits, loading docks, etc.

c) roads, grounds, parking, and other exterior areas including open-air covered areas where lighting is required and is energized through the building electrical service.

5.2.2 Exemptions for Interior Spaces. Rooms, spaces, areas and equipment exempt from this section include:

Exemptions related to space functions:

a) Lighting for dwelling units.

b) Lighting power for theatrical productions, television broadcasting, audio-visual presentations and those portions of entertainment facilities such as stage areas in hotel ballrooms, night clubs, discos and casinos where lighting is an essential technical element for the function performed.

c) Display lighting required for art exhibit or displays in galleries, museums and monuments.

d) Specialized luminaires for medical and dental purposes.

e) Special lighting required for research laboratories.

f) Classrooms specifically designed for the sight-impaired, hearing-impaired (lip-reading), and for elderly persons.

Exemptions related to special requirements:

g) Emergency lighting that is automatically "off" during normal operations.

h) High risk security areas identified by local ordinances, regulations, or security or safety personnel as requiring additional lighting.

i) Lighting to be used solely for indoor plant growth between 6:00 p.m. and 6:00 a.m.

5.2.3 Exemptions for Exterior Areas. Areas and equipment exempt from this section include:

a) Outdoor activities such as manufacturing, storage, commercial greenhouses and processing facilities.

b) Outdoor athletic facilities.

c) Exterior lighting for public monuments.

d) Lighting for signs.

e) Storefront display windows in retail facilities.

5.3 General. Compliance with the Basic Requirements listed in 5.4 is mandatory under all compliance paths. In addition, to comply with this section, one of the following sets of requirements must be met or exceeded:

a) the prescriptive requirements of 5.5, or

b) the system performance requirements of 5.6.

The lighting power determination procedures in this section are intended for compliance with the energy requirements only, and shall not be used as lighting design procedures. Once a lighting power limit has been determined, using either section 5.5 or 5.6, then the designer should strive to design a lighting system that will provide an effective and pleasing visual environment, within the recommended range of illumination, without exceeding the power limit, or reducing the level of control.

5.4 Basic Requirements

5.4.1 Illuminance levels. The lighting designs used should consider illumination criteria appropriate to the tasks involved. The illumination levels listed in Tables 5-5 and 5-7 are recommended levels, provided for guidance only. They are not requirements of this code. The required criteria in Tables 5-5 and 5-7 are the maximum allowed levels of lighting power, W/m^2. Further information on illuminance levels is provided in Appendix F and in the IES Lighting Handbook and similar documents

5.4.2 Lighting controls. All lighting systems, except those required for emergency or exit lighting, shall be provided with manual, automatic or programmable controls.

5.4.2.1 Minimum number of control points. Each space enclosed by walls or ceiling-height partitions shall be provided with a minimum of one manually operated on-off control capable of turning off all the lights within that space.

a) **Additional Controls for Task Locations.** In addition to the control just specified in 5.4.2.1., one control shall be provided for each principal task location assigned an area of 14 m^2 or more. For spaces with more than one task, the task area need not exceed 50% of the total area of the space.

b) **Controls for Daylighting in Perimeter Office Spaces.** Manual ON/OFF daylight controls are required in spaces containing office activities with the following characteristics:

1) within 5.0 metres of external walls.

2) external walls have WWR greater than 0.20.

The locations closest to the windows shall be controlled separately from the locations on the interior of the space.

A lighting power control credit may be taken, with a power adjustment factor of 0.05, for these spaces, per 5.4.3 and Table 5-2. Further information is provided in Appendix F.

Automatic controls for daylighting may be used in these spaces in lieu of this requirement.

5.4.2.2 Minimum number of controls. The use of certain manual and automatic control devices may reduce the number of control points required, as indicated in Table 5-1. However, the minimum number of controls required shall not be less than one for each 1500 Watts of Connected Lighting Power (CLP), including ballasts.

Table 5-1
Potential Reduction in Number of Control Points Required

Type of Control	Equivalent Number of Control Points
Occupancy sensors	2
Timer - Programmable from the space being controlled	2
Three level step control (including off) or pre-set dimming	2
Four level step control (including off) or pre-set dimming	3
Automatic or continuous dimming	3

5.4.2.3 Task lighting controls. Controls provided for task areas, if readily accessible, may be mounted as part of the task lighting luminaire.

5.4.2.4 Duplicate controls. Control of the same load from more than one location shall not be credited as additional control points.

Exception: Lighting control requirements for spaces which must be used as a whole may be controlled by a lesser number of control points but not less than one control point for each 1500 watts of connected lighting power, or a total of three control points, whichever is greater.

Examples of such spaces include public lobbies of office buildings, hotels and hospitals, retail and department stores, warehouses, and storerooms and service corridors under centralized supervision. Lighting in such places shall be controlled in accordance with the work activities.

5.4.2.5 Control Accessibility. All lighting controls should be located to be readily accessible to personnel occupying or using the space.

Exceptions: The following lighting controls may be centralized in remote locations:

a) lighting controls for spaces which must be used as a whole.
b) automatic controls.
c) programmable controls.
d) controls requiring trained operators.
e) controls for safety hazards and security.

5.4.2.6 Hotel and Motel Guest Room Lighting Controls. Hotel and motel guest rooms, excluding bathrooms, shall have one or more master switches at the main entry doors that turn off all permanently wired lighting fixtures and switched receptacles. This switch may be activated by the insertion and removal of the room key or a similar device. For multiple room hotel suites, switches at the entry of each room, in lieu of the switch at the main door, will be acceptable to meet these requirements.

5.4.2.7 Exterior Lighting Controls. Exterior lighting not intended for 24-hour continuous use shall be automatically switched by timer, photocell or a combination of timer and photocell. Timers shall be of the automatic type or otherwise capable of adjustment for 7 days and for seasonal daylight schedule variations. All time controllers shall be equipped with backup provisions to keep time during power outage of at least 4 hours.

5.4.3 Lighting Power Control Credits

5.4.3.1 Lighting Power Control Credit (LPCC). When determining compliance of the actual lighting design with the Interior Lighting Power Allowance (ILPA), the connected lighting power (CLP) used to determine compliance may be reduced if certain lighting controls are being used. The CLP may be reduced on specific area-by-area basis for lights automatically controlled by occupancy sensing control, daylight sensing control, lumen maintenance control, or programmable timing control.

This credit is the LPCC, and shall be determined by:

$$LPCC = CLP \times PAF \qquad \text{Eq. (5-1)}$$

where

LPCC = Lighting Power Control Credit, W

CLP = Connected Lighting Power for those luminaires controlled by the automatic control device, W

PAF = Power Adjustment Factor

The adjusted lighting power (ALP) is then equal to CLP - LPCC.

5.4.3.2 Power Adjustment Factor (PAF). When used, the PAF shall be applied as specified in Table 5-2 and shall meet the following criteria:

a) the PAF shall be limited to the specific area controlled by the automatic control device.
b) only one PAF may be used for each building space or luminaire, and 50% or more of the controlled luminaire shall be within the applicable space to qualify for the PAF.
c) controls shall be installed in series with the lights and in series with all manual switching devices in order to qualify for the PAF.
d) when sufficient daylight is available, daylight sensing controls shall be capable of reducing electrical power consumption for lighting (continuously or in steps) to 50% or less of maximum power consumption.
e) daylight sensing controls shall control all luminaires to which the PAF is applied and that direct a maximum of 50% of their light output into the daylight zone.
f) occupancy sensors located in daylighted spaces should be installed in conjunction with a manual ON switch, or photocell override for ON.
g) programmable timing controls used for credit in conjunction with Table 5-2 shall be capable of:
   1. programming different schedules for occupied and unoccupied days
   2. ready accessibility for temporary override by occupants of individual zones, spaces, or tasks with automatic return to original schedules.
   3. keeping time during power outages for a minimum of four hours.

5.4.4 Fluorescent Lamp Ballasts

5.4.4.1 Ballast Efficacy Factor. Fluorescent lamp ballasts which have all of the following characteristics shall meet or exceed the minimum ballast efficacy factor (BEF) shown in Table 5-3.

a) operate at nominal input voltage of 120, 220, and 240 volts.
b) input frequency of 50 HZ.
c) maximum lamp operating current less than 1000 milliamperes.
d) designed to be used for starting at temperatures above 4.4 °C.
e) used to operate one of the lamp types listed in Table 5-3.
f) not specifically designed for use with dimming controls.

The Ballast Efficacy Factor (BEF) shall be calculated by:

BEF = BF / power input (5-2)

where

BF = ballast factor, expressed as a percent, such as 95, as defined in Appendix F.

power input = total wattage of combined lamps and ballasts, as defined in Appendix F.

5.4.4.2 Power Factor. All ballasts shall have a power factor of 90% or greater.

Exceptions: a) dimming ballasts; and, b) ballasts for circline and compact fluorescent lamps and low wattage high intensity discharge lamps of 100 Watts or less.

5.4.4.3 Tandem Wiring. One-lamp or three-lamp fluorescent luminaires shall be tandem wired to eliminate unnecessary use of a single lamp ballast, if they are recessed-mounted within 3000 mm of each other (center-to-center) or pendant-mounted or surface-mounted within 300 mm of each other.

Exceptions:

a) three-lamp ballasts may be used.
b) two-lamp ballasts shall be used for either two lamp or four lamp fixtures. If one-lamp ballasts are used, then the losses for each shall be not greater than half the loss for a complying two-lamp ballast.

5.4.5 Building Exterior Lighting Power Allowances (ELPA). The exterior lighting power to be installed shall not exceed the Exterior Lighting Power Allowance (ELPA) listed in Table 5-4.

5.4.5.1 Tradeoffs. The following tradeoff criteria apply:

a) Tradeoffs between the Interior Lighting Power Allowance (ILPA) of section 5.5 or 5.6 and the Exterior Lighting Power Allowance (ELPA) of 5.4.5 are ***not*** allowed.
b) Tradeoffs among the Exterior Lighting Power Allowance (ELPA) values among exterior areas are allowed, as long as the total exterior lighting power to be installed does not exceed the ELPA.
c) For facilities with multiple buildings, the Exterior Lighting Power Allowances (ELPA) may be traded off among the buildings.

Table 5-2

Power Adjustment Factor (PAF)

	Control Device(s)	PAF
(1)	Daylight Sensing Controls (DS), continuous dimming	0.35
(2)	DS, multiple step dimming	0.25
(3)	DS, ON/OFF	0.15
(4)	Manual Daylight Controls, ON/OFF[(a)]	0.05
(5)	DS continuous dimming and programmable timing	0.40
(6)	DS multiple step dimming and programmable timing	0.30
(7)	DS ON/OFF and programmable timing	0.20
(8)	DS continuous dimming, programmable timing and lumen maintenance	0.45
(9)	DS multiple step dimming, programmable timing and lumen maintenance	0.35
(10)	DS ON/OFF, programmable timing and lumen maintenance	0.25
(11)	Lumen maintenance	0.10
(12)	Lumen maintenance and programmable timing control	0.15
(13)	Programmable timing control	0.15
(14)	Occupancy sensor	0.30
(15)	Occupancy sensor and DS, continuous dimming	0.45
(16)	Occupancy sensor and DS, multiple step dimming	0.40
(17)	Occupancy sensor and DS, ON/OFF	0.40
(18)	Occupancy sensor, DS continuous dimming and lumen maintenance	0.50
(19)	Occupancy sensor, DS multiple step dimming and lumen maintenance	0.45
(20)	Occupancy sensor, DS ON/OFF and lumen maintenance	0.40
(21)	Occupancy sensor and lumen maintenance	0.35
(22)	Occupancy sensor and programmable timing control	0.35

Notes:

(a) Minimum office daylight controls: in all office spaces within 5.0 metres of walls with WWR greater than 0.20, separate manual ON/OFF controls are required at minimum. See 5.4.2.1(a).

Table 5-3

Fluorescent Ballast Efficacy Factor (BEF)

Ballast Type	Min. BEF
one - 1200 mm, nom. 40 W, rapid-start lamp	1.80
two - 1200 mm, nom. 40 W, rapid-start lamps	1.05
two - 1200 mm, nom. 32 W, tri-phosphor lamps	1.30
two - 1800 mm, nom. 70 W, slimline lamps	0.57
two - 2400 mm, nom. 110 W, high-output, rapid-start lamps	0.39

Table 5-4

Lighting Power Requirements for Building Exteriors

Area Description	Lighting Power
Exit (with/without canopy)	6.0 W/lin. m of door opening
Entrance (without canopy)	9.0 W/lin. m of door opening
Entrance (with canopy)	
High Traffic (retail, hotel, airport, theatre, etc.)	108.0 W/m^2 of canopied area
Light Traffic (hospital, office, school, etc.)	43.0 W/m^2 of canopied area
Loading area	3.0 W/m^2
Loading door	6.0 W/lin. m of door opening
Building Exterior Surfaces/ Facades	2.7 W/m^2 of surface area to be illuminated
Storage and non-manufacturing work areas	2.1 W/m^2
Other activity areas for casual use such as picnic grounds, gardens, and other landscaped areas	1.1 W/m^2
Private driveways/walkways	1.1 W/m^2
Public driveways/walkways	1.5 W/m^2
Private parking lots	1.3 W/m^2
Public parking lots	2.0 W/m^2

5.5 Prescriptive Requirements - Building Interior. The building Interior Lighting Power Allowance (ILPA) calculations shall be based on the primary occupancies for which the building is intended. The ILPA for the total building interior area is determined by:

$$ILPA = ULPA \times GLA \qquad \text{Eq. (5-3)}$$

Where

ILPA = interior lighting power allowance, Watts.
ULPA = unit lighting power allowance, for major building activity area, W/m^2.
GLA = gross lighted area, m^2

5.5.1 Requirement. The unit lighting power allowance (ULPA) shall be selected from Table 5-5. For areas or activities other than those given in the table, select values for similar areas or activities.

5.5.2 Compliance. The total connected lighting power (CLP) load shall not exceed the ILPA as determined in Eq. 5-3. The CLP for a building shall be calculated including ballast losses and including both permanently installed lighting plus supplemental or task related lighting provided by movable or plug-in luminaires.

Exception: If 10% or more of the gross lighted area of the building is intended for multiple space activities such as parking, storage, and retail space in an office building, then the lighting power for each separate type of space area shall be calculated based on the ULPA shown for that space activity and shall be summed to obtain ILPA.

5.5.3 Adjustment for Building Size. For smaller buildings, additional lighting power may be used, by increasing the maximum allowable value of the ILPA by a certain percentage, in accordance with the values listed in Table 5-6.

5.6 System Performance Requirements. The prescriptive requirements in 5.5 have limited accuracy and flexibility, for they are based on building type only; thus, they are not sensitive to specific tasks and room configurations which can affect lighting power in a particular building.

A system performance compliance procedure provides a more flexible, accurate and detailed procedure than the prescriptive procedure. This system performance procedure may be used to calculate the total Interior Lighting Power Allowance (ILPA) in place of the requirements specified in 5.5.

5.6.1 Lighting Power Budget for Each Interior Space. The Lighting Power Budget (LPB) of each interior space shall be determined by:

$$LPB_i = A \times Pb \times AF \qquad \text{Eq. (5-4)}$$

Where:

LPB_i = Lighting power budget of the space, watts.

A = Area of the space, m^2.

Pb = Base UPD, W/m^2, from Table 5-7.

AF = Area factor of the space, from Fig. 5-1.

Table 5-5
Unit Lighting Power Allowances (ULPA)

Building Type/ Space	Recommended[1] Illuminance Levels (lux)	Maximum Lighting Power ULPA(W/m^2)
Service Station/ Auto Repair[3]	300	10.8
Apartments & Condos (Public spaces)	300	20.5
Banks	300-500	21.5
Barber Shops/ Beauty Parlors	750	21.5
Churches and Synagogues	150-300	16.1
Parking Garages	20-100	2.2
Hotels/Motels		
Guest Rooms & Corridors[3]	50	12.9
Public Areas	50-200	11.8
Banquet & Exhibit	300-500	21.5
Nursing Homes	300-500	19.4
Office Buildings	400-500	17.2
Fast Food/Cafeteria	50-100	14.0
Leisure Dining	50-100	16.1
Bar/Lounge	50-100	16.1
Retail		
General, merchandising and display[2]	500	21.5
Mall Concourse/ multi-store service	150	12.9
School		
Pre/elementary	300-500	16.1
High/Tech/Univ	300-500	18.3
Warehouse/Storage	50-100	3.2

(1) The illuminance levels, lux, are for guidance only; they are not required. Compliance with the maximum lighting power allowances, ULPA, W/m^2 *is* required.

(2) Applies to all lighting, including accent and display lighting.

(3) Supplemental lighting for task areas may be desirable.

Table 5-6
Percent Allowable Increase in Interior Lighting Power Allowances (ILPA)

If Total Gross Building Lighted Area Is Less Than, m^2	ILPA Value May Be Increased by (%)
1,000 m^2	15 %
200 m^2	25 %

In developing the LPB for a space:

a) The Room Area (A) shall be calculated from the inside dimensions of the room.

b) The Base UPD (Pb) shall be selected from Table 5-7. For areas or activities other than those given in the table, select values for similar areas or activities.

c) The Area Factor (AF) shall be determined from Figure 5-1 based on the room area and ceiling height. Rooms of identical ceiling height and activities may be listed as a group, and the AF of the group shall be determined from the average area of these rooms.

The LPB for special spaces and activities shall be determined as follows:

a) Multi-Function Rooms. For rooms serving multiple functions, such as hotel banquet/ meeting rooms and office conference & presentation rooms, a supplementary lighting system with independent controls may be installed. The installed power for the supplementary system shall not be greater than 50% of the base LPB calculated in accordance with Equation (5-4).

b) Simultaneous Activities. In rooms containing multiple simultaneous activities such as a large general office having separate accounting and drafting areas within the same room, the LPB for the rooms shall be the weighted average of the activities in proportion to the areas being served.

c) Indoor Sports. The activity of indoor sports areas shall be considered as an area 3 m beyond the playing boundaries of the sport not to exceed the floor area of this space less the spectator seating area.

5.6.2 Determining the Interior Lighting Power Allowance (ILPA) for the Building. The ILPA shall be calculated by:

$$ILPA = LPB_1 + ... + LPB_i + (LPB_u \times A_u) \quad \text{Eq. (5-5)}$$

Where:

ILPA	=	Interior Lighting Power Allowance.
LPB_i	=	Lighting power budget of the ith space, determined from Eq. (5-4), Watts.
LPB_u	=	2.2 W/m^2
A_u	=	area of unlisted space, m^2.

The Interior Lighting Power Allowance (ILPA) shall include a 2.2 W/m^2 allowance for unlisted space areas.

5.6.3 Determining Compliance with the ILPA. The total lighting connected load, including ballast losses and both permanently installed and moveable lighting, shall not exceed the ILPA, as determined in Eq. 5-5. Tradeoffs of Lighting Power Budgets (LPBs) among interior spaces are allowed as long as the total installed lighting power within the building does not exceed the Interior Lighting Power Allowance (ILPA).

6 ELECTRIC POWER AND DISTRIBUTION

6.1 Purpose. This section defines basic requirements for electrical power and distribution systems.

6.2 Scope. This section applies to all building electrical systems, except required emergency systems.

6.3 Blank for numbering consistency.

6.4 Basic Requirements

6.4.1 Check-Metering of the Electrical Distribution System. Buildings whose designed connected electric service is over 250 kVA shall have the electrical distribution system designed so that electrical energy consumption can be check-metered.

6.4.1.1 The electrical power feeders for each facility for which check-metering is required shall be subdivided in accordance with the following categories:

a) Lighting and receptacle outlets
b) VAC systems and equipment
c) Service water heating (SWH) systems, elevators, and special occupant equipment of more than 20 kW such as computer rooms, kitchens, or printing equipment.

Exception: 10 percent or less of the loads on a feeder may be for another usage category.

6.4.1.2 The feeders for each category shall contain provisions for portable or permanent check metering.

6.4.2 Transformers. If the total capacity of the transformers, excluding utility-owned transformers, exceeds 300 kVA, a calculation of total estimated annual operating costs of the transformer losses shall be made, based on estimated hours of transformer operation at projected part-load and full-load conditions, and the associated transformer core and coil losses. The calculation procedure is contained in Appendix G.

6.4.3 Electrical Motor Efficiency. All permanently wired polyphase motors of 0.375 kW or more serving the building and expected to operate more than 500 hours per year shall have a minimum acceptable nominal full-load motor efficiency no less than shown in Table 6-1.

The table applies to motors having nominal 1000, 1500 or 3000 RPM for 50 Hz supply (1200, 1800 or 3600 RPM for 60 Hz supply), with open, drip-proof, or TEFC enclosures. Other motor types are exempted from the efficiency requirements of this code.

Motors of horsepower differing from those listed in the table shall have an efficiency greater than that of the next lower listed kW motor.

Table 6-1

Minimum Full-Load Motor Efficiencies for Single Speed Polyphase Motors

	Rated Efficiency (Percent)	
kW	Minimum Requirements	Recommended (High-Effic.)
0.375 - 0.75	75.0	—
0.75 - 3.74	80.0	—
3.75 - 7.49	85.0	89.5
7.50 - 36.99	88.0	91.0
37.00 - 74.99	92.0	94.1
75.00 - 92.99	92.5	95.1
93.00 +	93.5	—
150.00 +	93.5	96.2

Note: Motors operating more than 750 hours per year are likely to be cost-effective with efficiencies greater than those listed under Minimum requirements for either 1990 or 1992. The more efficient motors are classified by most manufacturers as "high-efficiency," and are presently available for common applications with typical nominal efficiencies listed in the rightmost column. Guidance for evaluating the cost effectiveness of high-efficiency motor applications is given in NEMA MG 10-1983.

Table 5-7

Base UPD (Pb) for Activity/ Area

Building Type/ Space	Recommended Illuminance Level (lux)	UPD (Pb) (W/m^2)
Common Activity Areas		
Auditorium(4)	100	12.9
Classroom/Lecture Hall	300	21.5
Computer/Office Equipment	500	22.6
Conference/Meeting Room(4)	500	19.4
Corridor(1)	100	9.7
Elec/Mech Equipment Room		
General(1)	100	7.5
Control Rooms(1)	300	16.1
Filing, Inactive	300	10.8
Food Service		
Fast Food/Cafeteria	50-100	14.0
Leisure Dining(3)	50-100	21.5
Bar/Lounge(3)	50-100	16.1
Kitchen	500	15.1
Garage		
Auto & Pedestr. Circ.	100	3.2
Parking Area	20- 50	2.2
Laboratory	500	24.8
Lobby (General)		
Reception & Waiting	200	10.8
Elevator Lobbies	200	8.6
Atrium (Multi-Story)		
First 3 Floors	200	7.5
Each Additional Floor	—	2.2
Locker Room & Shower	100	8.6
Mail Room	750	19.4
Offices, Category 1(7)		
Reading, Typing, Filing(6)	500	17.2
Drafting(6)	750	28.0
Accounting(6)	750	22.6
Offices, Category 2		
Reading, Typing, Filing(1)	500	17.2
Drafting(1)	750	33.4
Accounting(1)	750	26.9
Offices, Category 3		
Reading, Typing, Filing(1)	500	17.2
Drafting(1)	750	37.7
Accounting(1)	750	30.1
Recreation/Lounge	50-200	7.5
Stair		
Active Traffic	100	6.5
Emergency Exit	50-150	4.3
Toilet & Washroom	150	8.6
Unlisted Space	20- 50	2.2

Building Type/ Space	Recommended Illuminance Level (lux)	UPD (Pb) (W/m^2)
Specific Buildings		
Airport, Bus and Rail Station		
Baggage Area	100-200	8.6
Concourse/Main Thruway	200	9.7
Ticket Counter	500	26.9
Waiting & Lounge Area	200	12.9
Bank		
Customer Area	300	10.8
Banking Activity Area	500	30.1
Barber & Beauty Parlor	750	21.5
Church, Synagogue, Chapel		
Worship/Congregational	150	16.1
Preaching & Sermon/Choir	300	21.5
Dormitory		
Bedroom	150	10.8
Bedroom with Study	300	14.0
Study Hall	500	19.4
Fire & Police Department		
Fire Engine Room	300	7.5
Jail Cell	300	8.6
Hospital/Nursing Home		
Corridor(1)	150	14.0
Dental Suite/Exam/Treat(8)	300	17.2
Emergency(8)	1000	24.8
Laboratory(8)	300	20.5
Lounge/Waiting Room	150	9.7
Medical Supplies	300-750	25.8
Nursery	300-500	21.5
Nurse Station	500-750	22.6
Occu. /Physical Therapy	300-500	17.2
Patient Room(8)	50-300	15.1
Pharmacy(8)	300-750	18.3
Radiology(8)	50-750	22.6
Surgical & O.R. Suites		
General Area	300-750	22.6
Operating Room	1500	75.3
Recovery	750-1500	32.3
Hotel/conference Center		
Banquet Room /Multipurpose(4)	300-500	21.5
Bathroom/Powder Room(8)	100	10.8
Guest Room(8)	50	12.9
Public Area	50-200	11.8
Exhibition Hall	300-500	26.9
Conference/Meeting(4)	500	19.4

continues on next page

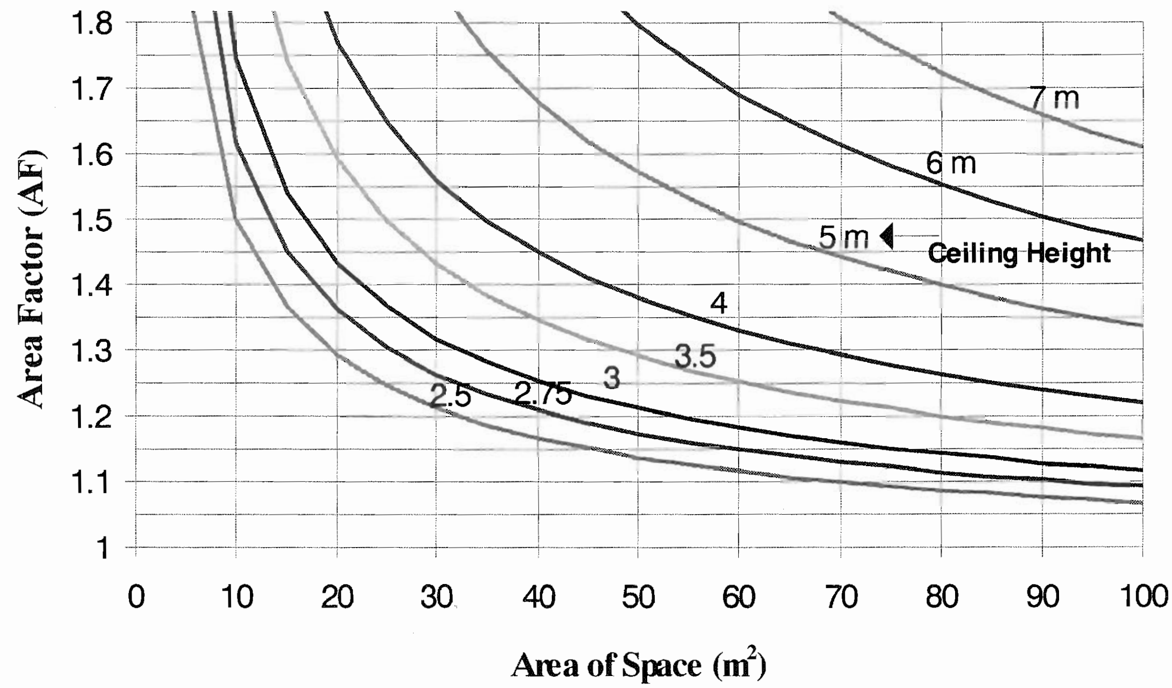
Table 5-7 (continued)
Base UPD (Pb) for Activity/ Area

Building Type/ Space	Recommended Illuminance Level (lux)	UPD (Pb) (W/m²)
Specific Buildings		
Laundry		
Washing	300	9.7
Ironing & Sorting	500	14.0
Library		
Audio Visual(8)	150-300	11.8
Stack Area	150	16.1
Card File & Cataloging	500	17.2
Reading Area	300-500	16.1
Museum & Gallery		
General Exhibition	50-300	20.5
Inspection/Restoration	500	42.0
Storage (Artifacts)		
Inactive	100	6.6
Active	150	7.5
Post Office		
Lobby	150	11.8
Sorting & Mailing	1000	22.6
Retail Establishments (Merchandising & Circulation Area) Applicable to all lighting, including accent and display lighting, installed in merchandising and circulation areas		
Type A Jewelry Disp(5)	500	43.1
Type B Fast Food(5)	500	17.2
Type C Clothing(5)	500	21.5
Type D Supermarkets(5)	500	21.5
Type E Drug Stores(5)	500	17.2
Mall Concourse	150	12.9
Retail Support Areas		
Tailoring	500	22.6
Dressing/Fitting Rooms	300	15.1
Ancillary Spaces	500	21.5
Service Station/ Auto Repair(8)	300	10.8
Shop (Non-Industrial)		
Machinery	300-750	26.9
Electrical/Electronic	300-1500	26.9
Painting	300	17.2
Carpentry(8)	300	24.8
Welding(8)	300	12.9
Storage & Warehouse		
Inactive Storage	50	3.2
Active Storage, Bulky	100	3.2
Active Storage, Fine(8)	300	10.8
Material Handling	300	10.8
Theatre		
Performance Arts	100	16.1
Motion Picture	100	10.8
Lobby	200	16.1
Unlisted Space	20- 50	2.2

Building Type/ Space	Recommended Illuminance Level (lux)	UPD (Pb) (W/m²)
Indoor Athletic Areas[(2)]	n\a	
Seating Area, All Sports		4.3
Badminton		
Club		5.4
Tournament		8.6
Basketball/Volleyball		
Intramural		8.6
College		14.0
Professional		20.5
Bowling		
Approach Area		5.4
Lanes		11.8
Boxing or Wrestling (Platform)		
Amateur		25.8
Professional		51.7
Gymnasium		
General Exercising & Recreation Only		10.8
Handball/Racquetball/Squash		
Club		14.0
Tournament		28.0
Hockey, ice		
Amateur		14.0
College or Professional		28.0
Skating Rink		
Recreational		6.5
Exhibition /Professional		28.0
Swimming		
Recreational		9.7
Exhibition		16.1
Tennis		
Recreational (Class III)		14.0
Club/College (Class II)		20.5
Professional (Class I)		28.0
Tennis, Table		
Club		10.8
Tournament		17.2

Notes for Table 5-7:

(1) Area Factor of 1.0 shall be used for these spaces.
(2) Area Factor of 1.0 shall be used for all indoor athletic spaces.
(3) Base UPD includes lighting power for clean-up purpose.
(4) Use a 1.5 adjustment factor for multi-functional spaces.
(5) See Section 13 - Definitions for Classification of Retail Facilities.
(6) Area Factor shall not exceed 1.55.
(7) See Section 13 - Definitions for Office Categories.
(8) Supplemental task lighting may be desirable.



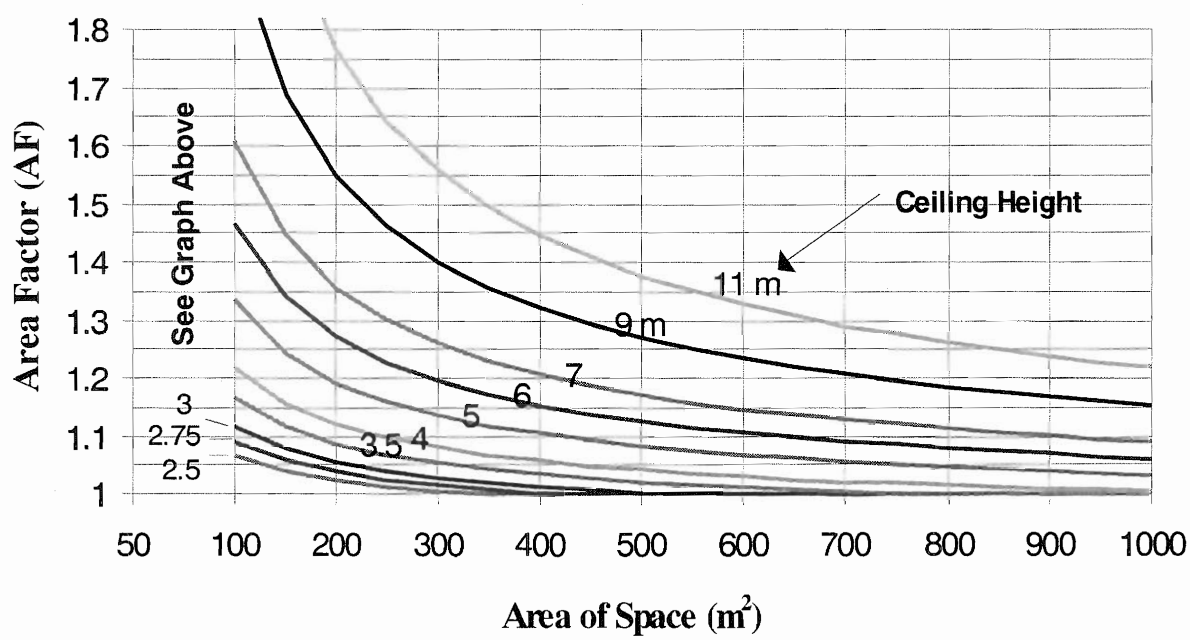


Figure 5.1: Lighting Area Factor

7 VENTILATING AND AIR-CONDITIONING SYSTEMS

7.1 Purpose. The requirements in this section represent minimum design parameters. It is recommended that the designer evaluate other energy conservation measures which may be applicable to the proposed building.

These requirements are intended to reduce energy consumption for space conditioning for the conversion of delivered energy (electric power, gas, oil, etc.) to cooling media delivered to the space by diffusers, registers, fan coils, or other devices to meet the space cooling load. This code applies to systems installed in buildings where general "comfort and health" conditions apply.

7.2 Scope. This section provides requirements for:

a) calculations of the cooling load, including ventilation air requirements
b) VAC system designs and controls
c) duct construction and design
d) duct and piping insulation for VAC distribution systems
e) dehumidification standards
f) mechanical ventilation requirements, and
g) fans, pumps, piping, sizing.

Exemptions: Special spaces exempt from the requirements in this section include those where "general comfort" is not the primary purpose. For those spaces the design concepts and parameters shall conform to the special requirements of the application. Such special applications within buildings include: industrial air-conditioning; laboratories; clean rooms; main-frame computer areas; printing plants; textile processing; environmental control specifically designed to accommodate animals and plants; farm crop storage; hospital operating rooms; commercial freezing and food store refrigeration; commercial kitchens; and, some manufacturing processes. Exemptions shall pertain only to the specific spaces involved and shall be allowed only to the extent necessary to accommodate the special use.

7.3 General. For compliance to be achieved, compliance with the Basic Requirements listed in section 7.4 is mandatory under all compliance paths. In addition, the prescriptive requirements of 7.5 must be met.

7.4 Basic Requirements

7.4.1 Load Calculations. Cooling system design loads for the purpose of sizing systems and equipment shall be determined in accordance with the procedures described in the ASHRAE Handbook, 1989 Fundamentals Volume or a similar computation procedure.

"Rules-of-thumb" shall not be used in lieu of the detailed load calculation procedures and values specified herein and discussed in detail in Appendix H. For those design parameters addressed in 7.4.1.1 through 7.4.1.8, the values specified shall be used.

7.4.1.1 Indoor design conditions. for cooling, the conditions shall be 24.4°C dry bulb and 55% R.H., or equivalent comfort conditions.

7.4.1.2 Outdoor design conditions. These shall be in accordance with the values listed in Table 7-1 for summer design loads for each of three climate zones.

Table 7-1
Outdoor Design Conditions
Summer Design Loads

Climate Zone	Example City	Dry Bulb (°C)	Wet Bulb (°C)
A	Kingston	33.9	27.2
B	Montego Bay	32.2	25.6
C	Mandeville	30.6	24.4

Note: See Figure 4-1 for map of climate zones.

7.4.1.3 Ventilation Air.

7.4.1.3.1 Rates. Outdoor air ventilation rates shall be based on 3.5 L/s per person in non-smoking areas, and 11.8 L/s per person in smoking areas and shall comply with ASHRAE standard 62-1989, "Ventilation for Acceptable Indoor Air Quantity" (or later edition). If smoking areas are not determined before final design, smoking shall be assumed in 25% of the occupied areas, except in schools, colleges, hospitals, auditoriums, and other areas where smoking is prohibited.

Exception: Outdoor air quantities may exceed those shown in ASHRAE Standard 62-1989 if required because of special occupancy or process requirements, source control of air contamination, or local codes, or if heat recovery with an efficiency of 50% is used.

7.4.1.3.2 Building Occupancy. Where occupancy is unknown, values shall be based on those listed in Table 7-2.

a) The occupant load in any building or portion thereof shall be determined by dividing the floor area assigned to the specific use by the square metres per occupant set forth in Table 7-2.

b) When the square metres per occupant are not given for a particular occupancy, it shall be determined by the Building Official based on the area given for the occupancy which it most nearly resembles.

Exceptions: The occupant load of an area having fixed seats shall be determined by the number of fixed seats installed. Aisles serving the fixed seats and not used for any other purpose shall not be assumed as adding to the occupant load.

7.4.1.3.3 Infiltration. Infiltration shall be calculated in accordance with the requirements listed in section 4.4 and shall be used for cooling loads.

7.4.1.3.4 Quantities for calculation. The outside air quantities due to the larger of infiltration or required ventilation shall be used in calculating the cooling loads.

7.4.1.4 Envelope. Envelope cooling loads shall be based on envelope characteristics, such as thermal conductance, shading coefficient, and air leakage, consistent with the values used to demonstrate com-pliance with Section 4.

7.4.1.5 Lighting. Lighting loads shall be based on actual design lighting levels or power budgets consistent with Section 5.

7.4.1.6 Other loads. Other VAC system loads, such as those due to people and equipment, shall be based on design data compiled from one or more of the following sources, listed in order of preference:

a) Actual information based on the intended use of the building.

b) Published data from manufacturers' technical publications and from technical societies, such as the ASHRAE Handbook, 1984 Systems Volume.

c) "Estimates of Recommended Heat Gains Due to Commercial Appliances and Equipment", ASHRAE Transactions 90 (Pt. 2A), 25 - 58 (1984).

Table 7-2

Occupancy Area by Use

Use	M^2/Occ
Assembly Areas, Concentrated Use	
(without fixed seats)	
Auditoriums	0.7
Bowling Alleys	
(Assembly areas)	0.7
Churches and Chapels	0.7
Dance Floors	0.7
Lodge Rooms	0.7
Assembly Areas, Less Concentrated Use	
Conference Rooms	1.4
Dining Rooms	1.4
Drinking Establishments	1.4
Exhibit Rooms	1.4
Gymnasiums	1.4
Lounges	1.4
Stages	1.4
Classrooms	1.9
Stores, Retail	2.8
Library Reading Room	4.6
Locker Rooms	4.6
Nurseries for Children	
(Day Care)	4.6
School Shops and	
Vocational Rooms	4.6
Children's Homes and	
Homes for the Aged	7.4
Hospitals and	
Sanitariums, Nursing Homes	7.4
Offices	9.3
Kitchen, Commercial	18.6
Garage, Parking	18.6
Mechanical Equipment Room	27.9
Warehouses	27.9
Aircraft Hangars	46.5
Hotel & Villas (occupants/room)	2.0
All other spaces	9.3

d) Default values to be used in determining the design energy budget or energy cost budget as specified in Section 12.

e) Other data based on designer's experience of expected loads and occupancy patterns.

7.4.1.7 Safety Factor. Design loads may, at the designer's option, be increased by as much as 10% to account for unexpected loads or changes in space usage.

7.4.1.8 Pick-up Loads. Transient loads such as cool-down loads which occur after off-hour set-back or shut-off, may be calculated from basic principles, based on the heat capacity of the building and its contents, the degree of setback, and desired recovery time, or may be assumed to be up 10% for cooling of the steady-state loads in addition to the design loads. The steady-state load may include a safety factor in accordance with Section 7.4.1.7.

7.4.2 Simultaneous Heating and Cooling

7.4.2.1 Dual duct, multi-zone, and terminal reheat systems. These systems are prohibited for buildings larger than 1,000 m^2 or for systems larger than 3,800 L/s, whichever is smaller. When these systems are employed, refer to Section 7.4.3 for requirements.

Exceptions: Hospital operating and intensive care suites, industrial process or laboratories requiring precise humidity control. Systems which employ waste heat or solar heat for 100% of the heating requirements.

7.4.2.2 Dual duct, multi-zone and terminal reheat systems. These systems shall not be used in a standard design (performance/ prescriptive) for comparisons prepared under the annual energy budget provisions of Appendix C.

7.4.2.3 Dual duct and multi-zone systems. These systems shall be provided with controls that will automatically reset the cold deck air supply to the highest temperature that will satisfy the zone requiring the coolest air, and the hot deck air supply to the lowest temperature that will satisfy the zone requiring the warmest air. Primary zone temperatures and/or flow volume may be used as the control for this requirement. The systems must be provided with heat pumps or recovery devices so that new energy is not required on the hot and cold deck or plenum simultaneously, with the exception of limited warm-up periods.

Constant volume dual duct or multi-zone systems, which utilize new energy to simultaneously heat and cool air supplies that are subsequently mixed for temperature control, shall not exceed 3,800 L/s total capacity in any one building, except for hospitals.

7.4.2.4 Multiple zones. For systems with multiple zones, one or more zones may be chosen to represent a number of zones with similar heating and/or cooling characteristics. A multi-zone system that employs reheating or recooling for control of not more than 2,350 L/s or 20 percent of the total supply air for the building, whichever is less, shall be exempt from the supply air temperature reset requirements of Section 7.5.4.

7.4.2.5 Reheat Systems. Systems employing reheat and serving multiple zones, shall be provided with control that will automatically reset the system cold air supply to the highest temperature level that will satisfy the zone requiring the coolest air. Single-zone reheat systems shall be controlled to sequence reheat and cooling. The total installed capacity for reheat systems shall not exceed 15 percent of the system cooling design.

7.4.2.6 Concurrent operation. Concurrent operation of independent heating and cooling systems serving the same zone and requiring the use of new energy for heating or cooling shall be minimized by the following: by providing sequential temperature control of both heating and cooling capacity in each zone; and/or by limiting the heating energy input through automatic reset control of the heating medium temperature (or energy input rate) to only that necessary to offset heat loss due to transmission and infiltration and, where applicable, to heat the ventilation air supply to the space.

7.4.2.7 Recovered energy. Energy recovered in excess of the new energy expended in the recovery process may be used for control of temperature and humidity.

7.4.3 Separate Air Distribution Systems

7.4.3.1 Non-simultaneously Operating Zones. Zones that are expected to operate non-simultaneously for more than 750 hours per year shall be served by separate air distribution systems. As an alternative, off-hour controls shall be provided in accordance with Section 7.4.5.

7.4.3.2 Zones with Special Requirements. Zones with special process temperature and/or humidity requirements should be served by separate air distribution systems from those serving zones requiring only comfort cooling, or shall include supplementary provisions so that the primary systems may be specifically controlled for comfort purposes only.

Exception: Zones requiring comfort cooling only that are served by a system primarily used for process temperature and humidity control, need not be served by a separate system if the total supply air to these zones is no more than 25% of the total system supply air, or the total conditioned floor area of the zones is less than 100 m^2.

7.4.4 Temperature Controls

7.4.4.1 System Control. Each AC system shall include at least one temperature control device.

7.4.4.2 Zone Control. The supply of cooling energy to each zone shall be controlled by individual thermostatic controls responding to temperature within the zone.

Exceptions: Independent perimeter systems may serve multiple zones of the primary/interior system with the following limitations:

a) the perimeter system shall include at least one thermostatic control zone for each building exposure having exterior walls facing only one orientation for 15 continuous metres or more.

b) the perimeter system cooling supply shall be controlled by thermostat(s) located within the zone(s) served by the system.

7.4.4.3 Thermostats. Where used to control comfort cooling, thermostats shall be capable of being set, locally or remotely, by adjustment or selection of sensors, up to 30 °C .

Exception: Buildings complying with the Whole-Building analyses in Appendix C, in the proposed building energy analysis, cooling thermostat set points are set to the same value between 24 °C and 25.5 °C inclusive and assumed to be constant throughout the year.

7.4.5 Off-hour Control

7.4.5.1 VAC systems shall be equipped with automatic controls capable of accomplishing a reduction of energy use through equipment shut-down during periods of non-use or alternative use of the spaces served by the system.

Exceptions:

a) Systems serving areas expected to operate continuously.

b) Equipment with a connected load of 2 kW or less may be controlled by readily accessible manual off-hour controls.

7.4.5.2 Outdoor air supply and exhaust systems shall be provided with motorized or gravity dampers or other means of automatic shutoff or reduction during periods of non-use or alternate use of the spaces by the system.

Exceptions:

a) Systems serving areas expected to operate continuously.

b) Systems having a design air flow of 1400 L/s or less.

c) Gravity and other non-electrical ventilation systems may be controlled by readily accessible manual damper controls.

d) Where restricted by process requirements such as combustion air intakes.

7.4.5.3 Isolation areas. Systems that serve zones that can be expected to operate non-simultaneously for more than 750 hours per year (e.g., 3 hours per day for a five day work week), should include isolation devices and controls to shut off the supply of cooling to each zone independently. Isolation is not required for zones expected to operate continuously.

For buildings where occupancy patterns are not known at time of system design, such as speculative buildings, isolation areas may be pre-designed. Zones may be grouped into a single isolation area provided the total conditioned floor area does not exceed 2300 m^2 per group nor include more than one floor.

7.4.6 Humidity Control. Where a humidistat is used for comfort dehumidification, it shall be capable of being set to prevent the use of fossil fuel or electricity to reduce relative humidities below 60%. Heat recovery, such as condenser or hot gas heat exchanger heat recovery, shall be considered where dehumidification requires the use of reheat. Solar energy, or other non-depletable heat sources may be used for reheat to control humidity levels.

7.4.7 Materials and Construction.

7.4.7.1 Piping Insulation. All VAC system piping shall be thermally insulated in accordance with Table 7-3.

Exceptions:

a) Factory installed piping within VAC equip-ment.

b) Piping that conveys fluids which have a design operating temperature range between 12.8 °C and 40.6 °C.

c) Piping that conveys fluids which have not been heated or cooled through the use of fossil fuels or electricity.

d) Where it can be shown that the heat gain or heat loss to or from piping without insulation will not increase building energy costs.

Insulation thicknesses in Table 7-3 are based on insulation with thermal conductivities within the range listed for each fluid operating temperature range, rated in accordance with ASTM C 335-84 at the mean temperature listed in the table. For insulation that has a conductivity outside the range shown for the applicable fluid operating temperature range at the mean rating temperature shown, when rounded to the nearest 0.00144 W/(m$^2\cdot$K), the minimum thicknesses shall be determined by:

$$T = PR[(1 + t/PR)^{K/k} - 1] \qquad \text{Eq. (7-1)}$$

Where

T = minimum insulation thickness for material with conductivity K, mm.

PR = pipe actual outside radius, mm.

t = insulation thickness from the table, mm.

K = conductivity of alternate material at the mean rating temperature indicated in the table for the applicable fluid temperature range, $W/(m^2 \cdot K)$.

k = the lower value of the conductivity range listed in the table for the applicable fluid temperature range, $W/(m^2 \cdot K)$.

7.4.7.2 Air Handling System Insulation. All air handling ducts and plenums installed as part of an VAC air distribution system shall be thermally insulated in accordance with Table 7-4.

Exceptions:

a) Factory installed plenums, casings, or ductwork furnished as a part of VAC equipment.

b) Where it can be shown that the heat gain to or heat loss from ducts without insulation will not increase building energy costs.

7.4.7.3 Insulation required by 7.4.7.1 and 7.4.7.2 shall be suitably protected from damage. Insulation should be installed in accordance with MICA Commercial and Industrial Insulation Standards, 1983.

7.4.7.4 Duct Construction. All air handling ductwork and plenums shall be constructed and erected in accordance with the following SMACNA Publications:

a) HVAC Duct Construction Standards -- Metal and Flexible, 1985

b) HVAC Duct Leakage Test Manual, 1985

c) Fibrous Glass Duct Construction Standards, 1979

In addition to the requirements of the above referenced standards, the following are required:

a) **Leakage Tests.** Ductwork which is designed to operate at static pressures in excess of 76 mm WC shall be leak tested and be in con-formance with sections of the HVAC Duct Leakage Test Manual, as follows: Test procedures shall be in accordance with those outlined in section 5, or equivalent; test reports shall be provided in accordance with section 6, or equivalent; the tested duct leakage class at a test pressure equal to the design duct pressure class rating shall be equal to or less than leakage class 6 as defined in 4.1 of the manual. Leakage testing may be limited to representative sections of the duct system but in no case shall such tested sections include less than 25% of the total installed duct area for the designated pressure class.

b) **Additional Sealing.** Where supply ductwork and plenums that are designed to operate at static pressures from 6.4 cm to 51 mm WC inclusive are located outside of the conditioned space or in return plenums, joints shall be sealed in accordance with Seal Class C as defined in the SMACNA manuals referenced above. Pressure sensitive tape shall not be used as the primary sealant where such ducts are designed to operate at static pressures of 25 mm WC or greater.

7.4.8 Completion Requirements

7.4.8.1 Operating and maintenance manual. This shall be provided to the building owner. The manual shall include basic data relating to the operation and maintenance of HVAC systems and equipment. Required routine maintenance actions shall be clearly identified. Where applicable, HVAC controls information such as diagrams, schematics, control sequence descriptions, and maintenance and calibration information shall be included.

7.4.8.2 Air system balancing. This shall be accomplished in a manner to first minimize throttling losses, then fan speed shall be adjusted to meet design flow conditions. Balancing procedures shall be in accordance with the National Environmental Balancing Bureau (NEBB) Procedural Standards (1983), the Associated Air Balance Council (AABC) National Standards (1982), or equivalent procedures.

Exception: Damper throttling may be used for air system balancing with fan motors of 0.75 kW or less, or if throttling results in no greater than 0.25 kW fan horsepower draw above that required if the fan speed were adjusted.

7.4.8.3 Hydronic system balancing. This shall be accomplished in a manner to first minimize throttling losses, then the pump impeller shall be trimmed or pump speed shall be adjusted to meet design flow conditions.

Table 7-3

Minimum Insulation Thickness[1),2)], mm , for Various Pipe Sizes

Fluid Temp. Range °C	Run-outs to 51.0	Less than 25.4	Pipe Diameter, mm 31.8 to 51.0	63.5 to 101.6	127.0 to 152.4	More than 203.2
Domestic and Service Hot Water Systems[3)]						
40.6+	12.7	25.4	25.4	38.1	38.1	38.1
Cooling Systems (chilled Water, Brine, and Refrigerant)[4)]						
4.4-12.8	12.7	12.7	19.1	25.4	25.4	25.4
< 4.4	25.4	25.4	38.1	38.1	38.1	38.1

Notes:
1) For minimum thicknesses of alternative insulation types, see7.4.7.1.
2) Insulation thicknesses, mm, in the table are based on insulation having thermal resistance in the range of 0.028 to 0.032 m^2-°C/ W-mm on a flat surface at a mean temperature of 24 °C. Minimum insulation thickness shall be increased for materials having R values less than 0.028 m^2- °C/ W-mm or may be reduced for materials having R values greater than 0.032 m^2- °C/W-mm. See Appendix I for details.
3) Applies to recirculating sections of service or domestic hot water systems and to first 2.4 m from storage tank for non-recirculating systems.
4) The required minimum thicknesses do not consider water vapor transmission and condensation. Additional insulation, vapor retarders, or both, may be required to limit water vapor transmission and condensation.

Table 7-4

Minimum Duct Insulation

Temp. Difference Between Design Air Duct Temp. & Temp. of Air Surrounding Ducts, °C	Minimum Insulation Thermal Resistance Exclusive of Film Resistance, R (m^2 °C/W)
0.0 - 4.2	No Requirements
4.3 - 16.5	1.76
16.6 - 30.5	2.82
Above 30.5	2.82, plus 0.176 for each 13.9 °C differential above 30.56 °C

Notes:
a) Where exterior walls are used as plenum walls, wall insulation shall be required by the most restrictive condition of this section or section 4.
b) Unconditioned spaces include crawl spaces and attics.

Exceptions: Valve throttling may be used for hydronic system balancing under any of the following conditions:

a) pumps with motors of 7.5 kW or less
b) if throttling results in no greater than 2.2 kW pump horsepower draw above that required if the impeller were trimmed
c) to reserve additional pump pressure capability in open circuit piping systems subject to fouling. Valve throttling pressure drop shall not exceed that expected for future fouling
d) where it can be shown that throttling will not increase overall building energy costs.

7.4.8.4 HVAC control systems. This shall be tested to assure that control elements are calibrated, adjusted, and in proper working condition.

7.5 Prescriptive Requirements

7.5.1 Sizing. VAC System and equipment shall be sized to provide no more than the space and system loads calculated in accordance with the procedures described in section 7.4.1 above, in Appendix H, in the latest edition of the ASHRAE Handbook of Fundamentals, or in other equivalent publications.

7.5.1.1 When the design load is greater than 500 kW a minimum of two chillers or a multiple com-pressor unit shall be provided to meet the required load.

7.5.1.2 Multiple units of the same equipment type, such as multiple chillers, with combined capac-ities exceeding the design load may be specified to operate concurrently only if controls are provided which sequence or otherwise optimally control the operation of each unit based on load.

7.5.2 Fan System Design Criteria

7.5.2.1 General. The following design criteria apply to all VAC systems used for comfort ventilating and/or air conditioning. For the purposes of this section, the energy demand of a fan system is the sum of the demand of all fans which are required to operate at design conditions to supply air from the cooling source to the conditioned space(s) and to return it back to the source or exhaust it to the outdoors.

Exception: Systems with total fan system motor horsepower of 7.5 kW or less.

7.5.2.2 Individual VAV fans with motors 25 KW and larger shall include controls and devices necessary for the fan motor to demand no more than 50% of design wattage at 50% of design air volume, based on manufacturer's test data.

7.5.2.3 Air transport for all-air systems. The Air Transport Factor (ATF) for each all-air VAC system shall not be less than 5.5. The ATF factor shall be based on design system air flow for constant volume systems. The factor for variable air volume systems may be based on average conditions of operation. Energy for the transfer of air through heat recovery devices shall not be included in determining the factor; however, such energy shall be included in the evaluation of the effectiveness of the heat recovery system.

$$ATF = \frac{\text{Space Sensible Heat Removal, in W}}{\text{Supply + Return Fan Power Input, in W}} \qquad \text{Eq. (7-2)}$$

For purposes of these calculations, Space Sensible Heat Removal is equivalent to the maximum coincident design sensible cooling load of all spaces served for which the system provides cooling. Fan Power Input is the rate of energy delivered to the fan prime mover.

7.5.2.4 Other Systems. Air and water, all-water and unitary systems employing chilled, hot, dual-temperature or condenser water transport systems to space terminals shall not require greater transport energy (including central and terminal fan power and pump power) than an equivalent all-air system providing the same space sensible heat removal and having an air transport factor not less than 5.5.

7.5.2.5 Power Consumption of Fans. Overall air capacity and air handling system components, such as ducts, filters, etc. shall be selected so as to provide an average Fan Performance Index (FPI) of less than 645 L/s-mm per m^2 of gross floor area of heated or cooled space. The Fan Performance Index shall be calculated by:

$$FPI = (AFR_t \times TP_t) / GFA \qquad \text{Eq. (7-3)}$$

Where

FPI = Fan Performance Index, (L/s)·mm per m^2.

AFR_t = total supply air flow quantity in L/s,

TP_t = the total pressure of the supply fans, mm of water.

GFA = Gross Floor Area, m^2.

7.5.2.6 Special Occupancies. Where the design m^2 per occupant in a space is less than 4.75 m^2 per person, the FPI may be increased as follows:

1) If m^2 per person is greater than 1.40, then FPI= 774,
2) If m^2 per person is less than or equal to 1.40, then FPI= 839.

7.5.2.7 Variable Volume Systems. The FPI limit may be modified to reflect the average power consumed by variable volume systems in accordance with Equations (7-4), (7-5), (7-6), and (7-7).

$$FPI_a = FPI_m \times C_{va} \qquad \text{Eq. (7-4)}$$

Where:

FPI_a = Adjusted Fan Power Index

FPI_m = Fan Power Index at maximum flow

C_{va} = Variable volume constant

The value of C_{va} shall be determined as follows:

1) For system having no static pressure control other than discharge air dampers.

$$C_{va} = (AFR_a / AFR_m)^{-2} \qquad \text{Eq. (7-5)}$$

2) For systems having static pressure control operating vortex type inlet vanes on centrifugal fans.

$$C_{va} = (AFR_a / AFR_m) \times (TP_a / Tpm)^2 \qquad \text{Eq. (7-6)}$$

3) For systems having static pressure control operating fan speed, variable pitch axial fan blades, or frequency controller.

$$C_{va} = (AFR_a / AFR_m) \times (TP_a / TP_m) \qquad \text{Eq. (7-7)}$$

Where

AFR_a = Average air flow rate, L/s

AFR_m = Maximum air flow rate, L/s

TP_a = Average system total pressure, mm of water.

TP_m = Maximum system total pressure, mm of water.

In the absence of verifying calculations, AFR_a may be assumed to be 0.85 x AFR_m.

7.5.3 Pumping System Design Criteria

7.5.3.1 General. The following design criteria apply to all VAC pumping systems used for comfort air conditioning. For purposes of this section, the energy demand of a pumping system is the sum of the demand of all pumps that are required to operate at design conditions to supply fluid from the cooling source to the conditioned space(s) or heat transfer device(s) and return it back to the source.

Exception: Systems with total pump system motor horsepower of 7.5 kW or less.

7.5.3.2 Friction Rate. Piping systems shall be designed at friction pressure loss rate of no more than 1.2 metres of water per 30 equivalent metres of pipe.

Note: Lower friction rates may be required for proper noise or corrosion control.

7.5.3.3 Variable Flow. Pumping systems that serve control valves designed to modulate or to step open and closed as a function of load, shall be designed for variable fluid flow.

Flow may be varied using variable speed driven pumps, staged multiple pumps, or pumps riding their characteristic performance curves.

Exceptions:

a) Systems where a minimum flow greater than 50% of the design flow is required for the proper operation of equipment served by the system, such as chillers.

b) Systems that serve no more than one control valve.

7.5.4 System Temperature Reset. For the purpose of resetting cold deck temperatures or fan discharge air temperatures, one representative zone may be chosen to represent a number of zones with similar cooling requirements. In no case however, shall the representative zone be allowed to represent more than ten similar zones.

The supply air temperature reset requirements shall not be required for VAC systems that employ recooling of less than 20% of the total air in the system. The cold deck temperature shall be automatically reset to the median temperature necessary to satisfy the average cooling requirements of the zone requiring the most cooling.

8 VENTILATING AND AIR CONDITIONING EQUIPMENT

8.1 and 8.2 Blank for numbering consistency.

8.3 General. For compliance to be achieved, compliance with the Basic Requirements listed in section 8.4 is mandatory under all compliance paths.

8.4 Basic Requirements.

8.4.1 Minimum Equipment Performance. Equipment shall have minimum performance criteria, at standard rating conditions, not more than the values shown in Table 8-1. The standard rating conditions that apply to these minimum performance criteria are listed in Appendix H. Data furnished by the equip-ment manufacturer or certified under a nationally recognized certification program or rating procedure shall be acceptable to satisfy these requirements. If more detail is desired on performance of various types of equipment, then Tables H-1 through H-9 in Appendix H may be used.

8.4.2 Coefficient of Performance (COP). The COP of an air-conditioning system is the ratio of the useful cooling effect to the total energy input. COPs for air-cooled electrically driven air-conditioners include compressor, evaporator, and condenser. COPs for water chilling packages do not include chilled water or condenser water pumps or cooling tower fans.

8.4.3 Integrated Part Load Value (IPLV). This is the ARI descriptor for part-load efficiency for certain types of equipment. Compliance with minimum efficiency requirements specified for HVAC equipment shall include compliance with part-load requirements where indicated as well as standard or full-load requirements. The procedure for determining the IPLV is provided in the referenced ARI Standards and is discussed in Appendix H.

8.4.4 Field Assembled Equipment & Components.

8.4.4.1 When components such as indoor or outdoor coils are used from more than one manufacturer as parts of air conditioning or heating equipment, component efficiencies shall be specified based on data provided by the component manufacturers, which shall provide a system which is in compliance with the requirements of 8.4.1.

8.4.4.2 Heat operated cooling equipment shall show C.O.P. not less than listed in Table 8-1 except when:

1) It is supplied by recovered energy, such as steam rejected from another process or solar energy or any other nondepleting source.

2) It is used in systems requiring air conditioning that is independent of local power sources (standby) for critical applications, i.e., hospitals, essential electronic processing systems, etc.

Table 8-1
Minimum Performance Requirements of Various Air Conditioning Equipment

Air Conditioning Equipment	kWe/ kWr	COP
Room A/C units		
Up to 2.6 kWr cap. 0.36	2.8	
Over 2.6 kWr cap. 0.32	3.1	
Unitary A/C units		
(air cooled)		
Up to 20 kWr	0.34	2.9
21 to 40 kWr	0.34	2.9
Over 40 kWr	0.34	2.9
(water cooled)		
Up to 20 kWr	0.24	4.1
21 to 40 kWr	0.24	4.1
Over 40 kWr	0.24	4.1
Split Systems		
(air cooled)		
Up to 20 kWr	0.33	3.0
21 to 40 kWr	0.33	3.0
Over 40 kWr	0.33	3.0
(water cooled)		
Up to 20 kWr	N/A	N/A
21 to 40 kWr	N/A	N/A
Over 40 kWr	N/A	N/A
Reciprocating chillers		
(air cooled)		
Up to 120 kWr	0.27	3.7
Above 120 kWr	0.27	3.7
(water cooled)		
Up to 120 kWr	0.21	4.7
Above 120 kWr	0.21	4.7
Rotary chillers		
(water cooled)	0.20	5.0
Centrifugal chillers		
(air cooled)		
Up to 880 kWr	0.29	3.5
Above 880 kWr	0.29	3.5
(water cooled)		
Up to 880 kWr	0.20	5.0
Above 880 kWr	0.19	5.3
Absorption chillers	1.43	0.70

Notes:
kWr = kilowatt refrigeration.
kWe/kWr = kilowatt electricity per kilowatt refrigeration.
kWe/Tr = kilowatt electricity per ton of refrigeration.
1 Tr = 3.51685 kWr

8.4.4.3 Total on-site energy input to the equipment shall be determined by combining the energy input to all components, elements and accessories such as compressor(s), internal circulating pump(s), condenser-air fan(s), cooling towers, evaporative-condenser cooling water pump(s), purge devices, viscosity control heaters, and controls.

8.4.5 Equipment Controls.

8.4.5.1 Heat pumps. If equipped with supplementary resistance heaters, they shall be installed with a control to prevent heater operation when the service hot water heating load can be met by the heat pump.

8.4.5.2 Cooling Equipment Auxiliary Controls. Evaporator coil frosting and excessive compressor cycling at part-load conditions should be controlled by limited and controlled cycling of the refrigerant prime mover rather than by the use of either hot gas by-pass or evaporator pressure regulator control.

8.4.6 Cooling Equipment Data. Cooling equipment shall be provided with full-load and part-load energy consumption data and information on the range of voltages at which the equipment such as fans, pumps, chillers and blowers shall be included in the energy input data provided.

8.4.7 Responsibility of Equipment Suppliers. Suppliers of VAC equipment shall furnish, upon request by prospective purchasers, designers, or contractors, the full and partial capacity and standby input(s) and output(s) of all equipment, and components of applied systems, based on equipment in new condition, to enable determination of their compliance with this code. This includes performance data under modes of operation and ambient conditions necessary to make the analysis outlined in this code.

Performance data furnished by the equipment supplier or certification under a nationally recognized program, when available, satisfies this requirement when all energy input(s), output(s) and operating modes are included.

8.4.8 Maintenance. The VAC system shall be provided with the preventive maintenance information required to maintain efficient operation of the assembled system. Maintenance procedures for equipment which require routine maintenance to maintain efficient operation, shall be furnished to the building owner complete with the necessary maintenance information. Required routine maintenance actions shall be clearly stated as required and incorpoporated on a permanent label, affixed in a readily accessible location on the equipment. The label may be limited to identifying required actions that are explained in greater detail in an operation and maintenance manual. The label should identify, the operation and maintenance manual for that particular model and type of product. At least one copy of each required manual shall be furnished to the building owners.

9 SERVICE WATER HEATING SYSTEMS AND EQUIPMENT

9.1 and 9.2 Blank for numbering consistency.

9.3 General. For compliance to be achieved, compliance with the Basic Requirements listed in section 9.4 is mandatory under all compliance paths. In addition, the Prescriptive Requirements of section 9.5 must be met.

Service water heating equipment shall be supplied with the information needed to make the analysis required to determine compliance with this code.

9.4 Basic Requirements.

9.4.1 Sizing of Systems. Service water heating system design loads for the purpose of sizing and selecting systems shall be determined in accordance with the procedures described in Chapter 54 of ASHRAE Handbook, 1987 HVAC Systems and Applications Volume, or a similar computation procedure.

9.4.2 Equipment Efficiency. All water heaters and hot water storage tanks shall meet the criteria of Table 9-1. Where multiple criteria are listed, all criteria shall be met.

Exception: Storage water heaters and hot water storage tanks having more than 1900 L of storage capacity need not meet the standby loss (SL) or heat loss (HL) requirements of Table 9-1 if the tank surface area is thermally insulated to R of (1.14, or R of 2.20 as of January 1, 1992 and if a standing pilot light is not used.

9.4.2.1 Acceptable data. Data furnished by the equipment manufacturer or certified under a nationally recognized certification program or rating procedure shall be acceptable to satisfy these requirements.

9.4.2.2 Omissions. Omissions of minimum performance requirements for certain classes of equipment do not preclude use of such equipment where appropriate.

9.4.3 Piping Insulation.

9.4.3.1 Circulating Systems. Piping insulation shall conform to the requirements of Table 7-3 or an equivalent level as calculated in accordance with Eq. 7.1.

9.4.3.2 Non-circulating Systems. The first 2.4 meters of outlet piping from a storage system that is maintained at a constant temperature and the inlet pipe between the storage tank and a heat trap shall be insulated as provided in Table 7-3 or to an equivalent level as calculated in accordance with Eq. 7-1. Systems without a heat trap to prevent circulation due to natural convection shall be considered circulating systems.

9.4.4 Controls

9.4.4.1 Temperature. Service water heating systems shall be equipped with temperature controls capable of adjusting storage temperatures from at least 32°C to a temperature setting compatible with the intended use. Some representative hot water utilization temperatures are listed in the ASHRAE Handbook, 1987 HVAC Systems and Applications Volume, Chapter 54, Table 3.

Exception: Service water heating systems serving residential dwelling units may be equipped with controls capable of adjustment down to 43°C only.

9.4.4.1.1 High temperatures. Where temperatures higher than 49°C are required at certain outlets for a particular intended use, separate remote heaters or booster heaters shall be installed for those outlets.

Exception**.** Where it can be shown that either energy cost is not reduced by the application of this requirement or that the total installed cost of the equipment, maintenance, and energy used over the life of the equipment is not reduced.

9.4.4.1.2 Circulating Hot Water Systems and Heated Pipes. Systems designed to maintain usage temperatures in hot water pipes, such as circulating hot water systems, shall be equipped with automatic time switches or other controls that can be set to turn off the system when use of hot water is not required.

9.4.5 Equipment and Control Requirements for the Conservation of Hot Water

9.4.5.1 Shower Flow. Showers using hot water and used for other than safety reasons shall limit the maximum water discharge to 0.2 L/s when tested according to ANSI A112.18.1M-1979.

When flow restricting inserts are used as a component part of a showerhead, they shall be mechanically

Table 9-1
Water Heating Equipment
Standard Rating Conditions and Minimum Performance

Type					Minimum Performance			
					1990		1992	
Class	Fuel	Storage Capacity L (gal)	Input Rating	Applicable Test Procedure	Eff.	Energy Factor	Eff.	Loss
Storage Water Heaters	Electric	<= 455	<= 12 kW	Note 1	-	$>=0.95-0.000348V_L$	-	-
		> 455	(or) > 12 kW	Note 2	-		-	SL < 20.5 W/m^2
	Gas	<= 380	<= 22000 W	Note	-	$>=0.62-0.0005V_L$	-	-
		> 380	(or) > 22000 W	Note 3	-		E_t 77%	SL < $1.3+144/V_L$
	Oil	<= 190	<= 22000 W	Note 1	-	EF $>=0.59-0.0005V_L$		-
		<= 190	<= 31000 W		-	EF $>=0.59-0.0005V_L$		-
		> 190	(or) > 31000 W		-		E_c 83%	SL < $1.3+144/V_L$
Unfired Storage Tanks	-	All Volumes	-		-			HL < 20.5 W/m^2
Non-Storage Water Heaters	Gas	-	All Input Ratings	Note 3	-		E_t 80%	-
	Distil. Oil	-	All Input Ratings		-		E_c 83%	-

(a) Terms defined:

EF = Energy Factor, overall heater efficiency by DOE test procedure.
E_t = Thermal efficiency with 21 C, water temperature difference
E_c = Combustion efficiency, 100% minus flue loss when smoke = 0 (trace is permitted)
SL = Standby loss in W/m^2 for electric water heaters based on 27 C water-air temp. difference; standby loss in % per hour for fuel-fired water heaters is based on nom. 32 C water-air temp. diff
HL = Heat loss of tank surface area, W/m^2, based on 27 C water-air temperature difference
V_L = Storage volume in liters
V_g = Storage volume in gallons

(b) A storage heater is a water heater that has an input rating of less than 4440 W per liter of stored water or a storage capacity of 38 liters or more. A non-storage water heater is a water heater that has an input rating of at least 4440 W per liter of stored water and a storage capacity of less than 38 liters.

(c) Applicable Test Procedure Notes: **Note 1:** DOE Test Procedures, 1988 Code of Federal Regulations, Title 10, Part 430[66]; **Note 2:** ANSI C72.1-972; **Note 3:** ANSI Z21.10.3 - 1987[68] retained at the point of manufacture. Mechanically retained shall mean a pushing or pulling force to remove the flow restricting insert of 36 N or more. This requirement shall not apply to showerheads that will cause water to leak significantly from areas other than the spray face if the flow restricting insert were removed.

9.4.5.2 Public Restrooms. Lavatories in public facility restrooms (such as those in service stations, airports, train terminals, and convention halls) shall meet all of the following requirements:

a) **Flow Rate.** Be equipped to limit the flow of hot water to, either,
   1) a maximum of 0.03 L/s or
   2) 0.05 L/s if a device or fitting is used that limits the period of water discharge such as a foot switch or fixture occupancy sensor or
   3) 0.16 L/s if equipped with a self closing valve.

b) **Total Flow.** Either:
   1) be equipped with a foot switch or fixture occupancy sensor or similar device or
   2) be equipped with a device or fitting that limits its delivery to a maximum of 1.0 liter per cycle of hot water for circulating systems and a maximum of 2.0 per cycle liters for non-circulating systems. Lavatories for physically handicapped persons need not be so equipped.

c) **Temperature.** Limit the outlet temperature to 43°C maximum.

9.5 Prescriptive Criteria

9.5.1 Combination Service Water Heating or Space Heating Equipment. Combination space and service water heating equipment may only be used when at least one of the following conditions is met:

a) the annual space heating energy is less than 50% of the annual service water heating energy.

b) the energy input or storage volume of the combined boiler or water heater is less than twice the energy input or storage volume of the smaller of the separate boilers or water heaters otherwise required.

c) the combined system uses no more energy cost than separate systems that meet the requirements of 8.4 and 9.4.

d) where the input to the combined boiler is less than 44,000 W.

9.5.1.1 Service water heating equipment used to provide additional functions (e.g. space heating) as part of a combination (integrated) system shall comply with minimum performance requirements for water heating equipment.

9.5.2 Additional Equipment Efficiency Measures

9.5.2.1 Electric Water Heaters. In applications where water temperatures not greater than 63° C are required, an economic evaluation shall be made on the potential benefit of using an electric heat pump water heater(s) instead of an electric resistance water heater(s). The analysis shall compare the extra installed costs of the heat pump unit with the benefits in reduced energy costs (less increased maintenance costs) over the estimated service life of the heat pump water heater.

Exceptions. Electric resistance water heaters used in conjunction with site-recovered or site-solar energy sources that provide 50% or more of the water heating load or off peak heating with thermal storage.

9.5.2.2 Gas-Fired Water Heaters. All gas-fired storage water heaters not equipped with a flue damper that use indoor air for combustion or draft hood dilution and that are installed in a conditioned space shall be equipped with a vent damper (unless the water heater is already so equipped). Unless the water heater has an available electrical supply, the installation of such a vent damper shall not require an electrical connection.

The vent damper shall be listed as meeting appropriate ANSI standards and shall be installed in accordance with the manufacturer's instructions and local codes.

Exception: Where the cost of the damper exceeds the value of reduced energy costs over the damper's lifetime.

9.5.2.3 Heat Traps. Storage water heaters not equipped with integral heat traps and having vertical pipe risers shall be installed with insulated heat traps on both the inlet and outlets. The heat trap shall be installed directly or as close as possible to the outlet fittings.

Exceptions. Water heaters that are used to supply circulating systems. These systems shall comply with section 9.4.3.1.

10 AUXILIARY SYSTEMS

10.1 Purpose. To suggest basic energy requirements for auxiliary systems.

10.2 Scope. Building transportation and refrigeration systems.

10.3 General. Auxiliary systems and equipment vary substantially among buildings. As a consequence there are few "shall" requirements in this section. For more detailed information see Appendix I, "Principles of Effective Energy Conserving Building Design."

10.4 Basic Requirements.

10.4.1 Transportation Systems. Consideration shall be given to the use of schedule controls and efficient motor controls such as solid state control devices for automatic elevator systems and conveyor systems.

10.4.2 Retail Food and Restaurant Refrigeration.

10.4.2.1 Refrigeration systems containing multiple compressors should have compressors sized to optimally match capacities with loads.

10.4.2.2 Variable speed should be considered.

10.4.2.3 Heat recovery shall be considered when coincident thermal and refrigeration loads of similar magnitude are expected.

11 ENERGY MANAGEMENT

11.1 Purpose. The intent is to provide design data along with a means of testing the facility in its completed form so that the facility can be operated in an energy conserving manner as intended by this standard.

11.2 Scope. This section describes the minimum measurement, control, testing, and documentation features that shall be provided for the building.

11.3 General. For compliance to be achieved, compliance with the Basic Requirements listed in section 11.4 is mandatory under all compliance paths.

See the following sections for specific control requirements for specific systems and equipment:

Section 5 -	Lighting Systems
Section 6 -	Electric Power and Distribution Systems
Section 7 -	VAC Systems
Section 8 -	VAC Equipment
Section 9 -	Service Water Heating Systems and Equipment.

11.4 Basic Requirements

11.4.1 Energy Measurement Capability. Each public utility energy service meter provided shall be located or arranged so that the meter can be monitored. Monitoring of utility company meters and the installation of submetering or check metering shall be in compliance with the utility company regulations.

Each distinct building energy service shall have a measurement system provided to accumulate a record or indicator reading of the overall amounts of the energy being delivered.

Exception: A building of 500 m^2 or less of gross floor area in a complex of buildings may have its measurement system included with another building in the same complex.

All equipment used for heating or cooling and VAC delivery systems of greater than 20 kVA or 17,500 W energy input shall be arranged so that the inputs and outputs such as flow, temperature, and pressure can be individually measured to determine the equipment energy consumption, the installed performance capabilities and efficiencies, or both. The intent of this requirement is to provide physical access or other provisions in the equipment or layout that will allow these measurements in the future if so desired. Installation of the measurement equipment is not required for compliance with this code.

11.4.2 Central Monitoring and Control Systems. An energy management system should be considered in any building exceeding 3,700 m^2 (39,828 ft^2) in gross floor area. The minimum energy management capabilities for such a system should be to:

a) provide readings and retain daily totals for all electric power and demand, and for external energy and fossil fuel use
b) record, summarize, and retain the appropriate weekly totals of all values
c) provide capability to turn VAC and Service Water Heating system equipment ON or OFF based on time schedules
d) provide capability to reset local loop control systems for VAC equipment
e) monitor and verify operations of heating, cooling, and energy delivery systems
f) provide capability to turn lighting systems ON or OFF based on time schedules
g) provide readily accessible override controls so that time based VAC and lighting controls may be temporarily overridden during off hours
h) provide optimum start/stop for VAC systems.

12 WHOLE-BUILDING ENERGY COST BUDGET METHOD

12.1 Purpose. This section provides criteria for the design of energy efficient buildings that allow greater design flexibility than the other compliance paths of this standard while providing building energy efficiency levels consistent with the other paths.

Since proposed designs may use varying amounts of different types of energy, energy cost is used as the common denominator. Using unit costs rather than units of energy or power such as kWh or kW allows the energy use contribution of different fuel sources at different times to be added and compared.

This path provides an opportunity for the building designer to evaluate and take credit for innovative energy conservation designs, materials, and equipment (such as daylighting, passive solar heating, heat recovery, better zonal temperature control, and thermal storage, as well as other applications of "off peak" electrical energy) that cannot be accounted for in the Prescriptive or System Performance paths.

NOTE: These procedures are intended only for the purpose of demonstrating design compliance and are not intended to be used to either predict, document, or verify annual energy consumption or annual energy costs.

12.2 Scope. Either the Building Annual Energy Budget Method (EB), described in Appendix C, or the Energy Cost Budget Method (ECB), described both here and in Appendix C, may be used when designs fail to meet either the Prescriptive or System Performance criteria of this standard. Either method may be employed for evaluating the compliance of all proposed designs (except shell buildings). Shell buildings may not use Section 12 for compliance.

12.3 General. Compliance using the procedures of Section 12 requires certification by an architect or engineer registered in Jamaica.

Compliance requires the calculation of the design energy consumption (DECON) via a detailed energy analyses of the entire proposed design. Then, an estimate of annual energy cost for the design is required, referred to as the design energy cost (DECOS). The DECOS is then compared against an energy cost budget (ECB). Compliance is achieved when the DECOS is not greater than the ECB (DECOS $\leq$ ECB). This section provides instructions for determining the ECB and for calculating the DECON and DECOS. The ECB shall be determined through calculation of the monthly energy consumption and energy cost of the prototype or reference building design configured to meet the requirements of Sections 4 through 11.

Designers are encouraged to try to minimize life cycle costs including capital costs and operation and maintenance costs along with energy costs over the projected lifetime of the building when comparing design options. The ECB is the highest allowable calculated annual Energy Cost Budget for a specific building design. Other alternative designs are likely to have lower annual energy costs and life cycle costs than those that minimally meet the ECB.

The ECB is a numerical target for annual energy cost. It is intended to assure neutrality with respect to choices of VAC system type, architectural design, fuel choice, etc., by providing a fixed repeatable budget target that is independent of any of these choices wherever possible (i.e., for the prototype buildings). The ECB for a given building size and type will vary only with climate, the number of stories and the choice of simulation tools.

The specifications of the prototypes are necessary to assure repeatability but have no other significance. They are not recommended energy conserving practice, or even physically reasonable in some cases, but rather are modeling assumptions that allow a calculation of the energy cost resulting from compliance with the spirit and the letter of Sections 5 through 12. It is anticipated that budget-calculating software or tables will become available to compute the ECB without reference to any of the specifications in Appendix C.

12.4 Annual Energy Cost Budget Method.

12.4.1 Requirement for the Annual Energy Cost Budget (ECB). Annual energy cost budgets (ECB) for the building design shall be determined in accordance with either the Prototype Building Method or the Reference Building Method in 12.6.

Both methods permit calculating an ECB that is the summation of the 12 monthly energy cost budgets (ECB_m). Each ECB_m is the product of the monthly budget energy consumption ($BECON_m$) of each type of energy used multiplied by that monthly energy cost

($ECOS_m$) per unit of energy for each type of energy used. The ECB shall be determined in accordance with Eq 12-1 as follows:

$$ECB = ECB_{jan} + ...ECB_m + ... + ECB_{dec} \quad \text{Eq. (12-1)}$$

Where ECB_m is based on Equation 12-2:

$$ECB_m = (BECON_{m1})(ECOS_{m1}) + ... + (BECON_{mi})(ECOS_{mi}) \quad \text{Eq. (12-2)}$$

Where:

ECB	=	The annual Energy Cost Budget
ECB_m	=	The monthly Energy Cost Budget
$BECON_{mi}$	=	The monthly Budget Energy Consumption of the i^{th} type of energy
$ECOS_{mi}$	=	The monthly Energy Cost, per unit of the i^{th} type of energy

The $ECOS_{mi}$ shall be determined using current rate schedules or contract prices available at the building site for all types of energy purchased. These costs shall include:

a) demand charges,
b) rate blocks,
c) time of use rates,
d) interruptable service rates,
e) delivery charges,
f) fuel adjustment factors,
g) taxes, and
h) all other charges applicable for the type, location, operation, and size of the proposed building.

The $BECON_{mi}$ shall be calculated from the first day through the last day of each month inclusive.

12.4.2 Compliance with the Annual Energy Cost Budget (ECB). If the DECOS, the annual energy cost estimated for the building design, is not greater than the ECB, the annual energy cost budget, as provided in Eq 12-3, and all of the basic requirements of 4,4, 5.4, 6.4, 7.4, 8.4, 9.4, 10.4, and 11.4 are met, the proposed design complies with this Standard.

$$DECOS \leq ECB \quad \text{Eq. (12-3)}$$

The DECOS shall be determined using the calculation procedures described in 12.5.

NOTE: The ECB, DECON, and DECOS calculations are applicable only for determining compliance with this standard. They are not predictions of actual energy consumption or costs of the proposed building after construction. Actual experience will differ from these calculations due to variations such as occupancy, building operation and maintenance, weather, energy use not covered by this standard, changes in energy rates between design of the building and occupancy, and precision of the calculation tool.

12.5 Calculation Procedures. This section defines calculation procedures that shall be used to calculate the ECB, DECON, and DECOS values for compliance purposes. Either the reference building procedure in 12.5.1 or the prototype building procedure in 12.5.2 shall be used to determine compliance.

The choice of procedure may depend upon designer and owner objectives and constraints. The prototype building procedure is considered generally easier to use, but it may not reflect actual conditions of the building design under consideration as well as the reference building procedure.

12.5.1 Reference Building Procedure. The reference building procedure should be used when the proposed design cannot be represented by one or a combination of the prototype buildings or the assumptions inherent in the prototype building description, such as occupancy and use-profiles, cannot reasonably be altered to accurately represent the proposed design.

If a reference building is used to set either the energy budget or the energy cost budget, then the reference building shall be based upon the characteristics of the proposed building design, but with characteristics modified to meet the energy requirements of sections 4 through 11 of the EEBC.

Each floor of the reference building shall be oriented exactly as in the proposed design. The form, gross and conditioned floor areas of each floor, the number of floors, and the lighting and VAC system types and zoning shall be as in the proposed design. All other characteristics of the reference building such as lighting, envelope and VAC system characteristics shall meet the requirements of Sections 4 through 11.

12.5.2 Prototype Building Procedure. The intent of the Prototype Building Procedure is to reduce the complexity and level of effort of compliance with this part of the EEBC. Prototypical building descriptions have been defined for a number of building types. Use of a prototypical building description should simplify compliance and save the user time relative to developing a reference building description.

The Prototype Building Procedure may be used to develop an ECB for all building types for which prototypical building descriptions have been defined. Descriptions of these buildings are contained in Appendix C. In developing an ECB, the form, orientation, occupancy, and use profiles for a prototype building shall be fixed. Envelope, lighting, electrical systems, and VAC systems shall meet the respective prescriptive or system performance requirements of Sections 4 through 11 and are standardized inputs.

The building designer shall determine the building type of the proposed design using the building prototype categories available in Appendix C. Using the appropriate prototype building characteristics from the tables in the appendix, the prototype building shall be simulated using the same gross floor area and number of floors as in the proposed design.

For mixed-use buildings the ECB shall be derived by allocating the floor space of each building type within the floor space of the Prototype Building. For buildings types for which prototypical building descriptions have been not been defined, the Reference Building Procedure of 12.5.1 shall be used.

12.5.3 Climate Data. The prototype or reference building shall be modeled using the calculation procedures defined in Appendix C. The modeling shall use a climate data set appropriate for both the site and the complexity of the energy conserving features of the design. ASHRAE WYEC weather tapes or bin weather data shall be a default choice.

12.5.4 Determination of the Design Energy Consumption and Design Energy Cost. The DECON shall be calculated by modeling the proposed design using the same methods, assumptions, climate data, and simulation tool as were used to establish the ECB (except as explicitly provided in Appendix C). The DECOS shall be calculated as provided in Eq 12-4.

$$DECOS = DECOS_{jan} + \ldots DECOS_{m} + \ldots + DECOS_{dec} \quad \text{Eq. (12-4)}$$

Where the $DECOS_m$ are based on Equation 12-5:

$$DECOS_m = (DECON_{m1})(ECOS_{m1}) + \ldots + (DECON_{mi})(ECOS_{mi}) \quad \text{Eq. (12-5)}$$

Where

$DECOS$ = The annual design energy cost

$DECOS_m$ = The monthly design energy cost

$DECON_{mi}$ = The monthly design energy consumption of the i^{th} type of energy

$ECOS_{mi}$ = The monthly Energy Cost, per unit of the i^{th} type of energy

The $DECON_{mi}$ shall be calculated from the first day through the last day of the month inclusive.

If the proposed design includes cogeneration or renewable energy sources designed for the sale of energy off site, the energy cost and income resulting from outside sales shall not be included in the calculation of DECOS. Such systems shall be modeled as operating to supply energy needs of the proposed design only.

12.5.5 Standard Calculation Procedures. The standard calculation procedures consist of methods and assumptions for calculating the ECB for the prototype or reference building and the DECON and DECOS of the proposed design. In order to maintain consistency between the ECB and the DECOS, two kinds of input assumptions shall be used. "Prescribed" assumptions shall be used without variation. "Default" assumptions shall be used unless the designer can demonstrate that a different assumption better characterizes the building's use over its expected life. Details of assumptions and procedures are contained in Appendix C.

Any modification of a default assumption shall be used to model both the prototype or reference building and the proposed design unless the designer demonstrates a clear cause to do otherwise. Special procedures necessary for speculative buildings are discussed in Appendix C.

13 DEFINITIONS, ABBREVIATIONS, ACRONYMS AND SYMBOLS

13.1 Purpose. The purpose of this section is to define terms, abbreviations, acronyms, and symbols.

13.2 Scope. These terms, abbreviations, acronyms, and symbols are applicable to all sections of this code.

13.3 Blank for numbering consistency.

13.4 Definitions

accessible (as applied to equipment): admitting close approach; not guarded by locked doors, elevation, or other effective means. (See also readily accessible.)[1]

adjusted lighting power: lighting power, ascribed to a luminaire(s) that has been reduced by deducting a lighting power control credit based on use of an automatic control device(s).

annual fuel utilization efficiency (AFUE): the ratio of annual output energy to annual input energy which includes any non-heating season pilot input loss.

air conditioning, comfort: treating air to control its temperature, relative humidity, cleanliness, and distribution to meet the comfort requirements of the occupants of the conditioned space. Some air conditioners may not accomplish all of these controls.[3]

area factor (AF): a multiplying factor which adjusts the unit power density (UPD) for spaces of various sizes to account for the impact of room configuration on lighting power utilization.

area of the space (A): the horizontal lighted area of a given space measured from the inside of the perimeter walls or partitions, at the height of the working surface.

automatic: self-acting, operating by its own mechanism when actuated by some impersonal influence, such as, a change in current strength, pressure, tem-perature or mechanical configuration. (See also manual.)[1]

ballast: a device used to obtain the necessary circuit conditions (voltage, current, and wave form) for starting and operating an electric-discharge lamp.

ballast efficacy factor - fluorescent: the ratio of the relative light output expressed as a percent to the power input in watts, at specified test conditions.

ballast factor (BF): the ratio of a commercial ballast lamp lumens to a reference ballast lamp lumens, used to correct the lamp lumen output from rated to actual.

building: any new structure to be constructed that includes provision for any of the following or any combination of the following: a space heating system, a space cooling system, or a service water heating system.

building energy cost: the computed annual energy cost of all purchased energy for the building, calculated using the methods of Section 12 of this code.

building envelope: the elements of a building that enclose conditioned spaces through which thermal energy may be transferred to or from the exterior or to or from unconditioned spaces.

building type: the classification of a building by usage as follows:

a) **assembly:** a building or structure for the gathering together of persons, such as auditoriums, churches, dance halls, gymnasiums, theaters, museums, passenger depots, sports facilities, and public assembly halls.

b) **health and institutional:** a building or structure for the purpose of providing medical treatment, confinement or care, and sleeping facilities such as hospitals, sanitariums, clinics, orphanages, nursing homes, mental institutions, reformatories, jails, and prisons.

c) **hotel or motel:** a building or structure for transient occupancy, such as resorts, hotels, motels, barracks, or dormitories.

d) **multifamily:** a building or structure containing three or more dwelling units (see dwelling units)

e) **office (business):** a building or structure for office, professional, or service type transactions; such as medical offices, banks, libraries, and governmental office buildings

f) **restaurant:** a building or a structure for the consumption of food or drink, including fast food, coffee shops, cafeterias, bars, and restaurants

g) **retail (mercantile):** a building or structure for the display and sale (wholesale or retail) of merchandise such as shopping malls, food markets, auto dealerships, department stores, and specialty shops (see also retail establishments)

h) **school (educational):** a building or structure for the purpose of instruction such as schools, colleges, universities, and academies

i) **warehouse (storage):** a building or structure for storage, such as aircraft hangers, garages, warehouses, storage buildings, and freight depots.

check metering: measurement instrumentation for the supplementary monitoring of energy consumption (electric, gas, oil, etc.) to isolate the various categories of energy use to permit conservation and control, in addition to the revenue metering furnished by the utility.

coefficient of performance (COP) -- cooling: the ratio of the rate of heat removal to the rate of energy input in consistent units, for a complete cooling system or factory assembled equipment, as tested under a nationally recognized standard or designated operating conditions.

coefficient of performance (COP), heat pump -- heating: the ratio of the rate of heat delivered to the rate of energy input, in consistent units, for a complete heat pump system under designated operating conditions.

combined thermal transmittance values (U_o): see thermal transmittance, overall.

conditioned floor area: the area of the conditioned space measured at floor level from the interior surfaces of the walls.

conditioned space: a cooled space, heated space, or indirectly conditioned space.

connected lighting power (CLP): the power required to energize luminaires and lamps connected to the building electrical service, in Watts.

control loop, local: a control system consisting of a sensor, a controller, and a controlled device.

control points: the quantity of equivalent ON or OFF switches ascribed to a device used for controlling the light output of a luminaire(s) or lamp(s).

cooled space: an enclosed space within a building that is cooled by a cooling system whose sensible capacity

a) exceeds 16 W/m^2, or

b) is capable of maintaining space dry bulb temperature of 32°C or less at design cooling conditions.

daylighted space: the space bounded by vertical planes rising from the boundaries of the daylighted area on the floor to the above floor or roof.

daylighted zone:

a) **under skylights:** the area under each skylight whose horizontal dimension in each direction is equal to the skylight dimension in that direction plus either the floor to ceiling height or the dimension to an opaque partition, or one-half the distance to an adjacent skylight or vertical glazing, whichever is least.

b) **at vertical glazing:** the area adjacent to vertical glazing which receives daylighting from the glazing. For purposes of this definition and unless more detailed daylighting analysis is provided, the daylighting zone depth is assumed to extend into the space a distance of 5 metres or to the nearest opaque partition, whichever is less. The daylighting zone width is assumed to be the width of the window plus either two feet on each side (the distance to an opaque partition) or one half the distance to an adjacent skylight or vertical glazing whichever is least.

daylight sensing control (DS): a device that automatically regulates the power input to electric lighting near the fenestration to maintain the desired workplace illumination, thus taking advantage of direct or indirect sunlight.

default assumption: the value of an input used in a calculation procedure when a value is not entered by the designer.

demand, electric: the rate at which electric energy is delivered to or by a system, part of a system, or a piece of equipment; expressed in kilowatts, kilovolt-amperes, or other suitable units at a given instant or averaged over any designated period.

design conditions: the exterior and interior environmental parameters specified for air-conditioning and electrical design for a facility.

design energy consumption (DECON): the computed annual energy usage of a proposed building design.

design energy costs (DECOS): the computed annual energy expenditure of a proposed building design.

dwelling unit: a single housekeeping unit comprised of one or more rooms providing complete independent living facilities for one or more persons including permanent provisions for living, sleeping, eating, cooking, and sanitation.

economizer, air: a ducting arrangement and automatic control system that allows a cooling supply fan system to supply outside air to reduce or eliminate the need for mechanical refrigeration during mild or cold weather.

economizer, water: a system by which the supply air of a cooling system is cooled directly or indirectly or both by evaporation of water or by other appropriate fluid (in order to reduce or eliminate the need for mechanical refrigeration).

efficiency, VAC system: the ratio of the useful energy output (at the point of use) to the energy input in consistent units for a designated time period, expressed in percent.

emergency system (back up system): a system that exists for the purpose of operating in the event of failure of a primary system.

energy: the capability for doing work; having several forms that may be transformed from one to another, such as thermal (heat), mechanical (work), electrical, or chemical.

energy cost: the cost of energy by unit and type of energy as proposed to be supplied to the building at the site including variations such as "time of day", "seasonal" and "rate of usage".

energy cost budget (ECB): the maximum allowable computed annual energy expenditure for a proposed building.

energy management system: a control system designed to monitor the environment and the use of energy in a facility and to adjust the parameters of local control loops to conserve energy while maintaining a suitable environment.

energy, recovered: see recovered energy.

enthalpy: a thermodynamic property of a substance defined as the sum of its internal energy plus the quantity Pv/J, where P is the pressure of the substance, v is its specific volume, and J is the mechanical equivalent of heat; formerly called total heat and heat content.[3]

exterior envelope: see building envelope.

exterior lighting power allowance (ELPA): the calculated maximum lighting power allowance for an exterior area of a building or facility, in Watts.

fenestration: any light-transmitting section in a building wall or roof. The fenestration includes glazing material (which may be glass or plastic), framing (mullions, muntins, and dividers) external shading devices, internal shading devices, and integral (between-glass) shading devices.

fenestration area: the total area of fenestration measured using the rough opening and including the glass or plastic, sash, and frame.

gross exterior wall area: the gross area of exterior walls separating a conditioned space from the outdoors or from unconditioned spaces as measured on the exterior above grade. It consists of the opaque wall including between floor spandrels, peripheral edges of flooring, window areas including sash, and door areas (excluding vents and grills).

gross floor area: the sum of the floor areas of the conditioned spaces within the building including basements, mezzanine and intermediate-floored tiers, and penthouses of headroom height 2286 cm or greater. It is measured from the exterior faces of exterior walls or from the centerline of walls separating buildings (excluding covered walkways, open roofed-over areas, porches and similar spaces, pipe trenches, exterior terraces or steps, chimneys, roof overhangs, and similar features).

gross floor area over outside or unconditioned spaces: the gross area of a floor assembly separating a conditioned space from the outdoors or from unconditioned spaces as measured from the exterior faces of exterior walls or from the center line of walls separating buildings. The floor assembly shall be considered to include all floor components through which heat may flow between indoor and outdoor or unconditioned environments.

gross lighted area (GLA): the sum of the total lighted areas of a building measured from the inside of the perimeter walls for each floor of the building.

gross roof area: the gross area of a roof assembly separating a conditioned space from the outdoors or from unconditioned spaces, measured from the exterior faces of exterior walls or from the centerline of walls separating buildings. The roof assembly shall be considered to include all roof or ceiling components through which heat may flow between indoor and outdoor environments including skylights but excluding service openings.

HVAC system: the equipment, distribution network, and terminals that provides either collectively or individually the processes of heating, ventilating, or air conditioning to a building.

HVAC system efficiency: see efficiency, HVAC system.

heat: the form of energy that is transferred by virtue of a temperature difference or a change in state of a material.

heat capacity (Hc): the amount of heat necessary to raise the temperature of a given mass one degree. Numerically, the mass multiplied by the specific heat.

humidistat: an automatic control device responsive to changes in humidity.

illuminance: the density of the luminous flux incident on a surface. It is the quotient of the luminous flux multiplied by the area of the surface when the latter is uniformly illuminated.

indirectly conditioned space: an enclosed space within the building that is not a cooled space, whose area weighted heat transfer coefficient to cooled spaces exceeds that to the outdoors or to unconditioned spaces; or through which air from cooled spaces is transferred at a rate exceeding three air changes per hour. (See also cooled space and unconditioned space.)

infiltration: the uncontrolled inward air leakage through cracks and crevices in any building element and around windows and doors of a building.

insolation: the rate of solar energy incident on a unit area with a given orientation.

integrated part-load value (IPLV): a single number figure of merit based on part-load EER or COP expressing part-load efficiency for air-conditioning and heat pump equipment on the basis of weighted operation at various load capacities for the equipment.

interior lighting power allowance (ILPA): the calculated maximum lighting power allowed for an interior space of a building or facility, in Watts.

interior unit lighting power allowance - prescriptive: the allotted interior lighting power for each individual building type, in W/m^2. (See 5.5.)

interior unit lighting power allowance - system performance: the allotted interior lighting power for each individual space, area or activity in a building, in W/m^2. (See 5.6.)

lighting power budget (LPB): the lighting power, in Watts, allowed for an interior or exterior area or activity.

lighting power control credit (LPCC): a credit applied to that part of the connected lighting power of a space which is turned off or dimmed by automatic control devices. It gives the specific value of lighting Watts to subtract from the connected interior lighting power when establishing compliance with the Interior Lighting Power Allowance (ILPA).

lumen (lm): SI unit of luminous flux. Radiometrically, it is determined from the radiant power. Photometrically, it is the luminous flux emitted within a unit solid angle (one steradian) by a point source having a uniform luminous intensity of one candela.

lumen maintenance control: a device that senses the illumination level and causes an increase or decrease of illuminance to maintain a preset illumination level.

luminaire: a complete lighting unit consisting of a lamp or lamps together with the parts designed to distribute the light, to position and protect the lamps, and to connect the lamps to the power supply.

manual (nonautomatic): action requiring personal intervention for its control. As applied to an electric controller, nonautomatic control does not necessarily imply a manual controller but only that personal intervention is necessary.[1] (See automatic.)

marked rating: the design load operating conditions of a device as shown by the manufacturer on the nameplate or otherwise marked on the device.

motor efficiency, minimum: the minimum efficiency occurring in a population of motors of the same manufacturer and rating.

motor efficiency, nominal: the median efficiency occurring in a population of motors of the same manufacturer and rating.

opaque areas: all exposed areas of a building envelope which enclose conditioned space except fenestration areas and building service openings such as vents and grilles.

occupancy sensor: a device that detects the presence or absence of people within an area and causes any combination of lighting, equipment, or appliances to be adjusted accordingly.

offices, category 1: Enclosed offices, all open plan offices without partitions or with partitions lower than 1372 mm below the ceiling, where 90% of all work stations are individually enclosed with partitions of at least the height described.

offices, category 2: Open plan offices 85 m^2 or larger with partitions 1067 to 1372 mm below the ceiling, where 90% of all work stations are individually enclosed with partitions of at least the height described. Offices less than 85 m^2 shall use category 1.

office category 3: large open plan offices 85 m^2 or larger with partitions higher than 1067 mm below the ceiling, where 90% of all work stations are individually enclosed with partitions of at least the height described. Offices less than 85 m^2 shall use category 1.

orientation: the directional placement of a building on a building site with reference to the building's longest horizontal axis, or if there is no longest horizontal axis then with reference to the designated main entrance.

outdoor (outside) air: air taken from the exterior of the building that has not been previously circulated through the building. (See also ventilation air.)

ozone depletion factor: a relative measure of the potency of chemicals in depleting stratospheric ozone. The ozone depletion factor potential depends upon the chlorine and the bromine content and atmospheric lifetime of the chemical. The depletion factor potential is normalized such that the factor for CFC-11 is set equal to unity and the factors for the other chemicals indicate their potential relative to CFC-11.[50]

packaged terminal air-conditioner (PTAC): a factory-selected wall sleeve and separate unencased combination of heating and cooling components, assemblies or sections (intended for mounting through the wall to serve a single room or zone). It includes heating capability by hot water, steam, or electricity.

packaged terminal heat pump: a PTAC capable of using the refrigeration system in a reverse cycle or heat pump mode to provide heat.

piping: a system for conveying fluids including pipes, valves, strainers, and fittings.

plenum: an enclosure that is part of the air handling system and is distinguished by having a very low air velocity. A plenum often is formed in part or in total by portions of the building.

power: in connection with machines, it is the time rate of doing work; in connection with the transmission of energy of all types, it is the rate at which energy is transmitted. It is measured in Watts (W) or British thermal units per hour.

power adjustment factor (PAF): a modifying factor that adjusts the effective connected lighting power (CLP) of a space to account for the use of energy conserving lighting control devices.

power factor (PF): the ratio of total Watts to the root-mean-square (RMS) volt amperes.

prescribed assumption: a fixed value of an input to the standard calculation procedure.

private driveways, walkways, and parking lots: exterior transit areas that are associated with a commercial or residential building and intended for use solely by the employees or tenants and not by the general public.

process energy: energy consumed in support of a manufacturing, industrial, or commercial process other than the maintenance of comfort and amenities for the occupants of a building.

process load: the calculated or measured time-integrated load on a building resulting from the consumption or release of process energy.

proposed design: a prospective design for a building that is to be evaluated for compliance.

prototype building: a generic building design of the same size and occupancy type as the proposed design which complies with the prescriptive requirements of this code and has prescribed assumptions used to generate the energy budget concerning shape, orientation, HVAC, and other system designs.

public driveways, walkways, and parking lots: exterior transit areas that are intended for use by the general public.

public facility restroom: a restroom used by the transient public.

qualified person: one familiar with the construction and operation of the equipment and the hazards involved.

radiant comfort heating: a system in which temperatures of room surfaces are adjusted to control the rate of heat loss by radiation from occupants.

readily accessible: capable of being reached quickly for operation, renewal, or inspections without requiring those to whom ready access is requisite to climb over or remove obstacles or to resort to portable ladders, chairs, etc. (See also accessible.)[1]

recommend: suggest as appropriate, not required.

recovered energy: energy utilized from an energy utilization system which would otherwise be wasted (not contributing to a desired end use).

reference building: a specific building design that has the same form, orientation and basic systems as the proposed design and meets all the criteria of the prescriptive compliance method.

reflectance: the ratio of the light reflected by a surface to the light incident upon it.

reheating: raising the temperature of air that has been previously cooled either by a refrigeration or an economizer system.

residential building low-rise: single, two family, and multifamily dwelling units of three stories or fewer of habitable space above grade.

reset: adjustment of the controller set point to a higher or lower value automatically or manually.

retail establishments: classifications set for the purpose of determining lighting power allowance for buildings based upon the following primary design functions:

- **Type A** - Jewelry merchandising, where minute examination of displayed merchandise is critical.
- **Type B** - Fine Merchandising: fine apparel and accessories, china, crystal and silver, art galleries, etc., where the detailed display and examination of merchandise is important.
- **Type C** - Mass Merchandising: general apparel, variety, stationery, books, sporting goods, hobby, cameras, gifts, luggage, etc. displayed in a warehouse type of building, where focused display and detailed examination of merchandise is important.
- **Type D** - General Merchandising: general apparel, variety, stationery, books, sporting goods, hobby, cameras, gifts, luggage, etc. displayed in a depart-ment store type of building, where general display and examination of merchandise is adequate.
- **Type E** - Food & Miscellaneous: bakeries, hard-ware and housewares, grocery, appliances and furniture, etc., where appetizing appearance is important.
- **Type F** - Service Establishments: establishments where functional performance is important.

roof: those portions of the building envelope including all opaque surfaces, fenestration, doors, and hatches which are above conditioned space and which are horizontal or tilted at less than 60° from horizontal. (See also walls.)

room area (A_r): for lighting power determination purpose, the area of a room or space shall be determined from the inside face of the walls or partitions measured at work plane height.

room air conditioner: an encased assembly designed as a unit to be mounted in a window or through a wall, or as a console. It is designed primarily to provide free delivery of conditioned air to an enclosed space, room, or zone. It includes a prime source of refrigeration for cooling and dehumidification and means for circulating and cleaning air and may also include means for ventilating and heating.

sash crack: the sum of all perimeters of all ventilators, sash, or doors based on overall dimensions of such parts expressed in metres (counting two adjacent lengths of perimeter as one).

sequence: a consecutive series of operations.

service systems: all energy-using or -distributing components in a building that are operated to support the occupant or process functions housed therein (including VAC, HVAC, service water heating, illumination, transportation, cooking or food preparation, laundering, or similar functions).

service water heating: the supply of hot water for purposes other than comfort heating and process requirements.

service water heating demand: the maximum design rate of water withdrawal from a service water heating system in a designated period of time (usually an hour or a day).

shading coefficient (SC): the ratio of solar heat gain through fenestration, with or without integral shading devices, to that occurring through unshaded 1/8 in. thick clear double strength glass.

shall: where shall is used with a special provision, that provision is mandatory if compliance with the code is claimed.

shell building: a building for which the envelope is designed, constructed, or both prior to knowing the occupancy type. (See also speculative building.)

should: term used to indicate provisions which are not mandatory but which are desirable as good practice.

solar energy source: natural daylighting or thermal, chemical, or electrical energy derived from direct conversion of incident solar radiation at the building site.

speculative building: a building for which the envelope is designed, constructed, or both prior to the design of the lighting, VAC systems, or both. A speculative building differs from a shell building in that the intended occupancy is known for the speculative building. (See also shell building.)

standard calculation procedure: an energy simulation model and a set of input assumptions that account for the dynamic thermal performance of the building; it produces estimates of annual energy consumption for heating, cooling, ventilation, lighting, and other uses.

system: a combination of equipment and/or controls, accessories, interconnecting means, and terminal elements by which energy is transformed so as to perform a specific function, such as VAC, service water heating, or illumination.

tandem wiring: pairs of luminaires operating with one lamp in each luminaire powered from a single two-lamp ballast contained in the other luminaire.

task lighting: lighting that provides illumination for specific visual functions and is directed to a specific surface or area.

task location: an area of the space where significant visual functions are performed and where lighting is required above and beyond that required for general ambient use.

terminal element: a device by which the transformed energy from a system is finally delivered; i.e., registers, diffusers, lighting fixtures, faucets, etc.

thermal conductance (C): the constant time rate of heat flow through unit area of a body induced by a unit temperature difference between the surfaces, $W/(m^2 \cdot °C)$. It is the reciprocal of thermal resistance. (See thermal resistance.)

thermal mass: materials with mass heat capacity and surface area capable of affecting building loads by storing and releasing heat as the interior and/or exterior temperature and radiant conditions fluctuate. (See also wall heat capacity.)

thermal resistance (R): the reciprocal of thermal conductance; 1/°C as well as 1/h, 1/U, $m^2 \cdot K/W$.

thermal transmittance (U): the overall coefficient of heat transfer from air to air. It is the time rate of heat flow per unit area under steady conditions from the fluid on the warm side of the barrier to the fluid on the cold side, per unit temperature difference between the two fluids, $W/(m^2 \cdot K)$.

thermal transmittance, overall (U_0): the gross overall (area weighted average) coefficient of heat transfer from air to air for a gross area of the building envelope, $W/(m^2 \cdot K)$. The U_0 value applies to the combined effect of the time rate of heat flows through the various parallel paths such as windows, doors, and opaque construction areas comprising the gross area of one or more building envelope components such as walls, floors, and roof or ceiling.

thermostat: an automatic control device responsive to temperature.

total lighting power allowance: the calculated lighting power allowed for the interior and exterior space areas of a building or facility.

unconditioned space: space within a building that is not a conditioned space. (See conditioned space.)

unit lighting power allowance (ULPA): the allotted lighting power for each individual building type in W/m^2.

Unit Power Density (UPD): the lighting power density, in W/m^2, of an area or activity.

unitary cooling equipment: one or more factory-made assemblies which normally include an evaporator or cooling coil, a compressor, and condenser combination (may include a heating function as well).

unitary heat pump: one or more factory-made assemblies which normally include an indoor conditioning coil, compressor(s), and outdoor coil or refrigerant-to-water heat exchanger (including means to provide both heating and cooling functions.

unlisted space: the difference in area between the gross lighted area and the sum of all listed spaces.

VAC system: the equipment, distribution network, and terminals that provides either collectively or individually the processes of ventilating or air conditioning to a building.

VAC system efficiency: see efficiency, VAC system.

variable air volume (VAV) VAC system: VAC systems that control the dry-bulb temperature within a space by varying the volume of supply air to the space.

ventilation: the process of supplying or removing air by natural or mechanical means to or from any space. Such air may or may not have been conditioned.[3]

ventilation air: that portion of supply air which comes from outside (outdoors) plus any recirculated air that has been treated to maintain the desired quality of air within a designated space. (See also outdoor air.)

visual task: those details and objects that must be seen for the performance of a given activity and includes the immediate background of the details or objects.

walls: those portions of the building envelope enclosing conditioned space including all opaque surfaces, fenestration, and doors which are vertical or tilted at an angle of 60° from horizontal or greater. (See also roof.)

wall heat capacity: the sum of the products of the mass of each individual material in the wall per unit area of wall surface times its individual specific heat, kJ/°C. (See thermal mass.)

Watt, (W): A unit of power. One watt is produced when one ampere, flows at an emf of one volt (unity power factor). (See also power.)

window to wall ratio (WWR): the ratio of the fenestration area to the gross exterior wall area.

zone: a space or group of spaces within a building with any combination of heating, cooling, or lighting requirements sufficiently similar so that desired conditions can be maintained throughout by a single controlling device.

13.5 Abbreviations, Acronyms and Symbols

A	area of the space
A_o	total building floor area
A_r	room area
$A_{wall,roof,etc.}$	area of a specific building component
AF	area factor
AFUE	annual fuel utilization efficiency
AHAM	Association of Home Appliance Manufacturers
AIA	American Institute of Architects
ALP	adjusted lighting power
ANSI	American National Standards Institute
ARI	Air-Conditioning and Refrigeration Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
$BECON_{mi}$	budget energy consumption by month (m) and fuel type (i)
BEF	ballast efficacy factor - fluorescent
BF	ballast factor
°C	degree Celsius
C	thermal conductance
CEEU	cost equivalent energy units
CH	ceiling height
CLP	connected lighting power
COP	coefficient of performance
$DECON_{mi}$	design energy consumption by month (m) and fuel type (i)
DECOS	annual design energy cost
DOE	U. S. Department of Energy
DS	daylight sensing control
ECB	annual energy cost budget
$ECOS_{mi}$	energy cost by month (m) and by fuel type (i)
ELPA	exterior lighting power allowance
EPD	equipment power density
GLA	gross lighted building area
H	height from bottom of window to bottom of external shading projection
Hc	heat capacity
hp	horsepower
HSPF	heating seasonal performance factor
IEPA	interior equipment power allowance
IES	Illuminating Engineering Society of North America
ILPA	interior lighting power allowance
IPLV	integrated part load value
IRF	internal reflecting film
K	Kelvin
LPB	lighting power budget
LPD	lighting power density
LPCC	lighting power control credit
NFPA	National Fire Protection Association
PAF	power adjustment factor
PTAC	packaged terminal air-conditioner
r	thermal resistivity
R	thermal resistance
SC	shading coefficient
SWH	service water heating
TEFC	totally enclosed, fan cooled
Tvis	See VLT, below
U_o	overall thermal transmittance
U_{or}	overall thermal transmittance of roof assembly
U_{ow}	overall thermal transmittance of opaque wall
ULPA	unit lighting power allowance

UPD	Unit Power Density
VAC	ventilating and air conditioning
VAV	variable air volume
VLT	transmittance of glazing material over visible portion of solar spectrum (Also, the equivalent term 'Tvis' may be used).
W	watts
WC	water column
WWR	window to wall ratio
WYEC	weather year for energy calculations (see ASHRAE 1989 Fundamentals Handbook, 24.3)

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VOLUME 2

Energy Efficiency Building Code (EEBC-94)

Section 2: Guidelines

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Preface to the EEBC Guidelines

This section contains Guidelines to the Energy Efficiency Building Code (EEBC). These guidelines are in the form of a series of appendices to the EEBC, that have been prepared to assist users in complying with the EEBC requirements. A separate appendix has been prepared to assist in interpreting and complying with each section of the EEBC. These guidelines contain design guidance, case studies, test methods, reference data, calculation methods, and compliance examples.

The two initial appendices provide introductory materials, including discussions of:

(1) the benefits of energy standards for buildings; and,

(2) general principles of energy-efficient building design.

Virtually the entire contents of both the EEBC-94 Requirements Volume (Section 1) and the Guidelines Volume (Section 2) have been prepared in electronic media for PC systems and are available on diskettes from ESMAP.

Compliance Forms and Diskette

Two complete sets of compliance forms are included in the guidelines (Appendix M). One set of 5 compliance forms is for small buildings (less than 1000 m^2 in floor area), and requests only the essential minimum information for compliance for smaller, and generally less complicated structures. A second set of 10 compliance forms is for larger buildings (equal to or greater than 1000 m^2 in floor area). These forms contain more options for compliance information, reflecting the greater complexity and diversity of larger buildings. The set of compliance forms intended for larger buildings may also be used for smaller buildings (those less than 1000 m^2) if so desired.

A diskette for PC compatible computers is provided as Appendix N. The diskette contains a copy of the compliance method for the building envelope system performance path.

Metrication in Jamaica

In keeping with the recent metrication process in Jamaica, these guidelines are presented entirely in metric units, as is the EEBC-94 itself. This represents a major departure from earlier drafts of both EEBC and guidelines, for both had been prepared originally in imperial (inch-pound) units only (circa 1992). As the metrication process proceeded, versions of the EEBC and of some guidelines materials were prepared in dual units, in late 1992 and in 1993. Then, in response to a policy to publish public documents only in metric units, these current 1994 versions of the EEBC and guidelines have been developed. To assist users in using the metric versions of these documents, Appendix M of these guidelines contains several pages of conversion factors between imperial and metric units.

Related References from ASHRAE

During the time that these final documents have been converted to metric format, some new reference materials have been published by ASHRAE in the US. While both contain valuable new information relative to complying with the types of requirements contained in the EEBC, unfortunately, both documents are prepared in imperial units. The reader is encouraged to become familiar with both of these documents as important references, even though their direct use is constrained by their being available only in imperial units.

A new second edition of the *Cooling and Heating Load Calculation Manual* has been published by ASHRAE in 1992 (by Faye C McQuiston, P.E. and Jeffrey D. Spitler, P.E.). This document represents a significant update to the methodology contained originally in the GRP 158 document that is extensively referenced. The GRP 158 version of the

Cooling and Heating Load Calculation Manual was described in detail during the 1991 Jamaican EEBC compliance workshops, and copies of the GRP 158 volume were presented to all workshop participants. This new 1992 version emphasizes use of the Tranfer Function method, recognised as the most rigorous of the three methods described in the new version. (The transfer function method was not highlighted in the earlier GRP 158 version). The new, revised 1992 document also comes with a diskette containing programs of the methods described in the volume.

The ASHRAE/IES Standard 90.1-1989 is a third generation energy efficiency standard for buildings prepared by ASHRAE. This standard was a major resource used in developing the EEBC for Jamaica. A User's Manual for the standard was published by ASHRAE in 1992. Like the *Cooling and Heating Load Calculation Manual,* the *ASHRAE/ IES Standard 90.1-1989 User's Manual* is written only in imperial units. However, considerable resources were available for the development of that document, and it contains many useful examples. While the document is oriented predominantly for US and Canadian use, many examples would be applicable under Jamaican conditions.

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These guidelines were prepared by a team of Jamaican consultants, with oversight and review from the Jamaica Bureau of Standards Energy Efficiency Building Code (EEBC) Committee, and with technical and production support from The Deringer Group, Berkeley, CA, USA. Joseph Deringer and Anne Sprunt developed an outline for the guidelines and assembled existing materials into a rough draft that was used to begin the writing of the guidelines. Mr. Joseph Gilling, Senior Economist with the World Bank, managed the effort to develop the guidelines, as part of a larger energy sector assistance project.

Appendices A and B were developed as team efforts. Nadine Isaacs wrote Appendix D, Building Envelope. Paul Hay wrote Appendix E, Daylighting. Keith Walters prepared Appendices F, Lighting, and G, Electric Power and Distribution. Donat Dundas wrote Appendix H, Ventilating and Air-Conditioning. Ken Wedderburn prepared Appendices I and J, Service Water Heating and Operations and Maintenance. Appendices K, Definitions, etc, and L, Conversion Factors were adaptations of materials from ASHRAE. Joseph Deringer developed Appendix C, Whole-Building Budgets from materials used with ASHRAE 90.1-1989, and developed the compliance forms in Appendix M from drafts prepared by Roddy Ashby and others.

A version of the guidelines was prepared in imperial units, using Pagemaker (tm) on a Macintosh (tm) system, by Electronic Easel, Ltd. of Kingston, Jamaica. A final version, in metric units, using Pagemaker (tm) under Microsoft Windows 3.1 (tm) for PC compatibles, was prepared by The Deringer Group, Berkeley, CA. Alexandra White was responsible for report production for the final metric version. Roosevelt DaCosta performed most of the metrication for the guidelines. Joseph Deringer performed metrication of some sections, plus technical editing of the final version.

Members of the Jamaica Bureau of Standards Energy Efficiency Building Code (EEBC) Committee included Mr. Winston G. Wakefield (Chairman), Mr. Roddy Ashby, Miss Grace Ashley, Mr. Milton Baker, Mr. Clive O.B. Broomfield, Mr. Richard Chambers, Mr. Dennis Chung, Mr. Roosevelt DaCosta, Mr. Marvin Goodman, Mr. Claon Rowe, and Mr. H.G. Sinclair.

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(b) Agencies and individuals who provided a rich source of technical material from existing codes and standards in the United States and elsewhere, including American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE), U.S. Department of Energy (US DOE), U.S. Agency for International Development (US AID); Tennessee Valley Authority (TVA); Bonneville Power Authority (BPA), States of California, Florida, Washington, Oregon, Massachusetts, New York, Tennessee.

Appendix A:
Benefits of Energy Standards

Contents of this Appendix

1 General Benefits of EEBCs A-1
2 Benefits of the Jamaican EEBC A-2
3 Conclusions from the Analyses A-6

Commentary

This appendix discusses benefits of energy efficiency standards in general and that of the Jamaican code in particular.

Data presented represents the experience of countries with well established energy codes; results of a recently completed ASEAN project, in S.E.Asia; and results of an analysis of Jamaican office-buildings, using the climate of Kingston, as well as construction and energy costs typical of Jamaica.

Particular emphasis is made of potential benefits expected on the implementation EEBC-94, as opposed to continuing current practices. These benefits are especially relevant to office buildings, but are also applicable to the envelopes of other building types.

It is nevertheless hoped that analysis of EEBC-94 will be extended in the near future to include benefits specifically relevant to hotels and retail buildings. Results of this analysis will then be incorporated into this appendix.

1 General Benefits of EEBCs

Building energy standards are important elements of energy policies within many countries of the Americas, the Pacific, and Europe. Countries having energy standards for commercial buildings and in many cases individual standards for new and existing buildings include the United States, Canada, Australia, New Zealand, Singapore, England, France, Germany, Sweden, Switzerland, Denmark, and Norway.

Available information indicates that energy standards have not been difficult to implement and have proved effective in reducing unnecessary energy costs. A number of countries are therefore engaged in second and third updates to their building energy standards.

In the United States for example, the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) developed a voluntary energy standard in 1975 (ASHRAE 9075). And by the early 1980s, all 50 U.S. states had adopted some modified form of this standard as mandatory.

ASHRAE subsequently published a major update to its energy standard for commercial buildings (ASHRAE/IES 90.1-1989): versions of which have already been adopted in Massachusetts, and other states are considering it. Estimated energy savings from ASHRAE 90-75 were:

a) **40%** of pre-1973 designs of oil-embargo, commercial buildings [A.D.Little, 1976]; and
b) **25-40%** of typical mid-70s building designs (AIA, 1980).

And, estimated savings from ASHRAE/IES 90.1-1989 are:

c) an additional **10-20%** from ASHRAE 90-75.

1.1 Benefits in Tropical Climates

Malaysia has adopted ASHRAE/IES 90.1-1989, and others with tropical climates (as the Philippines, Indonesia, and Thailand) have developed standards based on it; potential savings from which are:

a) **20%** in Malaysia,
b) **22%** in the Philippines,
c) **24%** in Indonesia, and
d) **23-43%** in Thailand.

1.2 Potential Savings and Payback Period for High Efficiency EEBC in Jamaica

A recent study in Thailand has indicated that energy savings in excess of present building energy standards are possible and cost effective.

In this study, high-efficiency measures of energy-conservation were evaluated for an office, hotel, and store. And, savings were found to be:

a) **45%** in the office,
b) **51%** in the hotel, and
c) **56%** in the store.

Payback for implementing these efficiency measures was found to vary from under 1 year to just over 2 years.

2 Benefits of the Jamaican EEBC

2.1 Potential Savings

The Jamaican Energy Efficiency Building Code (EEBC) is based on energy-efficiency experience within the U.S. and elsewhere; but is more stringent than even standards considered by a number of S.E. Asian countries, under a recently completed ASEAN project.

As Figure A-1 shows, estimated energy savings from implementing the Jamaican EEBC code are:

a) **30%** of annual consumption for large office buildings, and,
b) **36%** of annual consumption for small office buildings.

As Figure A-2 shows, peak electrical-demand is estimated to be reduced by an amount roughly equivalent to that for annual consumption. But, estimated reduction of peak cooling loads are:

c) **24%** for large offices, and
d) **29%** for small offices.

2.2 Convenience of Compliance Procedures

The Jamaican EEBC takes into consideration the climate, building materials and construction practices typical of Jamaica; as well as electrical and mechanical equipment; and systems appropriate and cost-effective in Jamaica.

All effort has nevertheless been made to keep compliance procedures simple and convenient. Consequently,

a) basic requirements are provided as a guide to energy-conscious design;
b) prescriptive requirements are provided as models of code compliance;
c) system performance requirements facilitate compliance of innovative designs;
d) whole-building analysis permits evaluation of complex designs; and
e) compliance forms are designed to be easily understood and completed.

2.3 Benefits to the Building Industry

A building energy code of this nature has not previously been introduced in Jamaica, but some of the more apparent benefits of its implementation are:

a) standards are established for evaluation of design decisions;
b) standards are established for building products and equipment;
c) practices such as computer-based energy analysis and daylighting are introduced; and;
d) the need for increasing Jamaica's generating capacity can be reduced without sacrificing the needs or comfort of building occupants.

2.4 Cost Effectiveness of Present Jamaica EEBC

A recently concluded Jamaican study indicates that implementing the Jamaican EEBC is cost effective.

Three types of energy and cost analyses were conducted on both the large and small office buildings, using the base case descriptions that represent current practice in Jamaica. First, a set of energy and cost parametric analyses were conducted separately across multiple values of each of about 20 energy measures. Second, a set of changes was made to the energy features of each base case building so that it would comply with the EEBC-90 code requirements, and energy and economic analyses were conducted of this combined "EEBC-90" set. Third, another set of changes was made to each base case building so that the result incorporated the features selected for the "high efficiency" case, and energy and economic analyses were conducted of this combined set.

An important feature of these analyses is that incremental construction costs have been identified for all changes from the base case values, whether for changes in individual parametric measures or for combined changes in multiple measures. The cost data was acquired from in-country suppliers and building designers. A quantity surveyor (cost estimator) provided detailed input for envelope-related features, while glass, lighting, and VAC suppliers provided information on those respective systems. Building design professionals reviewed the data for reasonableness.

In considering cost-effectiveness of measures that reduced loads, 60% of potential reductions in VAC sizing were used to calculate potential construction cost sav-

Figure A-1: Energy Results for Energy Code and for High-Efficiency Case

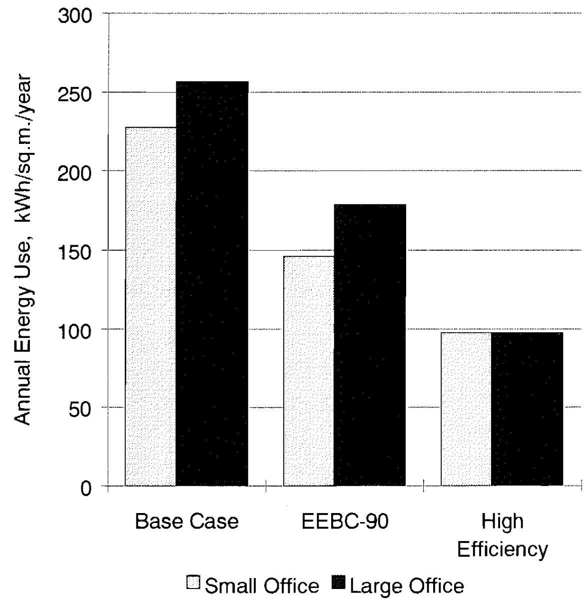
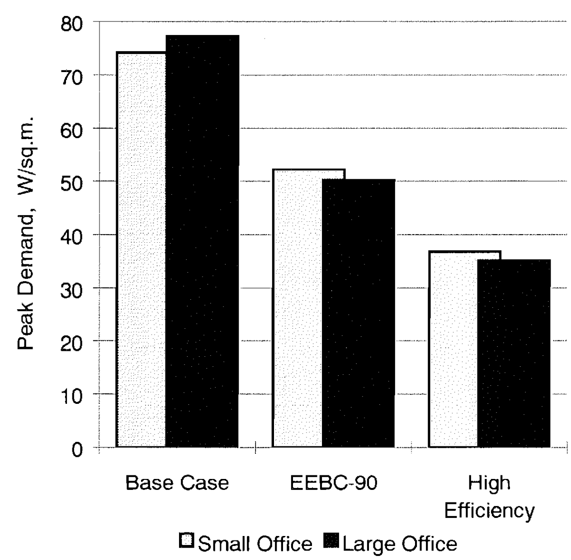


Figure A-2: Peak Demand Results for Energy Code and for High-Efficiency Case



ings. For all construction costs, the amount of import duties and taxes were identified separately, to permit assessment of impacts of these policy elements on the cost-effectiveness of energy measures.

In-country construction costs were identified whenever possible. When local costs were not available, as for energy products not yet used in Jamaica (such as daylighting controls), then US costs were used, with transportation costs, import duties and taxes applied. All costs were stated in US dollars, due to its more widespread use for energy-efficiency assessments internationally.

Both energy and economic impacts were assessed for each of the parametric measures. A financial analysis was done to assess impacts on a typical building owner. This analysis included the combined impacts of import duties and taxes. For the financial analysis, electricity costs used were current actual rates to the owner, including both kWh and kW components. Electricity rates increased twice during the course of the study, partly in response to fluctuations in the Jamaican dollar, and all economic and financial analyses reported in these guidelines use the JPS rates in effect during 1990 as a result of the first rate increase. Since the 1991 rates are higher in US$ than 1990 rates, the cost-effectiveness to the building owner for all energy efficiency measures will increase compared with the results reported here.

An economic analysis was done to assess the national economic impacts of the measures to Jamaica as a whole. For this analysis, taxes and import duties were excluded.

Figures A-1 and A-2 show that the estimated energy and peak demand reductions for the high efficiency cases exceed 50% for both large and small offices. The energy efficiency measures used to attain those results are not exotic and are widely available in the US marketplace, for example. The high efficiency case results indicate that much higher energy efficiency levels are attainable in Jamaica than are being required by the EEBC-94.

Furthermore, the energy savings attained by the EEBC are highly cost effective. The payback is:

a) **1.2 years** for large office buildings; and

Figure A-3: Economic Impacts of EEBC-90 Requirements

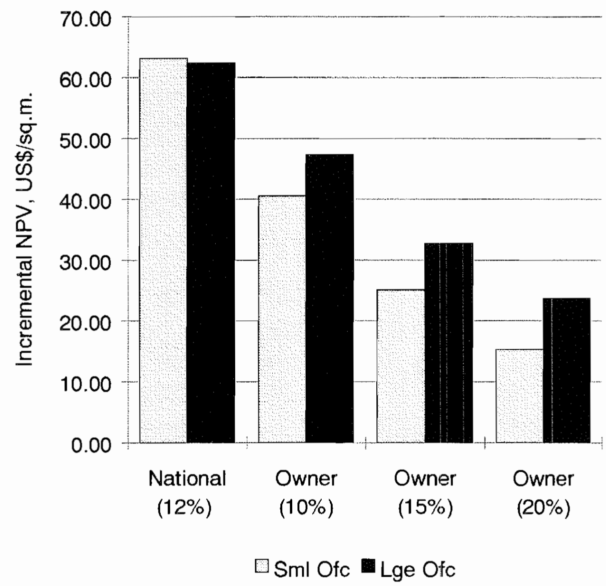
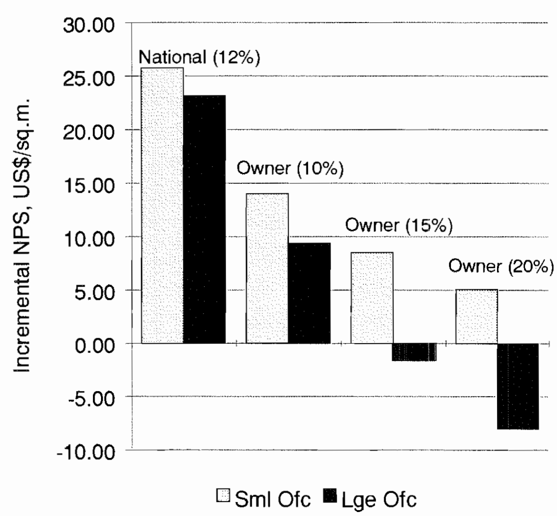


Figure A-4: Economic Impacts of the High-Efficiency Case



b) **2.6 years** for small office buildings.

These results are shown in Figure A-3. Consequently, additional expenses that may result from complying with the Jamaican EEBC requirements should be repaid within one to three years of use, depending upon specifics of the applications. Thereafter, the reduced energy costs will continue to contribute to savings in the building's operational cost, for the life of the conservation measures implemented.

The same study also indicates that the high efficiency energy measures are also highly cost effective from a national economic perspective, and sometimes cost effective from a private owner financial perspective. The payback for exceeding code requirements and achieving the high efficiency levels is:

c) **4.8 years** for large office buildings that meet the code requirements; and
d) **1.7 years** for small office buildings that meet the code requirements.

These positive economic results are summarized graphically in Net Present Value terms in Figure A-4. Consequently, additional expenses that may result from complying with, or exceeding, the Jamaican EEBC requirements should be repaid within five years of use; thereafter contributing to savings in the building's operational cost, for the life of the conservation measures implemented.

The analysis of the Jamaican code energy requirements has addressed the question of potential economically optimal levels. For the analysis, "economically optimal" was defined for the national economic perspective as the point where the incremental life cycle cost of energy efficiency measures (construction and operations) equalled the incremental life cycle benefits via reductions in energy costs, where the incremental net present value (NPV) equals zero, using a 12% discount rate (real), a 20 year accounting life, and no duties or taxes.

The analyses conducted to date do not permit identification of the actual point of the economic optimum. However, the analyses do identify a boundary condition on the economic optimum for office buildings from a national perspective. Namely, economically optimal levels will produce energy reductions from current Jamaican practice of more than 50%.

For the building owner in financial terms, the high efficiency case for the large office building produces a 62% energy reduction, with a simple payback period of 6.0 years, from current base case practice. The high efficiency case for the small office building produces a 57% energy reduction with a simple payback of 4.4 years, from current base case practice.

The high efficiency case produces mixed results for building owners, given current prices. For the small office building, net present values for the "high efficiency" case are positive and benefit/cost ratios are high for all discount rates. (These values are computed relative to the EEBC case). The result is that the high efficiency small office case is cost-effective for the building owner, using the EEBC requirements as a base case.

The large office building "high efficiency" case results are mixed, to the building owner. The net present values begin to go negative is the discount rate increases, and the B/C ratios begin to be less than one. These values also are computed relative to the energy code case. Thus, the high efficiency case for the large office represents at best only a marginal investment to building owners, given the current prices, and depending upon discount rates assumed.

However, from a national economic perspective, the high efficiency cases for *both* small and large offices are still very cost-effective for Jamaica, for both large and small offices. Based on the results of the Energy Sector Strategy and Investment Planning Study, ESMAP, 1992, the cost of conserved energy for the large and small offices is still less than the cost to JPS to generate electricity.

For the national economic perspective used, net present values and benefit/cost ratios are still quite high. The incremental net present values exceed US\$20/m^2. This result is important, for it indicates that the economically optimal point must be in excess of the results for this case. Thus, a lower boundary is established in excess of a 50% energy reduction from current practice. This result applies to both large and small offices.

3 Conclusions from Analyses

3.1 Current Code Requirements are not Close to Economically Optimal Levels

The energy and economic results for Jamaica indicate that economically optimal levels for specifying energy code requirements would result in over 50% energy reductions from current practice. While a lower bound has been identified, the optimal level has not been identified, from the current analysis, for the optimal economic level from a national perspective is beyond the high efficiency case for both for the large and small offices.

3.2 Combination of Correct Prices and Information is Critical

Interest in energy-efficiency is now high in Jamaica, primarily because of recent increases in electricity prices. The incentive to reduce energy use caused by this change is being recognized by building owners, managers, and investors.

In conjunction, the recent code implementation and demand-side management (DSM) activities in Jamaica have been providing much needed energy-efficiency information and analysis tools. The information and tools are needed to properly and quickly respond to the increased interest.

3.3 Shift Focus of International Support

More international economic support and expertise can be invested to increase energy efficiency in buildings in countries like Jamaica. Such investment makes clear economic sense, from the national economic perspective of countries like Jamaica. Also, developing countries in the tropics are where the most rapid growth is occurring in commercial building stocks. This includes tropical locations in Asia, Central and South America, and Africa.

In Jamaica, there is a need for continued development of code implementation activities and a continued strengthening of code related institutions. For example, additional economic analysis is planned, including the important area of analysis of hotels, but awaits further funding. Another example is that discussions have begun on the potential of creating at the newly formed architecture department at the College of Art, Science and Technology (CAST) in Kingston a regional center for building energy design excellence for the tropics. Such a center might provide a vehicle for assisting the adaptation of results to date to additional locations throughout the tropics.

3.4 Potential for Improved Energy Code

Energy codes are powerful information tools that embody cost-effective practice for use in conjunction with other policy measures and the implementation of demand-side management (DSM) programs. One can foresee the development of an energy code that provides better guidance toward the maximum levels of energy efficiency that are cost-effective for Jamaica from a national economic perspective. Such levels of efficiency might result in almost double the efficiency improvements as those required by present energy code requirements. If environmental externalities were factored into Jamaican electricity prices, the cost-effectiveness of increased efficiency would be further enhanced.

In the future, Jamaica may wish to use the analysis tools cited above to determine economically optimal levels or ranges for energy code provisions. The next step would be to determine the costs of moving from current levels of code requirements to the levels indicated as economically optimal. Given the number of barriers to attainment of economically optimal levels of conservation, an interim code structure that would provide two levels of requirements might be useful. Such a structure could include:

a) a set of minimum requirements, such as those requirements currently in the code; plus,
b) a set of optional requirements close to the identified economically optimal levels of efficiency from a national perspective.

Thus, energy codes can become even more powerful information tools for imbedding economically rational levels of investment in energy efficiency.

Appendix B:

Principles and Energy Design Process

Contents of this Appendix

1 Principles for Effective Energy Efficiency in Building Design B-1
2 Identification of Significant Energy Requirements B-1
3 Start Early in the Design Process B-2
4 Follow a Logical Sequence B-2

Commentary

This appendix contains two major parts. First, it discusses general Principles for the energy conscious design and retrofit of buildings. A major source of this material is from the "Principles" section (Appendix A) of ASHRAE/ IES Standard 90.1-1989. More detailed energy design principles, that apply to specific building systems, are also contained in later Appendices.

An excellent description of the process of designing for energy efficiency is contained in the introductory chapter of "Energy Design for Architects," by The American Architectural Foundation. The reader is encouraged to review that material. A copy is available at the Jamaican Bureau of Standards.

1 Principles for Effective Energy Efficiency in Building Design

This section complements the requirements of the Standard by providing general principles of effective building design. The intent of this section is to provide ideas on how to improve the integration of the building's major energy using subsystems in a cost effective manner without compromising the building's intended functional use or internal environmental conditions.

2 Identification of Significant Energy Requirements

Before energy design strategies can be developed for a commercial building, a clear picture of its most significant energy requirements should be developed. The basic approach to achieving an energy efficient design is to shift or reduce loads, improve transport systems and provide efficient environmental systems and controls. This is accomplished by first determining which aspects of the building's energy requirements are the most significant; those that would result in the largest annual energy costs to the building owner if energy conserving strategies were otherwise not applied. For example, for a given building, the largest annual energy cost component may be lighting, followed by cooling, heating, and ventilation, respectively. In this example, electricity would be the major energy source. Therefore, peaktime-rates of energy use (i.e., peak power demands), as well as direct energy use, would have to be included in any energy analysis.

Consideration of peak demands will reduce the requirement for oversizing of energy systems in the building and will also have the added impact of helping to reduce the need for additional, low utilization peak utility capacity.

Step 1 **Determine Energy Opportunities & Problems**

	Comments	Sources for Data
Estimate Loads	Seasonal and diurnal patterns are both important Relative loads values are as important as absolute values Examine annual or monthly peaks, depending on utility rate structures	Previous building designs of client and/or design team Case-study buildings, from local utility or from others Building-type parametric studies (utilities, USDOE, etc.) Typical building parametric studies (ASHRAE, NREL, TVA, ACEEE, etc.)
Estimate Energy	Energy Priorities are often different from Load Priorities - usually due to differences in system efficiencies - cooling system efficiencies usually higher than heating systems	Previous building designs of client and/or design team Case-study buildings, from local utility or from others Building-type parametric studies (utilities, USDOE, etc.) Typical building parametric studies (ASHRAE, NREL, TVA, ACEEE, etc.)
Estimate Energy & Demand Dollars	Energy Cost Priorities are often different from Energy Priorities Electricity demand costs may increase priority of all electricity end-uses Electricity costs are typically higher than gas, thereby changing cooling and heating priorities Energy costs vary by location more than by variations in climate	Utility company rates
Estimate Total Energy Costs	Construction and O&M costs of energy measures can influence priorities Owner investment time horizon and discount rates are key factors	Utility and other sources of cost data for energy measures (eg., CCIG) Typical investment scenarios and parameters by building type and owner type

Figure B-1: Determine Energy Opportunities and Problems

Once the most significant cost components of the building's energy requirements have been determined, apply the strategies and design solutions listed below and those that appear in each Section of the Standard. In the example noted above, lighting solutions would be addressed first, followed by cooling, heating, and then ventilation.

Research results indicate that the most significant energy uses for any given commercial building are generally not accurately identifiable by professional intuition. Therefore, use should be made of one of the several available analysis tools, some of which are microcomputer-based.

3 Start Early in the Design Process

As Figure B-2 shows, it is important to consider energy efficiency from the beginning of the building design process, since design improvements are most easily and effectively made then. Seek the active participation of

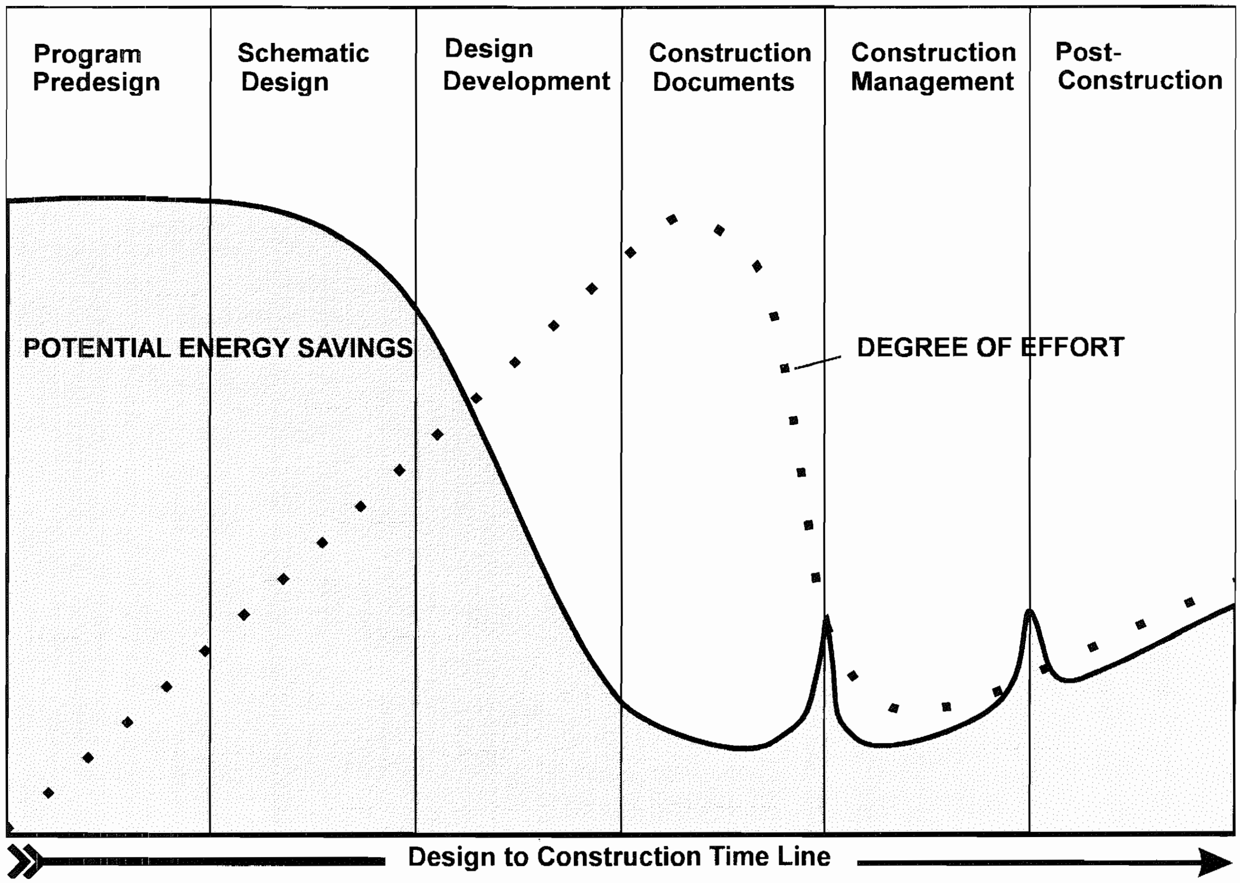


Figure B-2: Energy Efficiency Potential at Various Phases During the Design Process

members of the design team early in the design process, including the owner, architect, engineer, and builder. Consider building attributes such as building function, form, orientation, window/wall ratio, and HVAC system types early in the design process. Each has major energy implications. These considerations most likely will result in solutions that minimize both construction and operation costs, including energy demand charges.

4 Follow a Logical Sequence

Address the building's energy requirements in the following sequence, as shown in Figure B-3:

a) Minimize Impact of Functional Requirements

Identify the major areas that offer energy efficiency opportunities based on the building's functional use, human occupancy requirements and site characteristics. These areas will vary considerably from building to building depending upon function and service requirements, and should be considered when applying the criteria of this Standard.

b) Minimize Loads

Analyze the external and internal loads to be imposed on building energy-using subsystems, both for peak-load and part-load conditions. Include a determination of how the building relates to its external environment in the analysis, either adaptively or defensively. Consider changes in building form, aspect ratio, and other attributes that reduce, redistribute, or delay (shift) loads.

c) Improve Subsystems Efficiency

Analyze the diversified energy and demand (power) requirements of each energy-using subsystem serving the functional requirements of the building. Consider static and dynamic efficiency of energy conversion and energy transport subsystems and include consideration of opportunities to reclaim, redistribute, and store energy for later use.

d) Integrate Building Subsystems

Alternative ways to integrate systems into the building will be accomplished by considering both power and time components of energy use. Identify, evaluate and design each of these components to control the overall design energy consumption. The following should be considered when integrating major building subsystems:

1. Address more than one problem when developing design solutions, and make maximum use of building components already present for non-energy reasons (e.g. windows, structural mass);

2. Examine design solutions that consider time, since sufficient energy may already be present from the environment (e.g., solar heat, night cooling) or from internal equipment (e.g., lights, computers) but available at different times than needed. Thus, active (heat pumps with water tanks) and passive (building mass) storage techniques may be considered.

3. Examine design solutions that consider anticipated space utilization. For example, in large but relatively unoccupied spaces, task or zone heating may be considered. Transporting energy (light and heat) from locations of production and availability to locations of need should be considered instead of the purchase of additional energy.

4. Never reject waste energy at temperatures usable for space conditioning or other practical purposes without calculating the economic benefit of energy recovery or treatment and reuse.

5. Use design solutions that are easily understood as they have a greater probability of use by building occupants.

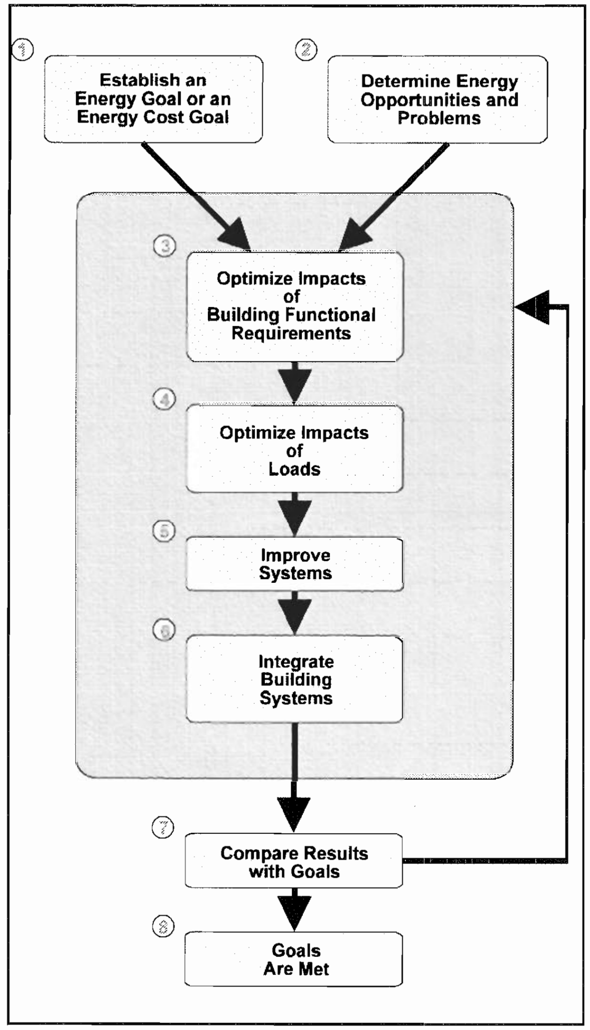


Figure B-3: Energy Design Process

e) Compare Results with Goals

Check the results of the energy analysis and design modifications. If they do not meet your goals, then go back to earlier steps in the process and iterate through the steps until your goals are met (or you must modify your goals).

f) Goals Are Met

If the energy goals are met, then the energy design process has been successfully accomplished.

Appendix C:

Compliance Guidelines for Whole-Building Energy Budgets and Energy Cost Budgets

Contents of this Appendix

1 Introduction C-1
2 Principles - Whole-building Energy Analysis C-2
3 Compliance Process C-2
4 General Calculation Procedures C-5
5 Standard Calculation Procedures and Default Values C-7
6 Compliance Submittal Forms C-18
7 References C-19
Attachment C-A, Speculative Building Example C-19

Commentary

This Appendix is intended to provide compliance guidance in conducting annual energy analyses on a whole-building basis. This Appendix focuses on WHAT is required to comply, and HOW the compliance processes work. Future examples can be inserted from energy and economic analysis of typical Jamaican buildings.

This guide is intended for use with annual energy simulation tools such as DOE-2 or ASEAM2D. These tools have been used to analyze Jamaican buildings, and information about them is available at JBS.

1 Introduction

This section provides criteria for the design of energy efficient buildings that allow greater design flexibility than the other compliance paths of this standard while providing building energy efficiency levels consistent with the other paths. Two main compliance paths are provided:

a) an Energy Budget (EB) path; and,
b) an Energy Cost Budget (ECB) path.

The Energy Budget (EB) path is provided for when the applicable utility rate makes the analysis of peak demand less critical. Within this path, there are two ways to determine a target:

a) Use the predetermined values listed in EEBC Table C-1.
b) Determine an Energy Budget using the rules and procedures specified in Section 1.3 below.

An Energy Cost Budget (ECB) compliance path is also provided. Since proposed designs may use varying rate structures, including those with high demand charges or even various amounts of different types of energy, energy cost is used as the common denominator. Using unit costs rather than units of energy or power such as Btu, kWh or kW allows the energy use contribution of different fuel sources at different times to be added and compared.

Both the EB and ECB paths provide an opportunity for the building designer to evaluate and take credit for innovative energy conservation designs, materials, and equipment (such as daylighting, passive solar heating, heat recovery, better zonal temperature control, and thermal storage, as well as other applications of "off peak" electrical energy) that cannot be accounted for in either the Prescriptive or System Performance paths.

For whole-building analysis, either the EB or the ECB compliance paths may be used. However, the ECB path is recommended. It will allow the designer and owner to more properly assess the cost-effectiveness impacts of alternative building energy choices. In most cases, the information on cost-effectiveness is well worth the slight increase in analysis effort.

When comparing design options, designers are encouraged to try to minimize life cycle costs including capital costs and operation and maintenance costs along with energy costs over the projected lifetime of the building. The ECB is the highest allowable calculated annual Energy Cost Budget for a specific building design. Other alternative designs are likely to have lower annual energy costs and lower life cycle costs than those that minimally meet the ECB.

NOTE: These procedures are intended only for the purpose of demonstrating design compliance and are not intended to be used to predict, to document, or to verify annual energy consumption or annual energy costs.

2 Principles - Whole-building Energy Analysis

Two very important principles exist relative to how and when whole-building energy analysis should be accomplished. They are:

a) ***Do the analysis early in the design process.*** (Well before the end of schematic or concept design). For example, many energy improvements reduce the loads on building systems. Therefore, the size of the systems can be reduced, saving considerable money.

b) ***Have the key members of the design team involved in the early analysis*** (architect, electrical engineer, mechanical engineer, etc). For example, saving money by reducing the size of systems is difficult unless all decision makers are involved in the process.

3 Compliance Process

When designs fail to meet either the Prescriptive or System Performance criteria of this standard, then either of the two whole-building analysis methods may be used:

a) **Energy Budget (EB) Method**; or,

b) **Energy Cost Budget (ECB) Method**.

Either method may be employed for evaluating the compliance of all proposed designs (except shell buildings).

This section defines calculation procedures for compliance purposes that shall be used to calculate the EB and DECON for the EB method and the ECB and DECOS values for the ECB method. Either the reference building procedure described in 5.1 or the prototype building procedure described in 5.2 shall be used to determine compliance.

The choice of procedure may depend upon designer and owner objectives and constraints. Generally, the prototype building procedure is considered easier to use. However, a prototype may not reflect actual conditions of the building design as well as a reference building. The ease of use of the prototype building procedure for a given project depends upon the availability of predefined prototype input files for the energy simulation tools being used. Then, the amount of work required for analysis purposes can be greatly reduced.

3.1 Building Energy Budget (EB) Method

3.1.1 Requirement for the Annual Energy Budget (EB). Compliance under the Building Energy Budget Method requires detailed energy analyses of the entire proposed design, referred to as the design energy consumption (DECON). The DECON is then compared against an annual energy budget (EB). Compliance is evaluated by comparing the energy estimate of the building design with the annual energy budget. Compliance is achieved when the estimated DECON is not greater than the EB (DECON <= EB).

This section provides instructions for determining the EB and for calculating the DECON. The EB shall be determined from Table C-1, below, or through calculation of annual energy consumption of the prototype or reference building design configured to meet the requirements of EEBC Sections 4 through 11.

3.1.2 Predefined Annual Energy Budgets. The EB shall be determined from Table C-1, based upon the most appropriate building type. For mixed use buildings, a weighted average of Energy Budgets may be used.

3.1.3 Calculating an Annual Energy Budget. If a reference building is used to set the energy budget, then the reference building shall be based upon the characteristics of the proposed building design, but with all other characteristics of the reference building such as lighting, envelope and VAC system modified to meet the energy requirements of sections 4 through 11 of the EEBC.

Each floor of the reference building shall be oriented exactly as in the proposed design. The form, gross and conditioned floor areas of each floor, the number of floors, and the lighting and VAC system types and zoning shall be as in the proposed design.

If a prototype building is used to set the energy budget, per 4.2 below, then the form, orientation, occupancy, and use profiles for a prototype building shall be fixed. Envelope, lighting, electrical systems, and VAC systems shall meet the respective prescriptive or system performance requirements of EEBC Sections 4 through 11 and are standardized inputs.

If a prototype building is used, the building designer shall determine the building type of the proposed design using the building prototype categories defined below in Section 5. The prototype building shall be simulated using the same gross floor area and number of floors as in the proposed design.

Table C-1
Maximum Annual Energy Budgets
(in kWh/m^2/year at the building site)
(based on 1 kWh = 3,413 Btu)

Building Type	kWh/m^2/yr
Place of Assembly, Auditorium	202
Bank or Savings and Loan	132
Clinic	142
Drug Store	173
School	
Classroom	126
Gymnasium (conditioned), auditorium	117
Office	132
Laboratory (Not including process)	173
Hotel, Motel	183
Library	214
Mercantile	
Strip Shop (stores less than 1,400 m^2)	186
Department Store (greater than 1,400 m^2)	230
Mall (conditioned common areas of malls)	148
Nursing Home	271
Office Building	132
Hospital	
Autopsy/Morgue	252
Central Supply	221
Operating Suite	448
Emergency Department	315
Intensive Care Unit	315
Laboratory	315
General Patient Care	252
Restaurant	630–1,260
Storage, Warehouse (conditioned)	79
Theater	151
Air Terminal	
Commercial	246
Concourse	268
Place of Worship	158
Apartment Houses - +3 stories	126

Note: The Energy Budgets listed in Table C-1 are derived from analyses and experience in the southern United States, especially Florida. The numbers are applied to Jamaica using professional judgment. Further refinement of these Energy Budgets could be obtained from analyses of typical Jamaican buildings using Jamaican weather data.

For mixed-use buildings the EB shall be derived by allocating the floor space of each building type within the floor space of the Prototype Building. For buildings types for which prototypical building descriptions have been not been defined, the Reference Building Procedure of 5.1 shall be used.

3.1.4 Compliance with the Annual Energy Budget (EB). If the DECON, the annual energy cost estimated for the building design, is not greater than the EB, the annual energy budget, and all of the basic requirements of 4.4, 5.4, 6.4, 7.4, 8.4, 9.4, 10.4, and 11.4 are met, the proposed design complies with this Standard. The DECON shall be calculated by modeling the proposed design using the same methods, assumptions, climate data, and simulation tool as were used to establish the EB (except as explicitly provided in this Appendix).

3.2 Building Energy Cost Budget (ECB) Method

The ECB method shall use the compliance procedures just defined above for determining the EB and DECON. In addition, the following procedures shall be used for determining ECB and DECOS.

3.2.1 Requirement for the Annual Energy Cost Budget (ECB). An annual Energy Cost Budget (ECB) for the building design shall be determined in accordance with either the Prototype Building Method or the Reference Building Method in Section 5 below.

Both methods permit calculating an ECB that is the summation of the 12 monthly energy cost budgets (ECB_m). Each ECB_m is the product of the monthly budget energy consumption ($BECON_m$) of each type of energy used multiplied by that monthly energy cost ($ECOS_m$) per unit of energy for each type of energy used. The ECB shall be determined in accordance with Eq 12-1 of the EEBC as follows:

$$ECB = ECB_{jan} + \ldots ECB_m + \ldots + ECB_{dec}$$

EEBC Eq. (12-1)

Where ECB_m is based on Equation 12-2:

$$ECB_m = (BECON_{m1})(ECOS_{m1}) + (BECON_{m2})(ECOS_{m2}) + \ldots + (BECON_{mi})(ECOS_{mi})$$

EEBC Eq. (12-2)

Where

ECB = The annual Energy Cost Budget

ECB_m = The general monthly Energy Cost Budget

$BECON_{mi}$ = The monthly Budget Energy Consumption of the i^{th} type of energy

$ECOS_{mi}$ = The monthly Energy Cost, per unit of the i^{th} type of energy

The $ECOS_{mi}$ shall be determined using current rate schedules or contract prices available at the building site for all types of energy purchased. These costs shall include:

a) demand charges,
b) rate blocks,
c) time of use rates,
d) interruptable service rates,
e) delivery charges,
f) fuel adjustment factors,
g) taxes, and
h) all other charges applicable for the type, location, operation, and size of the proposed building.

The $BECON_{mi}$ shall be calculated from the first day through the last day of each month inclusive.

3.2.2 Compliance with the Annual Energy Cost Budget (ECB). If the DECOS, the annual energy cost estimated for the building design, is not greater than the ECB, the annual energy cost budget, as provided in EEBC Eq 12-3, and all of the basic requirements of 4.4, 5.4, 6.4, 7.4, 8.4, 9.4, 10.4, and 11.4 are met, the proposed design complies.

$$DECOS \leq ECB$$

EEBC Eq. (12-3)

The DECOS shall be determined using the calculation procedures described in section C.6 below and shall be calculated as provided in EEBC Equation 12-4.

$$\text{DECOS} = \text{DECOS}_{jan} + \ldots\text{DECOS}_m + \ldots + \text{DECOS}_{dec} \qquad \text{EEBC Eq. (12-4)}$$

Where the DECOS_m are based on EEBC Equation 12-5:

$$\text{DECOS}_m = (\text{DECON}_{m1})(\text{ECOS}_{m1}) + \ldots + (\text{DECON}_{mi})(\text{ECOS}_{mi}) \qquad \text{EEBC Eq. (12-5)}$$

Where

DECOS = The annual design energy cost

DECOS_m = The monthly design energy cost

DECON_{mi} = The monthly design energy consumption of the i^{th} type of energy

ECOS_{mi} = The monthly Energy Cost, per unit of the i^{th} type of energy

The DECON_{mi} shall be calculated from the first day through the last day of the month inclusive.

If the proposed design includes cogeneration or renewable energy sources designed for the sale of energy off site, the energy cost and income resulting from outside sales shall not be included in the calculation of DECOS. Such systems shall be modeled as operating to supply energy needs of the proposed design only.

4 General Calculation Procedures

4.1 Reference Building Procedure.

The reference building procedure should be used when a customized comparison is desired between the EEBC requirements and the proposed building design. The reference building approach should also be used when:

a) the proposed design cannot be reasonably represented by one or a combination of the prototype buildings; or,

b) the assumptions inherent in the prototype building descriptions, such as occupancy and use-profiles, cannot reasonably be altered to accurately represent the proposed design.

If a reference building is used to set either the energy budget or the energy cost budget, then the reference building shall be based upon the characteristics of the proposed building design:

c) Each floor of the reference building shall be oriented exactly as in the proposed design.

d) The form, gross and conditioned floor area of each floor, and the number of floors shall be as in the proposed design.

e) the lighting and VAC system types and zoning shall be as in the proposed design.

All other characteristics of the reference building such as lighting, envelope and VAC system modified to meet the energy requirements of sections 4 through 11 of the EEBC.

4.2 Prototype Building Procedure

The intent of the Prototype Building Procedure is to reduce the complexity and level of effort of compliance with this part of the EEBC. Prototypical building descriptions have been defined for a number of building types. Use of a prototypical building description should simplify compliance and should involve less time than developing a reference building description. The Prototype Building Procedure may be used to develop either an EB or an ECB.

In developing either an EB or an ECB, the form, orientation, occupancy, and use profiles for a prototype building shall be fixed. Envelope, lighting, electrical systems, and VAC systems shall meet the respective prescriptive or system performance requirements of Sections 4 through 11 and are standardized inputs.

The building designer shall determine the building type of the proposed design using the building prototype categories available below in section 5 of this appendix. Using the appropriate prototype building characteristics from the tables in the appendix, the prototype building shall be simulated using the same gross floor area and number of floors as in the proposed design.

For mixed-use buildings the ECB shall be derived by allocating the floor space of each building type within the floor space of the Prototype Building. For building types for which prototypical building descriptions have not been defined, a Reference Building Procedure must be used.

4.3 Climate Data

The prototype or reference building shall be modeled using the calculation procedures defined in this appendix. The modeling shall use a climate data set appropriate for both the site and the complexity of the energy conserving features of the design. ASHRAE WYEC weather tapes or bin weather data shall be default choices.

To date, validated weather data has been prepared for one weather station in Jamaica. This is for the Mona location on the University of the West Indies (UWI) campus in Kingston. This data has been prepared for use with two energy simulation programs, DOE-2.1D or DOE-2.1E and ASEAM2D. The data is also available in "bin" format for ASEAM2.1.

Data for a second Jamaican location, Sangster Airport in Montego Bay, has been prepared for use with the DOE-2 program but has not yet been thoroughly checked. Copies of this data for both sites are available at the Jamaica Bureau of Standards (JBS).

4.4 Simulation Tools

Annual energy consumption should be simulated with a multizone, 8760 hours per year building energy simulation program. The tool should account for:

a) the dynamic heat transfer of the building envelope, including the effects of solar and internal gains
b) equipment efficiencies as a function of load and climate
c) lighting and VAC system controls and distribution systems by simulating the whole building
d) the operating schedule of the building including night setback during various times of the year
e) energy consumption information at a level necessary to determine the ECB and DECOS via the appropriate utility rate schedules.

While analysis tools should simulate an entire year on an hour by hour basis (8760 hours per year), tools that approximate this dynamic analysis procedure or provide equivalent results are acceptable.

Simulation tools shall be selected for their ability to simulate the relevant features of the building in question, as shown in the method's documentation. For example, a single zone program shall not be used to simulate a large, multizone building, and a steady-state method such as the "degree day method" shall not be used to simulate buildings when equipment efficiency or performance is significantly affected by the dynamic patterns of weather, solar radiation and occupancy.

Relevant features that shall be addressed by simulation tools, if the building makes use of these features, include daylighting, atriums or sunspaces, night ventilation or thermal storage, chilled water or ice storage or heat recovery, active or passive solar systems, and zoning and controls of heating and cooling systems. In addition, methods used shall be capable of translating the energy consumption (DECON) into energy cost (DECOS) using actual utility rate schedules against, for example, the coincidental electrical demand of a building.

All Simulation Tools shall use scientifically justifiable techniques and procedures for modeling building loads, systems and equipment. The algorithms used in the program shall have been verified by comparison with experimental measurements for loads, systems, and equipment. Examples of programs capable of handling such complex building systems and energy cost translations that are in the public domain are, in the United States, DOE-2.1D (or DOE-2.1E) and BLAST 3.0, and in Canada, Energy Systems Analysis Series. ASEAM2D is an acceptable tool for use in calculating EB/ECB and DECON/DECOS in conjunction with Jamaican climates and rate structures. Methods demonstrated to be equivalent to those mentioned above are also acceptable.

5 Standard Calculation Procedures and Default Values

The standard calculation procedures consist of methods and assumptions for calculating the EB or ECB for the prototype or reference building and the DECON or DECOS of the proposed design. In order to maintain consistency between the EB/DECON or the ECB/DECOS, two kinds of input assumptions shall be used:

a) "Prescribed" assumptions shall be used without variation.
b) "Default" assumptions shall be used unless the designer can demonstrate that a different assumption better characterizes the building's use over its expected life.

Any modification of a default assumption shall be used to model both the prototype or reference building and the proposed design unless the designer demonstrates a clear cause to do otherwise. Special procedures necessary for speculative buildings are discussed below in 5.7 of this appendix. Shell buildings may not use this appendix or EEBC Section 12 for compliance, and must comply with the EEBC by using either the prescriptive or system performance compliance methods.

5.1 Orientation and Shape

5.1.1 Prototype Building. The prototype building shall consist of the same number of stories and gross and conditioned floor area as the proposed design with equal area per story. The building shape shall be rectangular, with 2.5:1 aspect ratio. The long dimension of the building shall face east and west. This is intended to provide an energy budget that can be met even if there are unfavorable site constraints. The fenestration shall be uniformly distributed in proportion to exterior wall area.

Floor-to-floor height for the prototype building shall be 4.0 metres, except for dwelling units in hotel or motels and multifamily buildings whose floor-to-floor height shall be 2.9 metres.

5.1.2 Reference Building. The reference building shall consist of the same number of stories and gross floor area for each story as the proposed design. Each floor shall be oriented exactly as the proposed design. The geometric form shall be the same as the proposed design.

5.2 Internal Loads

Internal loads for multifamily buildings are prescribed assumptions presented in Table C-2. Internal loads for other building types shall be modeled as noted below.

Table C-2
Multifamily Building Schedules
Internal Loads per Dwelling Unit, W
One-Zone Dwelling Unit

	Occupants		Lights	Equipment	
Hr	Sens	Latent	Sens	Sens	Latent
1	88	76	0	220	32
2	88	76	0	220	32
3	88	76	0	220	32
4	88	76	0	220	32
5	88	76	0	220	32
6	88	76	0	220	32
7	88	76	287	366	56
8	62	76	246	762	123
9	29	23	0	343	53
10	29	23	0	372	56
11	29	23	0	372	90
12	29	23	0	648	97
13	29	23	0	648	97
14	29	23	0	372	56
15	29	23	0	372	56
16	29	23	0	372	56
17	29	23	0	372	56
18	88	76	0	891	132
19	88	76	0	985	147
20	88	76	281	437	64
21	88	76	281	437	64
22	88	76	281	437	64
23	88	76	281	311	60
24	88	76	281	311	160

NOTE: The systems and types of energy specified here are intended only as constraints in calculating either the EB or ECB. They are not intended as requirements or recommendations for systems or the type of energy to be used.

5.2.1 Occupancy. Occupancy schedules shall be default assumptions. The same assumptions shall be made in computing design energy consumption as were used in calculating the energy budget or energy cost budget. Occupancy levels vary by building type and time of day. Table C-3, Occupancy Density, establishes the density presented as m^2/person of conditioned floor area that will be used by each building type. Table C-5, Building Schedule Percentage Multipliers, establishes the percentage of the people that are in the building by hours of the day for each building type. Table C-5 also establishes the percentage of lighting and receptacle loads that are switched, the percentage of service hot water usage, and the hours of operation of the VAC system by hours of the day for each building type.

Table C-3
Occupancy Density

Building Type	Conditioned Floor Area m^2/person[a]
1. Assembly	5
2. Office	26
3. Retail	29
4. Warehouse	1400
5. School	7
6. Hotel/Motel	23
7. Restaurant	9
8. Health/Institutional	200
9. Multifamily	2 pers./unit[b]

Notes:

(a) Heat generation in W/person-hour:
67 sensible and 56 latent.

(b) See Table C-2.

5.2.2 Lighting. The interior lighting power allowance (ILPA) for calculating the EB or ECB shall be determined from EEBC Section 5. The lighting power used to calculate the DECOS shall be the actual adjusted lighting power of the proposed lighting design. If the lighting controls in the proposed design are more effective at saving energy than those required by EEBC 5.4, then:

a) the actual installed lighting power should be used along with the schedules reflecting the action of the controls to calculate the DECOS.

b) This "actual installed lighting power" should not be adjusted by the power adjustment factors listed in EEBC Table 5-2.

Lighting levels in buildings vary based on the type of uses within buildings, by area and by time of day. Table C-5 contains the lighting energy profiles which establish the percentage of the lighting load that is switched ON in each prototype or reference building by hour of the day. These profiles are default assumptions and can be changed if required when calculating the EB or ECB to provide, for example, a 12 hour rather than an 8 hour work day. The same profiles shall be used in calculating the DECOS as were used to calculate the EB or ECB.

5.2.3 Receptacle loads. Receptacle loads and profiles are default assumptions. The same assumptions shall be made in calculating the DECON as were used in calculating the EB/ECB.

Receptacle loads include all general service loads that are typical in a building. These loads should include additional process electrical usage but exclude VAC primary or auxiliary electrical usage. Table C-4, Receptacle Power Densities, establishes the density in W/m^2 to be used. The receptacle energy profiles shall be the same as the lighting energy profiles in Table C-5. This profile establishes the percentage of the receptacle load that is switched ON by hour of the day and by building type.

Table C-4
Receptacle Power Densities

Building Type		Watts/m^2 of Conditioned Floor Area
1.	Assembly	2.7
2.	Office	8.1
3.	Retail	2.7
4.	Warehouse	1.1
5.	School	5.9
6.	Hotel/Motel	2.7
7.	Restaurant	1.1
8.	Health	10.8
9.	Multifamily	Note (a)

Notes: Included in Table C-2, Lights and Equipment Columns

Table C-5

Building Schedule Percentage Multipliers

		Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
ASSEMBLY																										
	Occupancy	Weekday:	0	0	0	0	0	0	0	0	20	20	20	80	80	80	80	80	80	80	20	20	20	20	10	0
		Saturday:	0	0	0	0	0	0	0	0	20	20	20	60	60	60	60	60	60	60	60	60	60	80	10	0
		Sunday:	0	0	0	0	0	0	0	0	10	10	10	10	10	70	70	70	70	70	70	70	70	70	20	0
	Lighting & Receptacle	Weekday:	5	5	5	5	5	5	40	40	40	75	75	75	75	75	75	75	75	75	75	75	75	75	25	5
		Saturday:	5	5	5	5	5	5	5	30	30	50	50	50	50	50	50	50	50	50	50	50	50	50	5	5
		Sunday:	5	5	5	5	5	5	5	30	30	30	30	30	65	65	65	65	65	65	65	65	65	65	5	5
	VAC	Weekday:	off	off	off	off	off	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	off
		Saturday:	off	off	off	off	off	off	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	off
		Sunday:	off	off	off	off	off	off	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	off
	SWH	Weekday:	0	0	0	0	0	0	0	0	0	5	5	35	5	5	5	5	5	0	0	0	0	0	0	0
		Saturday:	0	0	0	0	0	0	0	0	0	5	5	20	0	0	0	0	0	0	0	65	30	0	0	0
		Sunday:	0	0	0	0	0	0	0	0	0	5	5	10	0	0	0	0	0	0	0	65	30	0	0	0
OFFICE																										
	Occupancy	Weekday:	0	0	0	0	0	0	0	10	20	95	95	95	45	95	95	95	95	50	30	10	5	5	0	0
		Saturday:	0	0	0	0	0	0	0	10	10	30	30	30	30	10	10	10	10	0	0	0	0	0	0	0
		Sunday:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Lighting & Receptacle	Weekday:	5	5	5	5	5	5	5	10	30	90	90	90	80	90	90	90	90	75	50	20	20	10	5	5
		Saturday:	5	5	5	5	5	5	5	10	10	30	30	30	30	10	10	10	10	5	5	5	5	5	5	5
		Sunday:	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	VAC	Weekday:	off	off	off	off	off	off	on	on	on	on	on	on	on	on	on	on	on	on	on	on	off	off	off	off
		Saturday:	off	off	off	off	off	off	on	on	on	on	on	on	on	on	on	on	on	off	off	off	off	off	off	off
		Sunday:	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off
	SWH	Weekday:	0	0	0	0	0	0	0	15	30	35	35	45	55	50	30	30	40	20	20	10	15	5	0	0
		Saturday:	0	0	0	0	0	0	0	10	10	20	15	20	15	15	10	10	10	0	0	0	0	0	0	0
		Sunday:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RETAIL																										
	Occupancy	Weekday:	0	0	0	0	0	0	0	10	20	50	50	70	70	70	70	80	70	50	50	30	30	0	0	0
		Saturday:	0	0	0	0	0	0	0	10	20	50	60	80	80	80	80	80	80	60	20	20	20	10	0	0
		Sunday:	0	0	0	0	0	0	0	0	0	10	20	20	40	40	40	40	40	20	10	0	0	0	0	0

Table C-5 (continued) Building Schedule Percentage Multipliers

	Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Lighting & Receptacle	Weekday:	5	5	5	5	5	5	5	20	50	90	90	90	90	90	90	90	90	90	60	60	50	5	5	5
	Saturday:	5	5	5	5	5	5	5	10	30	60	90	90	90	90	90	90	90	90	50	30	30	10	5	5
	Sunday:	5	5	5	5	5	5	5	5	5	10	40	40	60	60	60	60	60	40	20	5	5	5	5	5
VAC	Weekday:	off	off	off	off	off	off	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	off	off	off
	Saturday:	off	off	off	off	off	off	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	off	off	off
	Sunday:	off	off	off	off	off	off	off	off	on	on	on	on	on	on	on	on	on	on	on	off	off	off	off	off
SWH	Weekday:	0	0	0	0	0	0	0	10	20	30	40	55	60	60	45	40	45	45	40	30	30	0	0	0
	Saturday:	0	0	0	0	0	0	0	15	20	25	40	50	55	55	45	45	45	45	40	35	25	20	0	0
	Sunday:	0	0	0	0	0	0	0	0	0	10	25	30	35	35	30	30	35	30	20	0	0	0	0	0
WAREHOUSE																									
Occupancy	Weekday:	0	0	0	0	0	0	0	15	70	90	90	90	50	85	85	85	20	0	0	0	0	0	0	0
	Saturday:	0	0	0	0	0	0	0	0	20	20	20	20	10	10	10	10	0	0	0	0	0	0	0	0
	Sunday:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lighting & Receptacle	Weekday:	5	5	5	5	5	5	5	40	70	90	90	90	90	90	90	90	90	5	5	5	5	5	5	5
	Saturday:	5	5	5	5	5	5	5	5	10	25	25	25	10	10	10	10	5	5	5	5	5	5	5	5
	Sunday:	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
VAC	Weekday:	off	off	off	off	off	off	off	on	on	on	on	on	on	on	on	on	off	off	off	off	off	off	off	off
	Saturday:	off	off	off	off	off	off	off	off	on	on	on	on	on	on	on	on	off	off	off	off	off	off	off	off
	Sunday:	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off
SWH	Weekday:	0	0	0	0	0	0	0	5	25	35	35	45	55	40	35	40	15	0	0	0	0	0	0	0
	Saturday:	0	0	0	0	0	0	0	0	0	10	10	15	0	0	0	0	0	0	0	0	0	0	0	0
	Sunday:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SCHOOL																									
Occupancy	Weekday:	0	0	0	0	0	0	0	5	75	90	90	80	80	80	80	45	15	5	15	20	20	10	0	0
	Saturday:	0	0	0	0	0	0	0	0	10	10	10	10	10	0	0	0	0	0	0	0	0	0	0	0
	Sunday:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lighting & Receptacle	Weekday:	5	5	5	5	5	5	5	30	85	95	95	95	80	80	80	70	50	50	35	35	30	30	5	5
	Saturday:	5	5	5	5	5	5	5	5	15	15	15	15	15	5	5	5	5	5	5	5	5	5	5	5
	Sunday:	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
VAC	Weekday:	off	off	off	off	off	off	off	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	off	off
	Saturday:	off	off	off	off	off	off	off	off	on	on	on	on	on	off	off	off	off	off	off	off	off	off	off	off
	Sunday:	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off

Table C-5 (continued) Building Schedule Percentage Multipliers

	Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
SWH	Weekday:	0	0	0	0	0	0	0	5	30	55	60	70	75	80	60	60	5	5	15	20	20	20	0	0
	Saturday:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sunday:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

HOTEL/MOTEL

	Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Occupancy	Weekday:	90	90	90	90	90	90	70	40	40	20	20	20	20	20	20	30	50	50	50	70	70	80	90	90
	Saturday:	90	90	90	90	90	90	70	50	50	30	30	30	30	30	30	30	30	50	60	60	60	70	70	70
	Sunday:	70	70	70	70	70	70	70	70	50	50	50	30	30	20	20	20	30	40	40	60	60	80	80	80
Lighting &	Weekday:	20	15	10	10	10	20	40	50	40	40	25	25	25	25	25	25	25	25	60	80	90	80	60	30
Receptacle	Saturday:	20	20	10	10	10	10	30	30	40	40	30	25	25	25	25	25	25	25	60	70	70	70	60	30
	Sunday:	30	30	20	20	20	20	30	40	40	30	30	30	30	20	20	20	20	20	50	70	80	60	50	30
VAC	Weekday:	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on
	Saturday:	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on
	Sunday:	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on
SWH	Weekday:	20	15	15	15	20	25	50	60	40	45	40	45	40	35	30	30	30	40	55	60	50	55	45	25
	Saturday:	20	15	15	15	20	25	40	50	50	50	45	50	50	45	40	40	35	40	55	55	50	55	40	30
	Sunday:	20	20	20	20	20	30	50	50	50	55	50	50	40	40	30	30	30	40	50	50	40	50	40	20

RESTAURANT

	Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Occupancy	Weekday:	15	15	5	0	0	0	0	5	5	5	20	50	80	70	40	20	25	50	80	80	80	50	35	20
	Saturday:	30	25	5	0	0	0	0	0	0	5	20	45	50	50	35	30	30	30	70	90	70	65	55	35
	Sunday:	20	20	5	0	0	0	0	0	0	0	10	20	25	25	15	20	25	35	55	65	70	35	20	20
Lighting &	Weekday:	15	15	15	15	15	20	40	40	60	60	90	90	90	90	90	90	90	90	90	90	90	90	50	30
Receptacle	Saturday:	20	15	15	15	15	15	30	30	60	60	80	80	80	80	80	80	80	90	90	90	90	90	50	30
	Sunday:	20	15	15	15	15	15	30	30	50	50	70	70	70	70	70	70	60	60	60	60	60	60	50	30
VAC	Weekday:	on	on	on	off	off	off	off	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on
	Saturday:	on	on	on	off	off	off	off	off	off	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on
	Sunday:	on	on	on	off	off	off	off	off	off	off	on	on	on	on	on	on	on	on	on	on	on	on	on	on
SWH	Weekday:	20	15	15	0	0	0	0	60	55	45	40	45	40	35	30	30	30	40	55	60	50	55	45	25
	Saturday:	20	15	15	0	0	0	0	0	0	50	45	50	50	45	40	40	35	40	55	55	50	55	40	30
	Sunday:	25	20	20	0	0	0	0	0	0	0	50	50	40	40	30	30	30	40	50	50	40	50	40	20

Table C-5 (continued) Building Schedule Percentage Multipliers

	Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
HEALTH																									
Occupancy	Weekday:	0	0	0	0	0	0	0	10	50	80	80	80	80	80	80	80	80	50	30	30	20	20	0	0
	Saturday:	0	0	0	0	0	0	0	10	30	40	40	40	40	40	40	40	40	10	10	0	0	0	0	0
	Sunday:	0	0	0	0	0	0	0	0	5	5	5	5	5	5	5	5	0	0	0	0	0	0	0	0
Lighting & Receptacle	Weekday:	5	5	5	5	5	5	5	50	90	90	90	90	90	90	90	90	90	30	30	30	30	30	5	5
	Saturday:	5	5	5	5	5	5	5	20	40	40	40	40	40	40	40	40	40	40	10	5	5	5	5	5
	Sunday:	5	5	5	5	5	5	5	5	10	10	10	10	10	10	10	10	5	5	5	5	5	5	5	5
VAC	Weekday:	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on
	Saturday:	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on
	Sunday:	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on
SWH	Weekday:	0	0	0	0	0	0	0	15	55	65	75	80	70	80	75	70	60	40	15	15	15	5	0	0
	Saturday:	0	0	0	0	0	0	0	0	15	25	25	25	20	20	20	20	20	20	5	0	0	0	0	0
	Sunday:	0	0	0	0	0	0	0	0	0	15	15	15	15	15	15	0	0	0	0	0	0	0	0	0
MULTI-FAMILY																									
SWH	Weekday:	0	0	0	5	5	5	80	70	50	40	20	20	25	25	50	50	70	70	35	20	15	15	5	0
	Saturday:	0	0	0	0	0	0	20	45	50	50	35	30	30	30	70	90	70	65	55	35	30	25	5	0
	Sunday:	0	0	0	0	0	0	0	20	25	25	15	20	25	35	55	65	70	35	20	20	20	20	5	0

Footnotes for Table C-5:

(a) Reference: Recommendations for Energy Conservation Standards and Guidelines for New Commercial Buildings, Vol. III, App. A. Pacific Northwest Laboratory, PNL-4870-8 , 1983

(b) Table C-5 contains multipliers for converting the nominal values for building occupancy (Table C-3), receptacle power density (Table C-4), service hot water (Table C-6), and lighting energy (EEBC Section 5) into time series data for estimating building loads under the standard calculation procedure. For each standard building profile there are three series—one each for weekdays, Saturday, and Sunday. There are 24 elements per series. These represent the multiplier that should be used to estimate building loads from 12 a.m. to 1 a.m. (series element #1) through 11 p.m. to 12 a.m. (series element #24). The estimated load for any hour is simply the multiplier from the appropriate standard profile multiplied by the appropriate value from the tables cited above.

(c) The building VAC system schedule listed in Table C-5 lists the hours when the HVAC system shall be considered ON or OFF in accordance with section 5.6.2 of this appendix.

5.3 Envelope

5.3.1 Opaque Envelope and Glazing. The opaque envelope and glazing characteristics of the prototype and reference building envelope shall be determined by using any of the five applicable options for the appropriate building type and window-to-wall ratio (WWR) range, as defined in EEBC Tables 4-1 or 4-2. The opaque envelope and glazing characteristics thus selected shall be used as prescribed assumptions for prototype and reference buildings for calculating the EB or ECB. However, in the calculation of the DECON or DECOS of the proposed design, the envelope characteristics of the proposed design shall be used.

5.3.2 Infiltration. For prototype and reference buildings, infiltration assumptions shall use the prescribed assumptions for calculating the ECB and default assumptions for the DECON. Infiltration shall impact only perimeter zones.

When the VAC system is OFF, the infiltration rate for buildings with or without operable windows shall be assumed to be 0.0017 L/s per m^2 of the gross exterior wall. When the VAC system is ON, one of the following infiltration assumptions may be used, as appropriate:

a) no infiltration is assumed to occur (most likely in a positively pressurized building, with no operable windows).

b) the infiltration rate is assumed to be 0.0008 L/s per m^2 of the gross exterior wall (more likely in a building with operable windows).

Exception. Hotels or motels and multifamily buildings shall have infiltration rates of 0.0017 L/s per m^2 of gross exterior wall area at all times.

5.3.3 Envelope and Ground Absorptivities. For prototype and reference buildings, absorptivity assumptions shall be prescribed assumptions for computing the EB or ECB and default assumptions for computing the DECON or DECOS.

5.3.3.1 Prescribed values: For computing the EB or EB, the following prescribed values shall be used: the solar absorptivity of opaque elements of the building envelope shall be assumed to be 70%. The solar absorptivity of ground surfaces shall be assumed to be 80% (20% reflectivity).

5.3.3.2 Default values: For computing the DECON or DECOS, default values of envelope and ground absorptivities shall be used that are consistent with the intended treatments of these surfaces in the building design, and nearby site design. If values lower than 70% are used, the specific intended surface treatments shall be documented. Values for solar absorptivity may be obtained from Appendix D of this guide, Building Envelope.

5.3.4 Window Management. The following assumptions shall be used:

a) **For setting EB or ECB:** For the prototype and reference buildings, the following window management blind or drapery assumptions shall be default assumptions for setting the EB or ECB. Glazing shall be assumed to be internally shaded by medium horizontal venetian blinds closed one-half time. The blinds shall be modeled by assuming that one half the area in each zone is covered by closed blinds and one half is not.

b) **For calculating the DECON or DECOS of the proposed design:** These assumptions shall be default assumptions that should reflect the intended devices to be installed in the proposed design. If manually operated draperies, shades or blinds are to be used in the proposed design, the DECOS shall be calculated by assuming they are effective over one-half the glazed area in each zone.

5.3.5 Shading. For prototype and reference buildings and the proposed design, shading by permanent structures, terrain, and vegetation shall be taken into account for computing energy consumption. Such permanent structures shall be considered whether or not these features are located on the building site. A permanent structure is one that is intended to have more than a temporary life, for example:

a) overhangs, fins, and solar screens that are likely to remain for the life of the proposed design.

b) awnings that, like lighting or VAC systems, are likely to be replaced at the end of its life cycle.

5.4 VAC Systems and Equipment

The specifications and requirements for the VAC systems of prototype buildings shall be those in Table C-6, VAC Systems of prototype buildings. For the calculation of the DECOS, the VAC systems and equipment of the proposed design shall be used.

Table C-6
HVAC Systems of Prototype Buildings[a]

Building/space Occupancy	System No. (Table C-7)	Remarks (Notes to Table C-7)
1. Assembly		
a. Churches (any size)	1	
b. <4,700 m^2 or < 3 floors	1 or 3	Note 1
c. >4,700 m^2 or > 3 floors	3	
2. Office		
a. <1,900 m^2	1	
b. >1,900 m^2 and either <3 floors or <7,000 m^2	4	
c. >7,000 m^2 or >3 floors	5	
3. Retail		
a. <4,700 m^2	1 or 3	Note 1
b. >4,700 m^2	4 or 5	Note 1
4. Warehouse		Note 4
5. Schools		
a. <7,000 m^2 or <3 floors	1	
b. >7,000 m^2 or >3 floors	3	
6. Hotel/Motel		
a. <3 stories	2 or 7	Notes 5, 7
b. >3 stories	6	Note 6
7. Restaurant	1 or 3	Note 1
8. Health		
a. Nursing home (any size)	2 or 7	Note 7
b. <1,400 m^2	1	
c. >1,400 m^2 & <4,700 m^2	4	Note 2
d. >4,700 m^2	5	Notes 2, 3
9. Multifamily	7	

Footnote to Table C-6: The systems and energy types presented in this table are not intended as requirements or recommendations for the proposed design. Floor areas in the table are the total conditioned floor areas for the listed occupancy type in the building. The number of floors indicated in the table is the total number of occupied floors for the listed occupancy type. The numbered notes are listed immediately following Table C-7.

5.4.1 VAC Zones.

5.4.4.1 Prototype buildings: VAC zones for calculating the EB or ECB of prototype buildings shall consist of at least four perimeter and one interior zone per floor. Prototype buildings shall have at least one perimeter zone facing each cardinal direction. The perimeter zones of prototype buildings shall be 4.6 metres in width or one-third the narrow dimension of the building when this dimension is between 9 and 14 metres inclusive or half the narrow dimension of the building when this dimension is less than 9 metres. Zoning requirements shall be a default assumption for calculating the ECB.

Exception. For multifamily buildings, the prototype building shall have one zone per dwelling unit. The proposed design shall have one zone per unit unless zonal thermostatic controls are provided within units, in which case two zones per unit shall be modeled. Building types such as assembly or warehouse may be modeled as a single zone if there is only one space.

5.4.4.2 Proposed building design: For calculating the DECON/DECOS, no fewer zones shall be used than those used in the prototype or reference building. The zones in the simulation shall correspond to the zones provided by the controls in the proposed design. Thermally similar zones, such as those facing one orientation on different floors, may be grouped together for the purposes of either the DECON/DECOS or EB/ECB simulation.

5.4.2 Equipment Sizing and Redundant Equipment. Process loads should be modeled in calculating both the EB/ECB and the DECON/DECOS. If process loads are modeled, the VAC equipment shall be sized in accordance with the methods of EEBC Section 8 to include the capacity to meet the process loads. The designer shall document the installation of process equipment and the size of process loads.

If process loads are not modeled, then for calculating the EB/ECB of prototype or reference buildings, VAC equipment shall be sized to meet the requirements of EEBC Section 8 without utilizing any of the exceptions. For calculating the DECON/DECOS, actual air flow rates and installed equipment size shall be used in the simulation (except that excess capacity provided to

Table C-7
HVAC System Descriptions for Prototype and Reference Buildings[a, b]

HVAC Component	System #1	System #2	System #3	System #4	System #5	System #6	System #7
System Description	Packaged roof-top single zone, one unit per zone	Packaged terminal air conditioner, one cooling unit per zone	Air handler per zone with central plant	Packaged rooftop VAV with perimeter reheat	Built-up central VAV with perimeter reheat	Four-pipe fan coil per zone with central plant	Water source heat pump
Fan System Design supply circulation rate	Note 9	Note 10	Note 9	Note 9	Note 9	Note 9	Note 10
Supply fan total static pressure	30 mm WC	N/A	50 mm WC	75 mm WC	100 mm WC	12 mm WC	12 mm W.C.
Combined supply fan, motor, and drive efficiency	40%	N/A	50%	45%	55%	25%	25%
Supply fan control	Constant volume	Fan cycles with call for cooling	Constant volume	Fan cycles with call for cooling	VAV with air-foil centrifugal fan and AC frequencyvariable speed drive	Fan cycles with call for heating or cooling	Fan cycles with call for heating or cooling
Return fan total static pressure	N/A	N/A	15 mm WC	15 mm WC	25 mm WC	N/A	N/A
Combined return fan, motor, and drive efficiency	N/A	N/A	25%	25%	30%	N/A	N/A
Return fan control	N/A	N/A	Constant volume	VAV with forward curved centrifugal fan and discharge dampers	VAV with air-foil centrifugal fan and AC frequency variable speed drive	N/A	N/A
Cooling System	Direct expansion air cooled	Direct expansion air cooled	Chilled water (Note 11)	Direct expansion air cooled	Chilled water (Note 11)	Chilled water (Note 11)	Closed circuit, centrifugal blower type cooling tower sized per Note 11. Circulating pump sized for 0.048 L/s per kW
Heating System	Furnace, heat pump, or electric resistance	Heat pump w/ electric resistance aux. or	Hot water (Note 8, 12)	Hot water (Note 12) or electric resistance (Note 8)	Hot water (Note 12) or electric resistance (Note 8)	Hot water (Note 12) or electric resistance (Note 8)	Electric or natural draft fossil fuel boiler (Note 8)
Remarks	Drybulb economizer (barometric relief)	No economizer	Drybulb economizer.	Drybulb economizer Minimum VAV setting. Exception: supply air reset by zone of greatest cooling demand	Drybulb economizer Minimum VAV setting. Exception: supply air reset by zone of greatest cooling demand	No economizer	Tower fans and boiler cycled to maintain circulating water temp. between 15.6°C and design tower leaving water temp.

Footnotes to Table C-7:

a. The systems and energy types in this Table are not intended as requirements or recommendations for the proposed design.

b.Numbered notes are contained on the following page.

Numbered Footnotes for Table C-7: HVAC System Descriptions for Prototype Buildings

1. For occupancies such as restaurants, assembly and retail that are part of a mixed use building which, according to Table C-6, includes a central chilled water plant (systems 3, 5, or 6), chilled water system type 3 or 5 shall be used as indicated in the table.

2. Constant volume may be used in zones where pressurization relationships must be maintained by code. VAV shall be used in all other areas, in accordance with EEBC 7.5.

3. Provide run-around heat recovery systems for all fan systems with minimum outside air intake greater than 75%. Recovery effectiveness shall be 0.60.

4. If a warehouse is not intended to be mechanically cooled, both the ECB and DECOS may be calculated assuming no mechanical cooling.

5. The system listed is for guest rooms only. Areas such as public areas and back-of-house areas shall be served by system 4. Other areas such as offices and retail shall be served by the systems listed in Table C-6 for these occupancy types.

6. The system listed is for guest rooms only. Areas such as public areas and back-of-house areas shall be served by system 5. Other areas such as offices and retail shall be served by the systems listed in Table C-6 for these occupancy types.

7. System 2 shall be used for ECB calculation.

8. Prototype energy budget cost calculations shall be made using both electricity and natural gas. If natural gas is not available at the site, electricity and fuel oil shall be used. The ECB shall be the lower of these results. Alternately, the ECB may be based on the fuel source that minimizes total operating, maintenance, equipment, and installation costs for the prototype over the building lifetime.

Equipment and installation cost estimates shall be prepared using professionally recognized cost estimating tools, guides, and techniques. The methods of analysis shall conform to those of Subpart A of 10 CFR 436. Energy costs shall be based on actual costs to the building as defined in this Section.

9. Design supply air circulation rate shall be based on a supply-air-to-room-air temperature difference of 11 °C. A higher supply air temperature may be used if required to maintain a minimum circulation rate of 4.5 air changes per hour or 7.1 L/s per person to each zone served by the system, at design conditions.

If return fans are specified, they shall be sized for the supply fan capacity less the required minimum ventilation with outside air, or 75% of the supply air capacity, whichever is larger. Except where noted, supply and return fans shall be operated continuously during occupied hours.

10. Fan energy when included in the efficiency rating of the unit as defined in EEBC 8.4, need not be modeled explicitly for this system. The fan shall cycle with calls for heating or cooling.

11. Chilled water systems shall be modeled using a reciprocating chiller for systems with total cooling capacities less than 600 kW, and centrifugal chillers for systems with cooling capacities of 600 kW or greater. For systems with cooling capacities of 2000 kW or more, the ECB shall be calculated using two centrifugal chillers, lead/lag controlled. Chilled water shall be assumed to be controlled at a constant 6.7 °C. Chilled water pumps shall be sized using a 8 °C temperature rise, from 6.7°C to 13.3°C, operating at 22.9 metre of head and 65% combined impeller and motor efficiency. Condenser water pumps shall be sized using a 5.6 °C temperature rise, operating at 18.3 metre of head and 60% combined impeller and motor efficiency. The cooling tower shall be an open circuit, centrifugal blower type sized for the larger of 29.4 °C leaving water temperature or 5.6 °C approach to design wet-bulb temperature. The tower shall be controlled to provide a 18.3 °C leaving water temperature whenever weather conditions permit, floating up to design leaving water temperature at design conditions.

12. Hot water system shall include a natural draft fossil fuel or electric boiler per Note 8. The hot water pump shall be sized based on a 16.7 °C temperature drop, from 82.3 °C to 65.6 °C, operating at 18.3 metre of head and a combined impeller and motor efficiency of 60%. Hot water supply temperature shall be reset in accordance with EEBC section 9.

meet process loads need not be modeled if the process load was not modeled in setting the ECB). Equipment sizing in the simulation of the proposed design, as it is being analyzed for compliance, shall correspond to the equipment actually selected for the design. The designer shall not calculate energy use in the actual compliance simulation using equipment sized automatically by the simulation tool.

Redundant and emergency equipment need not be simulated if they are controlled such that they will not be operated during normal operations of the building.

5.5 Service Water Heating

The service water heating loads for prototype buildings are defined in terms of watts/person in Table C-8. The values in the table refer to energy content of the heated water. The service water heating loads from Table C-8 are prescribed for multifamily buildings and default for all other buildings. The same service-water-heating load assumptions shall be made in calculating the DECON/DECOS as were used in calculating the EB/ECB.

Table C-8
Service Hot Water Quantities

Building Type	W/Person[a]
1. Assembly	63
2. Office	51
3. Retail	40
4. Warehouse	66
5. School	63
6. Hotel/Motel	325
7. Restaurant	114
8. Health	40
9. Multifamily	500[b]

Footnotes to Table C-8:

a) This value is the number to be multiplied by the percentage multipliers of the building profile schedules in Table C-5. See Table C-3 for occupancy levels.

b) Total hot water use per dwelling unit for each hour shall be 1 kW times the multifamily SWH system multiplier from Table C-5.

The service water heating system, including piping losses for the prototype or reference building, shall be modeled using the methods of the ASHRAE Handbook, 1987 HVAC Systems and Applications Volume[29], using a system that meets all requirements of EEBC Section 9. The same fuel or fuels shall be used in the prototype or reference building as are used in the proposed design.

5.6 Controls

5.6.1 Prescribed Assumptions. The assumptions in this section are prescribed assumptions. If portions of the proposed design do not include equipment for cooling, the DECON or DECOS shall be determined to the extent feasible by the schedule specifications for calculating the EB or ECB as described in Table C-5.

Exceptions:

a) If the entire building is not provided with cooling, both the prototype or reference building and the proposed design shall be simulated using the same assumptions. For the non-conditioned portions of the prototype building, the analysis shall show that the building interior temperature meets the comfort criteria of ANSI/ASHRAE 55-1981,[4] at least 98% of the occupied hours during the year.

b) If the entire building is not intended to be mechanically cooled, both the EB/ECB and DECON/DECOS shall be modeled using the same assumptions about the portions of the building that are mechanically cooled.

5.6.2 Space temperature controls. Space temperature controls for the prototype or reference building shall be set at 24 °C for space cooling. The system shall be OFF during off-hours according to the appropriate schedule in Table C-5.

Exceptions:

a) setback shall not be modeled in determining either the EB/ECB or DECON or DECOS if setback is not realistic for the proposed design such as a facility being operated 24 hours/day.

b) space control temperatures for multifamily buildings shall use the thermostat settings in Table C-9.

Table C-9
Thermostat Settings °C Multifamily Buildings

	Single Zone Dwelling Unit	Two Zone Dwelling Unit Bedrms /Bathrms	Other Rooms
Time of Day	**Cool**	**Cool**	**Cool**
00:00 - 06:00	25.5	25.5	29.5
06:00 - 09:00	25.5	25.5	25.5
09:00 - 17:00	25.5	29.5	25.5
17:00 - 23:00	25.5	25.5	25.5
23:00 - 24:00	25.5	25.5	25.5

Note: The systems and types of energy presented in Table C-9 are intended only as constraints in calculating the Energy Budget or Energy Cost Budget. They are not intended as either requirements or recommendations for either the systems or the type of energy to be used in the proposed building or for the calculation of the design energy or design energy cost.

5.6.3 Outdoor Air Ventilation. When providing for outdoor air ventilation when calculating the EB/ECB, controls shall be assumed to close the outside air intake to reduce the flow of outside air to 0.0 L/s during "setback" and "unoccupied" periods. Ventilation using inside air may still be required to maintain scheduled setback temperature. Outside air ventilation, during occupied periods, shall be as required by EEBC section 7 or the proposed design, whichever is greater.

5.6.4 Dehumidification. If dehumidification requires subcooling of supply air, then reheat for the prototype or reference building shall be from recovered waste heat such as condenser waste heat.

5.7 Speculative Buildings

For buildings being designed and constructed "for speculation" without full specification of all systems, because the occupants are not yet identified, the following instructions shall apply.

5.7.1 Lighting. The interior lighting power allowance (ILPA) for calculating the EB/ECB shall be determined from EEBC section 5.5 using EEBC Table 5-5. The DECON/DECOS may be based on an assumed adjusted lighting power for future lighting improvements.

The assumption about future lighting power used to calculate the DECON/DECOS must be documented so that the future installed lighting systems may be in compliance with the EEBC. Documentation must be provided to enable future lighting systems to use either the Prescriptive Method of EEBC 5.5 or the System Performance method of EEBC 5.6.

Documentation for future lighting systems that use the Prescriptive Method of EEBC 5.5 shall be stated as a maximum adjusted lighting power for the tenant spaces. The adjusted lighting power allowance for tenant spaces shall account for the lighting power provided for the common areas of the building.

Documentation for future lighting systems that use the System Performance method of EEBC 5.6 shall be stated as a required lighting adjustment. The required lighting adjustment is the whole building lighting power assumed in order to calculate the DECON/DECOS minus the ILPA value from EEBC Table 5-5 that was used to calculate the EB/ECB. When the required lighting adjustment is less than zero, a complete lighting design must be developed for one or more representative tenant spaces demonstrating acceptable lighting within the limits of the assumed lighting power limit.

5.7.2 VAC Systems and Equipment. If the VAC system is not completely specified in the plans, the DECON/DECOS shall be based on reasonable assumptions about the construction of future VAC systems and equipment. These assumptions shall be documented so that future VAC systems and equipment may be in compliance with the EEBC.

6 Compliance Submittal Forms

Copies of input files and summary (BEPS) output pages are sufficient compliance submittal materials. Examples of such inputs and outputs are contained in Section 3, Energy and Economic Analyses for the Jamaica EEBC.

7 References

ASEAM2.1 Documentation (at JBS)

ASEAM2D Documentation (at JBS)

DOE-2.1D Documentation (at JBS)

ASHRAE Handbook, 1985 Fundamentals Volume, Inch-Pound Edition

ASHRAE Handbook, 1989 and 1993 FundamentalsVolumes, I-P and SI Editions

ASHRAE Handbook, 1987 HVAC Systems and Applications

Energy Calculations I: Procedures for Determining Heating and Cooling Loads for Computerizing Energy Calculations--Algorithms for Building Heat Transfer Subroutines, ASHRAE, 1976

Energy Calculations II: Procedures for Simulating the Performance of Components and Systems for Energy Calculations, ASHRAE, 1976

Knebel, David E.,*Simplified Energy Analysis Using the Modified Bin Method*, ASHRAE, 1983

IES LEM-2, Recommended Procedure for Lighting Energy Limit Determination for Buildings, Illuminating Engineering Society of North America (IESNA), New York, NY 10017, 1984

IES LEM-4, Recommended Procedure for Energy Analysis of Building Lighting Design and Installations, IESNA, 1984.

Attachment C-A

Speculative Building Example

To illustrate the procedure that addresses the lighting requirement for speculative buildings, consider a 10,000 m^2 speculative office building. The building consists of 1,000 m^2 of common area, including the lobby, washrooms and common corridors. Tenant spaces represent 9,000 m^2.

The lighting system has been designed for the common area. The common area system in the proposed design has an adjusted lighting power of (ALP) 118,000 watts or 11.8 W/m^2. No lighting system design exists for the tenant spaces.

The lighting power to be assumed in the prototype building is taken from EEBC Table 5-5 (prescriptive method). The result is 17.2 W/m^2. Therefore, the Interior Lighting Power Allowance required by EEBC-94 Section 6 is 17.2 W/m^2 X 10,000 m^2, or 172,000 W. This is then the lighting power used to calculate the Energy Cost Budget (ECB) for the building.

In order to calculate the energy cost of the proposed building design, the DECOS, it is necessary to make an assumption about the lighting power in the tenant spaces of the proposed design. Based on previous design experience, an average lighting power of 24.8 W/m^2 is assumed for the tenant space. Thus the total Connected Lighting Power (CLP) for the proposed design of the building is 2,008,000 W (20.1 W/m^2).

The CLP of 20.1 W/m^2 is greater than the allowed ILPA of 17.2 W/m^2 (see above). For the lighting system t o comply, the CLP should be less than or equal to 17.2 W/m^2. Thus, the proposed lighting design for the building does not meet the prescriptive requirements of EEBC-94 Section 6. However, the CLP of 20.1 W/m^2 is acceptable if the entire building complies using the Whole-building Energy Cost Budget (ECB) method, that is if DECOS < ECB. This would involve another building system, say the envelope or VAC system being much better than code requirements. For this example, we shall assume that the DECOS < ECB and therefore the building complies.

The lighting power assumed for the proposed design is summarized below:

	Lighting Power (W/m^2)	Area (m^2)	Total Power (W)
Common Area	11.8	10,000	118,000
Tenant Space	21.0	90,000	1,890,000
	20.1	100,000	2,008,000

The DECOS is calculated for the proposed design and the building is shown to meet the standard through the Cost Budget Method.

Since the lighting systems for the tenant spaces have not been designed, it is necessary to document the assumptions made to calculate the DECOS. These assumptions will then become requirements for future tenant lighting improvements. The assumption shall be documented so that the tenant lighting systems may meet the standard by using either the prescriptive or system performance method.

If the prescriptive method is used to determine future tenant lighting improvement, the ILPA for the tenant spaces is the same as the assumption used to calculate the DECOS. Therefore, the tenant lighting systems must be designed with an adjusted lighting power less than 20.1 W/m^2. This will ensure that the building meets the standard since this same assumption was used to calculate the DECOS.

If the system performance method is used to show that future tenant lighting improvements meet the standard, then it is necessary to calculate the required lighting adjustment (RLA). This is shown below:

$$
\begin{aligned}
\text{RLA} &= \text{ALP assumed for DECOS - ALP assumed for ECB}\\
&= 20.1 - 17.2\\
&= 2.9\ \text{W/m}^2
\end{aligned}
$$

Suppose a tenant takes a 1,000 m^2 space in the building and uses the system performance method. It is determined through a task-by-task analysis that the internal lighting power allowance ILPA for the tenant space is 17.7 W/m^2. The adjusted lighting power allowance for the tenant space is, therefore, 17.7 W/m^2 plus the RLA as shown below:

$$
\begin{aligned}
\text{Adjusted ILPA} &= \text{ILPA} + \text{RLA}\\
&= 17.7 + 2.9\\
&= 20.6\ \text{W/m}^2
\end{aligned}
$$

The lighting system for this tenant space must be designed with an adjusted lighting power of less than 20.6W/m^2. This will ensure that the building as a whole will meet the standard.

Appendix D:

Compliance Guidelines for the Building Envelope

Contents of this Appendix

1 Envelope Design Principles D-1
2 Compliance Procedures: General Process D-4
3 Basic Criteria D-4
4 Prescriptive Criteria D-5
5 System Performance Criteria D-20
6 More Envelope Calculation Details (Selected Topics) D-33

Commentary

This section of the guidebook sets out methods to assist the architect to design the building envelope so that it will meet the energy efficiency requirements of the EEBC code.

1 Envelope Design Principles

1.1 General Introduction

The building envelope moderates the outdoor climate to permit comfortable and productive indoor conditions.

In Jamaica's climate, the main envelope design objective for energy efficiency is to reduce the heat gains from both external and internal sources:

a) The predominant external load is from solar heat gain.
b) The internal load from electric lights is also a predominant load that can be reduced by using daylighting.
c) The difference in air temperature between indoor and outdoor air is not nearly so important for building envelope design.
d) Air temperature differences are, however, very important to the ventilation loads on the air-conditioning system.

Energy reductions from various envelope strategies have been calculated for a typical five story large office in Kingston. Figure D-1 shows the percentage change in total building annual energy use as a result of applying each envelope strategy to a Base Case building that represents current Jamaican construction practice. In each case, some of the energy reduction has resulted directly from the measure used, and additional energy reduction has resulted from the reduced size of the air-conditioning system.

Thus, the general priorities of envelope strategies for Jamaican office buildings are indicated by Figure D-1. While these priorities will vary somewhat for specific buildings and with building type, the figure shows the relative importance of changes in total building energy use depending modification of envelope measures.

The figure also permits a comparison to be made between the effect of each envelope strategy and the combined impacts of all EEBC code requirements on total building energy savings. From Appendix A, the combined reduction in total building energy use is approximate 30% to 35%. As Figure D-1 shows, several envelope-related efficiency measures can each produce substantial savings on the order of 15%. This indicates that envelope strategies can be important to achieving the overall energy savings resulting from the application of the entire code.

1.2 Windows

Figure D-1 shows that the most important strategies for reducing external loads are those that reduce solar heat gain through the windows. Strategies include control of:

a) Window area, expressed as window-to-wall ratio (WWR).
b) Glass type, expressed as the shading coefficient for the glass (SC_g).
c) Use of internal shading devices (SC_{int}) and external shading devices (SC_{ext}) (external sunscreens, overhangs, fins, venetian blinds).

If properly used together, in conjunction with downsized air-conditioning equipment, these strategies can easily reduce total building energy use 15% to 20% or more.

1.3 Daylighting

From Figure D-l, a second very important envelope strategy is daylighting, which reduces the internal load from the electric lighting system in the perimeter areas. Daylighting can be very effective. The Cumper/Marston study (see Refs.) shows total building energy reduction potentials in the range of 15% for several daylight strategies relating to windows.

This strategy also depends on the use of special controls on the lighting system. Simple on/off switches are low cost, but only reduce energy 4%-5%. Use of either two-level switching or continuous dimming controls will produce energy savings in the 10% to 15% range. Continuous dimming controls are more effective, but also are more expensive.

Several window strategies are very important for effective daylight use:

a) Minimize heat gain: blocking the direct solar rays will reduce heat gain and glare. External shading devices (overhangs, fins, screens, lightshelves, etc.) are much more effective in minimizing heat gain than glazing with low shading coefficients, for daylighting purposes.
b) Maximize light transmission (VLT) while reducing heat transmission through the glass (SC): new type of glazing can permit up to twice as much light to pass through the glass for a given amount of heat gain passing through. Figure D-l shows that two-level light switching with high VLT can save 5% more energy than using the two-level switching by itself. In the sample building, this results in 16% total building energy reduction instead of 11%.

1.4 Roof Insulation and Colour

For office buildings, this is a third high priority area for reducing building energy use through envelope design. Figure D-1 shows that, for 3 to 5 story buildings, roof insulation can reduce total building energy use by 5% to 9%. (The percent reduction would be higher for 1 and 2 story buildings). Studies show that about 50 mm of rigid insulation is optimum economically in typical office situations. This again assumes appropriate downsizing of the air-conditioning system because the peak load is reduced.

Significant energy reductions can also be achieved from using light coloured roof surfaces or special coatings with low solar absorptivities. In Figure D-l, lighter colours (low colour correction factor numbers) can reduce total building energy use in the range of 3% to 10% from the base case, depending upon whether the building is 5 or 3 stories.

These roof strategies can also greatly improve interior comfort conditions on the top floor of the building, because less heat is entering the space through the roof.

1.5 Wall Insulation and Colour

These strategies have less impact on reducing energy use than the same strategies applied to the roof. For a 5 story building, wall insulation and colour strategies have about 2/3rds of the impact as roof insulation and colour strategies. For a 3 story building, they have about 1/2 of the impact.

Wall insulation and colour strategies have much less impact on energy than either the window or the daylighting strategies. Because of their low cost, strategies that use light wall colours are more cost effective than wall insulation strategies.

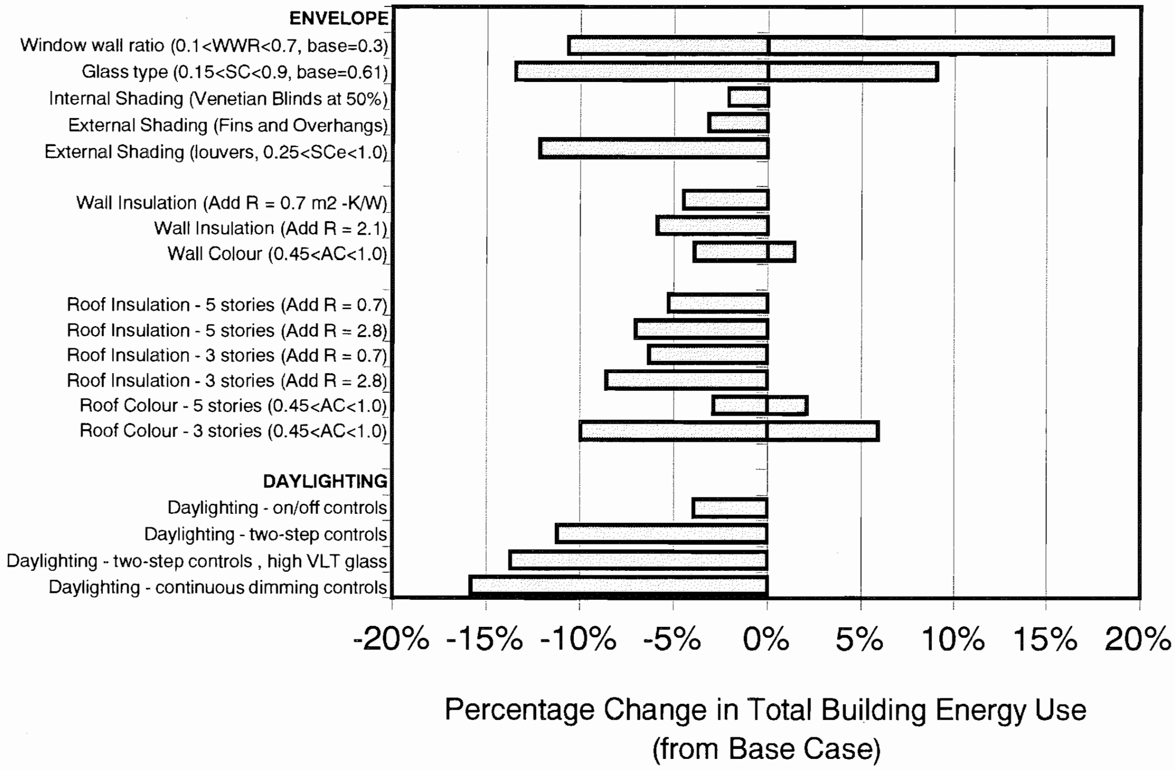


Figure D-1 Impacts of Energy Strategies for the Building Envelope (Office Buildings)

1.6 Infiltration

Leaky buildings are not a problem in Jamaica's climate if the buildings are NOT air-conditioned; indeed, natural ventilation is highly desirable. However, the opposite is the case for buildings that are air-conditioned; leaky air-conditioned buildings can waste considerable amounts of energy. Air leaks caused by inattentive construction or building operation, can allow large amounts of hot humid outside air to enter the building, decreasing comfort and increasing the load on the air-conditioning system.

Thus, it is important to pay proper attention to caulking of all joints and to construction and installation of windows and doors. It is difficult to evaluate these impacts via computer simulation. We estimate that in the Jamaican climate a very leaky building can use 10% more total energy than a properly sealed one.

The EEBC code compliance forms require certification by window and door suppliers that their products meet minimum specified air leakage criteria. The EEBC also requires that the architect specify proper caulking and sealing of the building to reduce the negative impacts of high infiltration rates.

2 Compliance Procedures: General Process

The envelope design of a building is in compliance with the EEBC requirements when the Basic Criteria of Section 4.4 and the Prescriptive (Section 4.5) or System Performance (Section 4.6) requirements are met for exterior and interior walls and roof. These alternative compliance paths prescriptive or system performance - are shown in Fig. D-2.

Compliance criteria for the prescriptive method are set out in EEBC Tables 4-1 through 4-3. Achieving compliance using the system performance method will necessitate the use of the Overall Thermal Transmittance Value (OTTV) equations and microcomputer spreadsheets or programs based on these equations, and which are included as a part of the Guide Book.

Compliance procedures for Basic, Prescriptive and System Performance Criteria are discussed in Sections 3, 4 and 5, respectively of this Appendix.

2.1 Basic Criteria

The basic criteria must always be met. Thus, the basic air leakage requirements are the only envelope criteria that must be met irrespective of what compliance path is selected.

2.2 Prescriptive Criteria

These criteria, defined in Section 4 of the EEBC, provide a simple compliance procedure with limited flexibility, but they are easy to use. These criteria have been derived from the System Performance Procedure. The equations for system performance were solved to identify sets of "typical" combinations of wall and roof constructions that would meet the System Performance requirements. In a sense, the prescriptive criteria are pre-calculated solutions to the system performance equations. Therefore, they are consistent with System Performance criteria. However, they are usually also more stringent because they are based on the most stringent point in each range examined.

2.3 System Performance Criteria

The System Performance criteria defined in Section 5 of this appendix provide a more complex but more flexible compliance procedure. These criteria are separate performance specifications for the entire wall and roof systems.

These are defined relative to Overall Thermal Transmittance Value (OTTV) equations for the roof and walls. So long as the energy flux is less than the limit set, the wall and/or roof system is considered to comply (to be sufficiently energy efficient). The relative importance of the various elements of the roof and wall systems are defined by the coefficients in the OTTV equations for each variable.

When using the System Performance criteria, the microcomputer-based procedures on the attached diskettes may be used to calculate both the criteria and compliance values.

3 Basic Criteria

Air leakage requirements are the only basic building envelope criteria to be met. (Section 4.4 of the EEBC). Basic criteria must always be met, no matter what compliance path is selected.

3.1 Joints

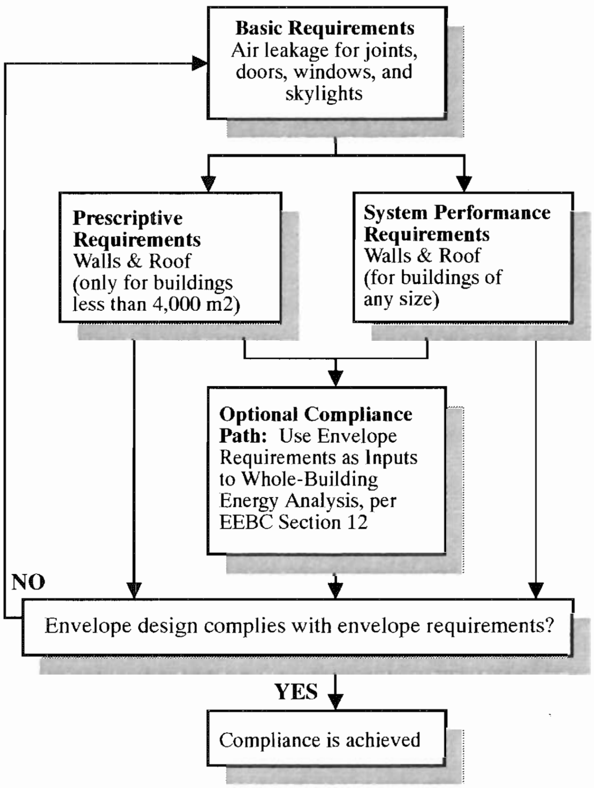
Specifications for caulking with joint sealers and weatherstripping shall be shown on drawings where required and must be properly specified and detailed.

Joint sealers should be easy to apply and must retain their shape in hot climates without creep or slump.

3.2 Windows/Doors/Skylights

The manufacturers technical information on the product must state the standard to which it has been manufactured. This standard must be that required by the Code or the particular standard be compared with the required standard.

Figure D-2:
Envelope Compliance Paths



3.3 Access to the Standards

The relevant air leakage standards are listed below. They will be available for reference from the Jamaica Bureau of Standards Library:

Windows:
ANSI/AAMA 101-1985: Aluminium prime windows
ASTM D 4099-83: Poly vinyl chloride (PVC) prime windows
ANSI/NWMA I.S. 2-80 Wood window units (Improved performance rating only)
Sliding Doors:
ANSI/AAMA 101-1985: Aluminium sliding glass doors
ANSI/NWMA I.S.3-83: Wood sliding patio doors
Swinging/Revolving Doors - Commercial:
ASTM E283-84: Air leakage not to exceed O.59 L/s
Swinging Doors - Residential and Skylights:
ASTM E283-84: Air leakage not to exceed 0.236 L/s

4 Prescriptive Criteria

This section explains how to comply with the EEBC prescriptive envelope criteria for roof and walls.

Climate Locations: These prescriptive criteria apply to all climate locations in Jamaica. For purposes of the EEBC, Jamaica has been divided into three climatic regions. See map in Figure D-3. These regions are intended to group the various climate conditions throughout the island, including variations in solar intensity, temperature and wind patterns.

However, for simplicity, a single set of prescriptive criteria are defined that apply to all climate regions. The criteria have been defined using the most stringent climate conditions, those for climate zone 1 (e.g., Kingston)

Building Size: These prescriptive criteria may be applied to all buildings with gross floor area less than 4,000 m^2. However, the prescriptive criteria are not intended for buildings larger than 4,000 m^2.

4.1 Prescriptive Criteria: Walls

The prescriptive wall criteria are specified in Tables 4-1 and 4-2 contained in Section 4.5 of the EEBC.

4.1.1 Wall Prescriptive Compliance. This involves a three step process:

a) Select either EEBC Table 4-1 or 4-2 depending on the size of the building.

   For the opaque portions of the wall, two requirements are specified at the top of each table:

   1) Maximum U-Value
   2) Wall colour (maximum solar absorptance.

   To determine appropriate requirements for the windows (fenestration) two additional steps are required, as follows:

b) Select the appropriate range of window-to-wall ratio (WWR) in the table, based upon the overall WWR of the building envelope.

c) For the WWR range select one of the five options available (in one of the five columns) so that the building envelope will meets all requirements.

Compliance is attained if the wall construction of the proposed building design meets or surpasses the values for each of the requirements in the column selected, plus the U-value and A_c requirements listed at the top of the table.

For example, per 4.1.1(a), first select the appropriate table for the building type. If the building is an office with gross floor area less than 4,000 m^2, then use Table 4-1. For any other building type with gross floor area less than 4,000 m^2, then use Table 4-2.

Note: if the building's gross floor area exceeds 4,000 m^2, then the prescriptive method cannot be used. Instead, one must use either the system performance compliance method (see EEBC-94, Section 4.6 and Section 5 of this Appendix) or the whole-building energy budget compliance method (see EEBC-94, Section 12 and Appendix C of this Guideline).

Tables 4-1 and 4-2 contain values for the climate region in which Kingston is located (climate region A). For purposes of the EEBC, Jamaica has been divided into three climatic regions, as shown in the map in Figure D-3. However, as stated earlier, for simplicity, a single set of prescriptive criteria are defined using the most stringent climate conditions, those for climate zone A (e.g., Kingston). However, per EEBC-94 Section 4.5.1, an adjustment may be made for other climate regions.

Second, per 4.1.1(b), select the WWR Range, by choosing which part of the table to use in determining requirements, based upon the overall window-to-wall ratio (WWR) for the building envelope. To do this step, you need to know the window-to-wall ratio (WWR) for the building. The WWR is the ratio of the fenestration area to the gross exterior wall area.

For EEBC Table 4-1 for small offices, five ranges of WWR are specified as follows:

WWR < 0.10	less than 10% glass
O.ll = <WWR<0.20	11% - 20% glass
0.21 = <WWR<0.30	21% - 30% glass
0.31 = <WWR<0.40	31% - 40% glass
0.41 = <WWR<0.05	41% - 50% glass

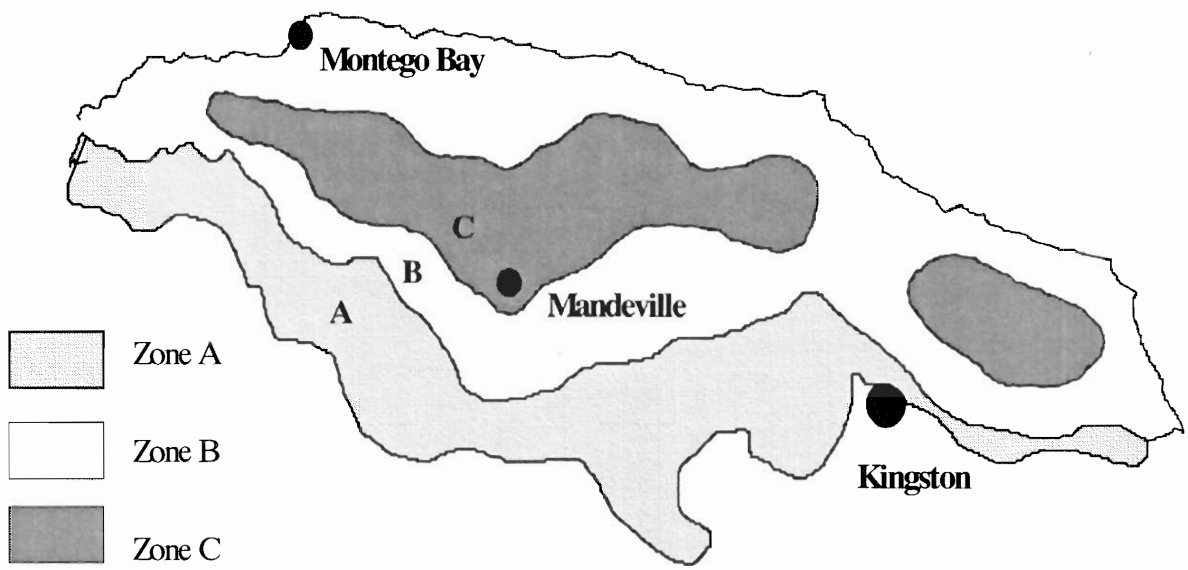


Figure D-3: Jamaica - Climatic Zones

Within each table, the criteria are set using the upper bound of WWR in each range, namely, 0.10, 0.20, 0.30, 0.40 and 0.50.

Buildings with WWR equal to, or greater than 0.50 (50% glass) for offices, and 0.30 (30% glass) for all other building types, must use the System Performance criteria specified in Section 5 of this Appendix.

Computing WWR: To compute the WWR for the building, divide the gross exterior wall area of the building (including the areas of fenestration) by the total area of fenestration masonry opening. Examples and procedures for computing various WWR situations are contained in Section 6. However a simple example is shown here. A wall is 6 m wide by 3 m high and has 1.5 m high windows along the full width of the wall. The WWR is calculated as follows:

Gross wall area	=	6 x 3	=	18 m^2
Window area	=	6 x 1.5	=	9 m^2
WWR	=	9/18	=	0.5

(A WWR = 0.5 is equivalent to a total window area that is 50% of the total wall area). If the WWR for any one orientation facing E, SE, S, SW and W is more than double the WWR for the building as a whole, then go to the next highest range in the WWR tables when determining compliance.

An example of such a building would be a store with a glazed front and small or no windows on the other sides.

The south elevation of the store is fully glazed (100% glass). There is no glazing in the other elevations. The dimensions of each elevation are as follows:

South and North	3.7 m x 3.0 m	=	11.1 m^2
East and West	7.3 m x 3.0 m	=	21.9 m^2
WWR (South)	(11.1/11.1)	=	1.0
Total wall area	(11.1 x 2) +		
	(21.9 x 2)	=	66.0 m^2
WWR (for store)	(11.1/66.0)	=	0.168

A WWR of 0.168 for the store is equivalent to windows that are 16.8% of the total wall area of the store. The WWR for the glazed front is approximately six times the WWR for the building. Therefore the range in the table to be used is WWR = 0.21 - 0.30.

Third, per 4.1.1(c), select fenestration requirements within any one of the five columns of the table. Select one of five sets of options, listed in the five columns, in the WWR portion of the table just selected. In each column, required minimum and maximum values are specified for six variables:

- Five for the windows (the fenestration)
- One for automatic daylighting controls

Each of the five columns in the table emphasize different elements in achieving about the same level of envelope energy efficiency.

All requirements in each column must be used. Requirements from different columns cannot be mixed.

For the prescriptive method, only a few options for each variable have been selected. However, in the System Performance option many values for each variable can be chosen, and trade-offs may be made among these six items. We briefly summarize the options provided in the tables.

4.1.2 Opaque Wall Variables

4.1.2.1 U-Value: The U-Value is the thermal transmittance of the opaque wall measured in W/m^2. EEBC Tables 4-1 through 4-2 show MAXIMUM U-Values. Compliance is achieved when the U-Value for the building design is equal to or less than the number in the table for the option selected.

There are many wall construction options, each with its U-Value. However, the prescriptive tables use just one option, the most commonly used construction in Jamaica. Nevertheless a few other construction options, are as follows:

a) Masonry construction, no insulation
b) Wood frame construction, no insulation
c) Addition of various levels of insulation on both types of construction

Typical R-values and U-values for common Jamaican wall construction are shown in Section 6, Tables D-1, D-2, and D-3. Table D-3 shows how the U-values in Table D-1 are derived by using the R-values listed in Table D-

2. If you choose to calculate your U-value, example calculations are given below in this appendix, in Sections 4.1.4.3, 4.1.4.4, and 5.4.4.1.

For example, a small one-storey office building has its external walls composed entirely of 150 mm concrete block, with 12 mm rendering on each side. Each block has two cavities, with one of the cavities containing reinforcing rods and concrete fill. The second cavity is empty.

Requirement: From the top of EEBC Table 4-1, the Maximum U-Value allowed in the prescriptive compliance approach for the opaque wall is 3.01 W/m^2-K.

Compliance: From Table D-1, the 150 mm concrete block with 12 mm rendering on each side and one cavity filled with concrete just meets the requirement. The U-Value for this construction is 3.008 W/m^2-K. Thus, this example wall complies with the prescriptive U-Value requirement for opaque walls.

Another solution from Table D-3 that complies with the prescriptive U-Value requirement for opaque walls is the 150 mm concrete block with 12 mm rendering on each side and one cavity filled with concrete and the other cavity filled with perlite insulation. This construction has much better insulating capability than the first

Table D-1: Typical U-Values for Common Types of Wall Constructions

Description of Construction	U-Value (W/sq.m.-K)
200 mm concrete block, both pockets filled with concrete and 12 mm sand-cement both sides	2.986
200 mm concrete block, one pocket filled with concrete and 12 mm sand-cement both sides	2.798
200 mm concrete block, one pocket filled with concrete, one with perlite, and 12 mm sand/ cement both sides	1.636
150 mm concrete block, both pockets filled with concrete and 12 mm sand-cement both sides	3.336
150 mm concrete block, one pocket filled with concrete and 12 mm sand-cement both sides	3.008
150 mm concrete block, one pocket filled with concrete, one with perlite, and 12 mm sand/ cement both sides	2.135

Table D-2: Resistances (R) for Common Types of Materials Used in Construction in Jamaica

Description of Material	Resistance (sq.m.-K/W)
Outside air film	0.044
Inside air film	0.121
12 mm sand/cement render	0.018
200 mm concrete block, one pocket filled with concrete	0.134
200 mm concrete block, one pocket filled with concrete	0.157
200 mm concrete block, one pocket filled with concrete, one with perlite	0.411
150 mm concrete block, both pockets filled with concrete	0.099
150 mm concrete block, one pocket filled with concrete	0.132
150 mm concrete block, one pocket filled with concrete, one with perlite	0.268

Table D-3: Typical R-Values and U-Values for Common Types of Wall Construction

Wall Layer	Common Wall Constructions: 200 mm Conc. Block	200 mm Conc. Block	200 mm Conc. Block	150 mm Conc. Block	150 mm Conc. Block	150 mm Conc. Block	150 mm Concrete Frame
Outside air film	0.044	0.044	0.044	0.044	0.044	0.044	0.044
12 mm rendering	0.018	0.018	0.018	0.018	0.018	0.018	0.018
200 mm concrete block, 2 cavities filled w/ concrete	0.134						
200 mm concrete block, 1 cavity filled w/ concrete 1 cavity filled w/ air		0.157					
200 mm concrete block, 1 cavity filled w/ concrete 1 cavity filled w/ perlite			0.411				
150 mm concrete block, 2 cavities filled w/ concrete				0.099			
150 mm concrete block, 1 cavity filled w/ concrete 1 cavity filled w/ air					0.132		
150 mm concrete block, 1 cavity filled w/ concrete 1 cavity filled w/ perlite						0.268	
150 mm reinforced concrete frame							0.084
12 mm rendering	0.018	0.018	0.018	0.018	0.018	0.018	0.018
Inside air film	0.121	0.121	0.121	0.121	0.121	0.121	0.121
Total R (sum of layers) =	**0.335**	**0.357**	**0.611**	**0.300**	**0.332**	**0.468**	**0.285**
U-Value (1/R-Value) =	**2.986**	**2.798**	**1.636**	**3.336**	**3.008**	**2.135**	**3.507**

example, for the U-Value for this construction is 2.135 W/m^2-K.

4.1.2.2 Solar Absorptivity Correction Factor: the solar absorptivity correction factor (A_c) provides for a credit for surfaces with lighter colours, which do not absorb as much radiant solar energy as do darker colours. Compliance is achieved when the Solar Absorptivity Correction Factor for the material or color being used is less than or equal to the relevant maximum number listed in the tables.

The correction factor (A_c) is related to the solar absorptivity (α), which is the property of a material evaluated by the ratio of solar energy absorbed by a surface to that falling upon it. Solar absorptivity correction factors (A_c) and related solar absorptivity values (α) for a number of materials and paints are listed in Table D-7.

The criteria in the prescriptive tables have used only dark or light colour options. The value used for dark colours is Ac = 1.0 (α = 0.9). The value used for light colours is Ac = 0.7 (α = 0.62). Using light coloured surfaces can be a very cost effective measure.

4.1.3 Fenestration Variables

4.1.3.1 Percent of Window Externally Shaded: EEBC Tables 4-1 and 4-2 show the ***minimum*** values for the percent of the window area that is externally shaded. Compliance is met when the percent area of the window that is externally shaded from 8:00 a.m. through 5:00 p.m. is equal to, or greater than the figures in the tables.

Currently, this value must be estimated. A computer program is being written which will generate example sets of external shading configurations, by major orientation, that will meet or exceed the minimum requirement, The table thus generated will be made available as an addendum to these guidelines (check with JBS for availability).

Trees and vegetation can provide excellent sources of shading for windows and building surfaces. Procedures for calculating credit for trees and vegetation can be found in "Energy Conservation Site Design," by McPherson.

4.1.3.2 Internal Shading Devices: As with the other window design options just discussed, the prescriptive tables use only a few of the many options available for internal shading devices, namely:

a) No shading device
b) Venetian blinds, light color
c) Venetian blinds, medium color
d) Translucent shade
e) Drapes

4.1.3.3 Fenestration Variables: As can be seen from Table D-5, Fenestration, SC and U-Values, use of internal shading devices can substantially improve (reduce) the SC compared with the SC of the glass alone. SC is defined as the ratio of solar heat gain through the fenestration, with or without integral or interior shading devices, to that occurring through an unshaded 3 mm thick clear double strength glass. Thus, the lower the SC value the less heat gain passes through each square foot of glass into the interior spaces.

For example, the SC_g is 0.95 for a clear single pane 6 mm glass; but, with a light color venetian blind the combined SC_x of 0.67 is much lower. Likewise, the SC_g is 0.58 for tinted double pane 6 mm glass; but, with the addition of a light color venetian blind the combined SC_x of 0.36 is much lower.

Other shading devices may be used in place of the devices listed in EEBC Tables 4-1 and 4-2, if they have

Table D-4:
Solar Absorptance Correction Factors (AC) for Opaque Surfaces

Exterior Wall Wall Colours (Typical)	Solar Absorptance (a)	Solar Absorptance Coefficient (Ac)
Dark	0.9	1
Medium	0.76	0.85
Light	0.62	0.7
White	0.43	0.5
Intense White	0.32	0.4

equivalent or better (lower) shading coefficient (SC) to the device for the option listed in the tables.

4.1.3.4 Glass Type and Number of Panes: To generate the prescriptive tables, only a few types of glass are used—clear, tinted, and reflective—and only two options are used for the number of panes/films— single pane and double pane. Without considering the impact of internal or integral shading devices, this yields the options shown in EEBC Tables 4-1 and 4-2.

For Glass Type, the key variable is the glass Shading Coefficient (SC_g), which defines the relative amount of solar heat gain that the glass will permit to enter the space. The requirement listed in EEBC Tables 4-1 and 4-2 is the ***maximum*** shading coefficient allowed for the glass by itself without considering the internal or integral shading devices.

Note that the formal definition of SC includes the impacts of integral shading devices. However, for clarity of information in the EEBC-94 prescriptive tables, SC_g values are listed for the glazing, and a separate SC_x value is listed for the combined impact of the glass and any internal and external shading devices that may be used.

The SC_g values are for information purposes. The SC_x values specify the shading coefficient requirement for the fenestration, including those shading devices for which an SC_{int} or and SC_{ext} is specified. Other fenestration combinations may be used, so long as they have SC_x values equivalent to or less than those listed in the prescriptive tables. Procedures and examples for calculating SC_x as a composite of SC_g, SC_{int}, and SC_{ext} are provided below in section 5.4.3.2.

Table D-5: Fenestration Shading Coefficients (SC) and U-Values

Glazing Type	No Int. Shades		With Interior Shades				With Interior Drapes			
	SCg	U-Value	Shading Coefficient (SCx)			U-Value	Shading Coefficient (SCx)			U-Value
	Glass & Frame (a)	(d)	Venetian Blinds Medium (b,c)	Venetian Blinds Light (b,c)	Roll Shade Translucent (b,c)	Glass & Shade (d)	Closed Weave Light Colour 10% open	Medium Weave Medium Colour 30% open	Light Weave Light Colour 50% open	Glass & Shade (d)
Single pane clear	0.95	5.91	0.74	0.67	0.44	4.60	0.7	0.6	0.5	4.60
Single pane tinted	0.73	5.91	0.57	0.53	0.36	4.60	0.52	0.46	0.41	4.60
Single pane reflective	0.60	5.91	0.50	0.46	-	4.60	0.51	0.46	0.41	4.60
Single pane reflective	0.50	5.91	0.42	0.38	-	4.60	0.42	0.39	0.36	4.60
Single pane reflective	0.40	5.91	0.33	0.29	-	4.60	0.34	0.32	0.29	4.60
Single pane reflective	0.30	5.91	0.25	0.23	-	4.60	0.24	0.23	0.22	4.60
Double pane clear	0.82	3.18	0.57	0.51	0.40	2.95	0.65	0.57	0.48	2.95
Double pane tinted	0.58	3.18	0.39	0.36	0.30	2.95	0.45	0.41	0.37	2.95
Double pane reflective	0.30	3.18	0.34	0.33	-	2.95	0.37	0.34	0.31	2.95
Double pane reflective	0.30	3.18	0.27	0.26	-	2.95	0.27	0.26	0.25	2.95

For options including daylighting credits, another characteristic of the glass is important. This is visible transmittance (VLT).

For the prescriptive criteria, only 2 options are used for the "number of panes" option, single pane and double pane. See the System Performance approach for a discussion of the many additional options that are available.

4.1.4 Example - A Base Case Building

An example Kingston building has been selected in order to illustrate the prescriptive compliance method for the walls of a building. The Base Case for this wall example has several features that prevent the building from complying with the prescriptive wall criteria. The building is a two story office building with a total floor area of 676 m^2. Refer to Figures D-4, D-5, and D-6.

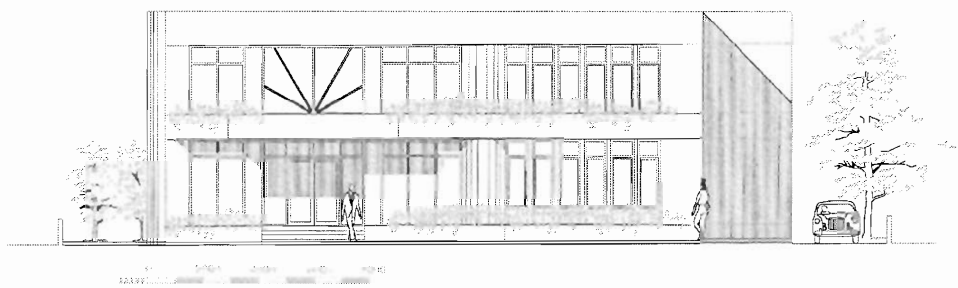


Figure D-4: Example Kingston Small Office Building -- Front Elevation (View from the SE)

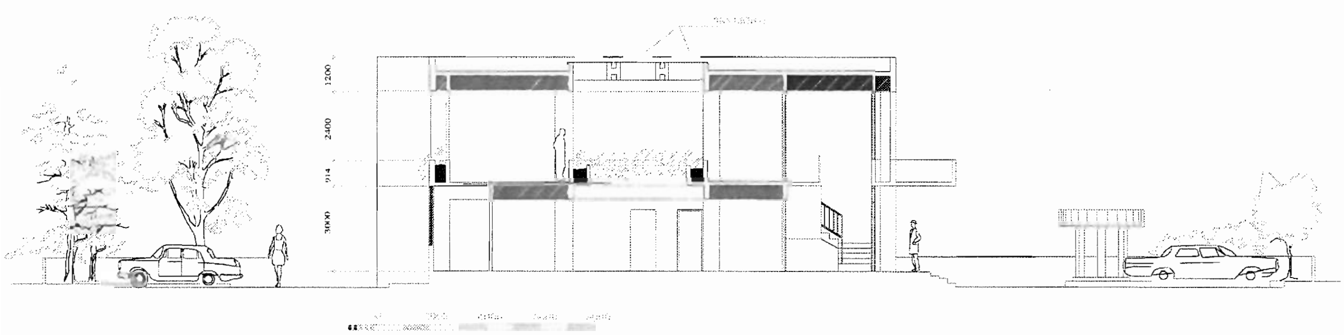


Figure D-5: Example Kingston Small Office Building -- Section (View from the SW)

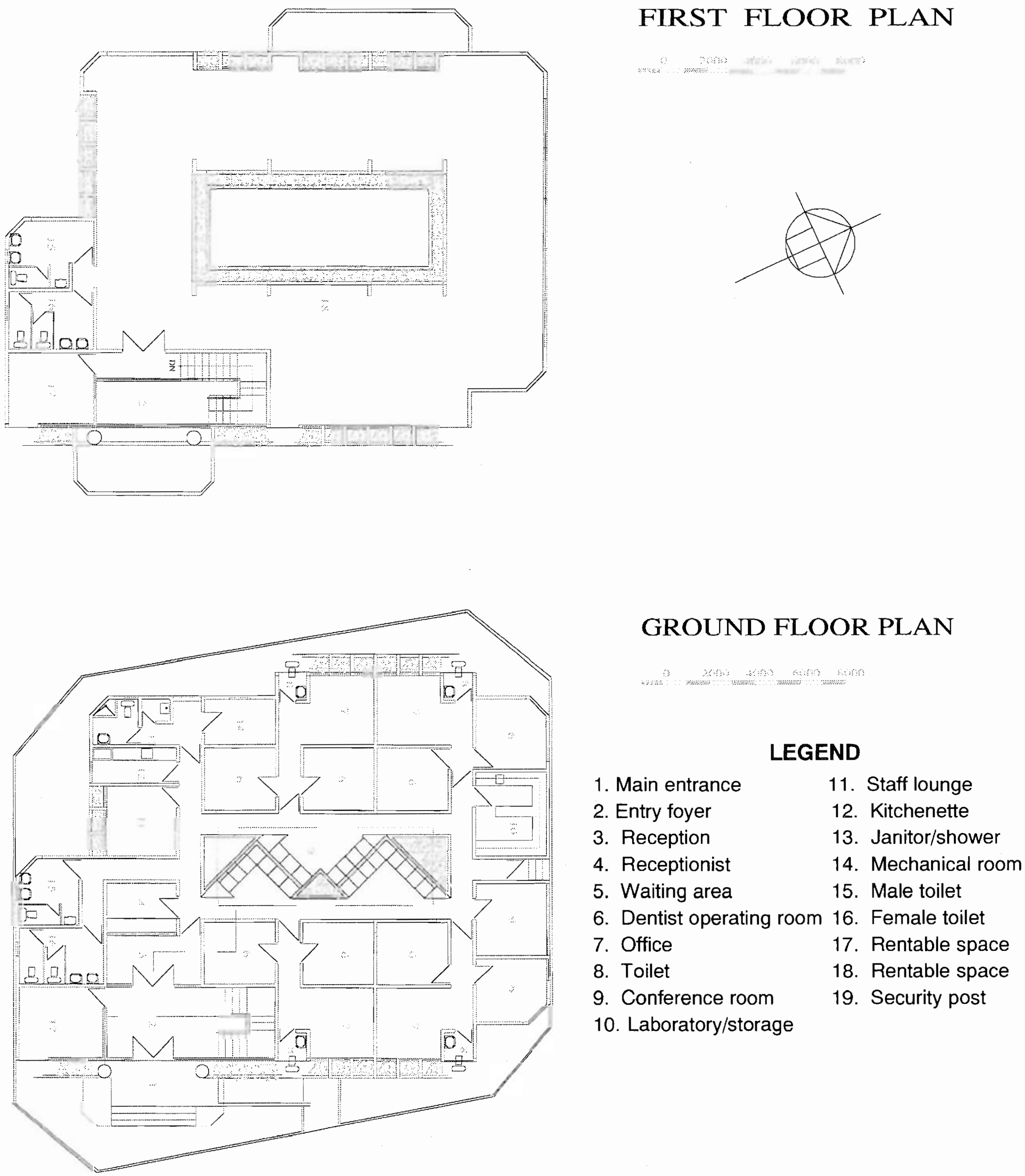


Figure D-6: Example Kingston Small Office Building -- Ground and First Floor Plans

4.1.4.1 Opaque Wall Construction: This is cast-in-place reinforced concrete frame, with reinforced concrete block in-fill sections, which are of 150 mm concrete block, with 12 mm rendering on each side. Of the total wall surface area, 23.3% is the cast-in-place concrete frame, and 76.7% is the 150 mm concrete block in-fill. Each concrete block has two cavities, with one of the cavities containing reinforcing rods and concrete fill. The second cavity is empty. The walls will be painted a light colour ($A_c < 0.70$).

4.1.4.2 Fenestration: Windows and doors are of single pane 6 mm thick tinted plate glass set in anodized aluminum frames. There are no internal shading devices (drapes or venetian blinds) specified. The shading coefficient of the glazing is $SC_g = 0.73$. The glazing U-value is 5.91 W/m^2-K. The window-to-wall ratio has been calculated at WWR = 0.266. That is, 26.6% of the total wall area is glass. (Note: details of computing the WWR for this example building are discussed below in section 5.5.2, as part of the System Performance compliance method). The building makes ample use of external shading devices (fins and overhangs). We assume for this example that, on a year-round average, 80% of the glass area is shaded from the direct rays of the sun between 8:00 a.m. and 5:00 p.m.

4.1.4.3 Compliance with the Base Case: Wall compliance is a 3 step process, per section 4.1.1(a), (b) and (c), above. This process is described below via an example.

First, Select a Table: One must select one of two tables containing the wall criteria (EEBC Table 4-1 or 4-2), depending on building size and type. Since the building is an office and is less than 4,000 m^2, then EEBC Table 4-1 is selected.

Opaque Wall Requirements: These are specified at the top of EEBC Table 4-1. There are two requirements, a maximum U-value and a maximum Solar Absorptivity Coefficient (A_c). The maximum allowable U-Value is 3.01 W/m^2-K. The maximum Solar Absorptivity Coef-

Table D-6: Non-Complying Wall Example - Base Case Prescriptive Wall, R-Value and U-Value Calculations

Wall Layer		150 mm Conc. Block	Cast-in-place Concrete Frame
Outside air film		0.044	0.044
12 mm rendering		0.018	0.018
150 mm reinforced concrete frame			0.084
150 mm concrete block, 1 cavity filled w/ concrete		0.132	
12 mm rendering		0.018	0.018
Inside air film		0.121	0.121
Total R	=	**0.332**	**0.285**
U-Value (1/R-Value)	=	**3.008**	**3.507**
Weighted U-Value	=	3.008 x .767 + 3.507 x .233	
	=	**3.124**	

Table D-7: Complying Wall Example - Modified Prescriptive Wall, R-Value and U-Value Calculations

Wall Layer		150 mm Conc. Block	Cast-in-place Concrete Frame
Outside air film		0.044	0.044
12 mm rendering		0.018	0.018
150 mm reinforced concrete frame			0.084
150 mm concrete block, 1 cavity filled w/ concrete, 1 with perlite		0.268	
12 mm rendering		0.018	0.018
Inside air film		0.121	0.121
Total R	=	**0.468**	**0.285**
U-Value (1/R-Value)	=	**2.137**	**3.507**
Weighted U-Value	=	2.137 x .767 + 3.507 x .233	
	=	**2.456**	

ficient is $A_c = 0.70$. Since the walls of the base case example building will be painted a light colour, with $A_c < 0.70$, the walls do comply with the maximum Solar Absorptivity Coefficient requirement.

The R-Values and U-Values for the base case opaque wall have been computed in Table D-4. The U-Value of the concrete block in-fill is 3.008 W/m^2-K. By itself, the concrete block would pass the U-Value criteria in EEBC Table 4-1. However, the U-Value of the cast-in-place concrete frame is 3.507 W/m^2-K. This exceeds the requirement. The weighted average for the entire wall surface is computed as follows:

$$\text{U-Value}_{tot} = 3.008 \times 767 + 3.507 \times 233$$
$$= 3.124 \ \text{W/m}^2\text{-K}$$

The weighted average U-Value exceeds the maximum allowable U-Value of 3.01 W/ m^2-K from EEBC Table 4-1, and the wall does ***not*** comply with the U-Value requirement.

Second, Select a WWR Range: There are 5 WWR ranges listed along the left side of EEBC Table 4-1. Since the building has a WWR = 0.266, the third WWR range is selected (WWR from 0.21 to 0.30).

Third, Select glazing requirements: Choose these from within any one of the five columns. From inspection of the requirements in the five columns, the base case glazing (fenestration) design cannot comply, no matter which column is chosen:

Table D-8: Excerpt from EEBC-94 Table 4-1

Table 4-1 **EXTERNAL WALL PRESCRIPTIVE REQUIREMENTS**

Table 4-1 is chosen because the small office has a total area less than 700 m².

Building Type: SMALL OFFICE

Gross Floor Area less than 4,000 sq. metres

Requirement: OTTVw of design shall be <= 61.7 W/m2

OPAQUE WALL *Base Case opaque wall does not comply.*

U-Value, W/sq.m.-K	(Max.)	3.01	<-- For example, 150 mm conc. block with 12 mm rendering both sides, 1 core filled with conc. (no insulating fill)
Solar Absorptivity Coefficient (Ac)	(Min.)	Ac = 0.7	<-- For example, light or white color

WWR	Fenestration Features	FENESTRATION OPTIONS 1	2	3	4	5
•						

WWR range of 0.21 - 0.30 is chosen because building WWR = 0.266.

WWR	Fenestration Features	1	2	3	4	5
From 0.21 to 0.30	Percent of Window Ext. Shaded (Min.)	100%	80%	80%	70%	50%
	Glass Type (Max. SCg of glass)	Refl (0.60)	Refl (0.40)	Tinted (0.58)	Refl (0.40)	Tinted (0.73)
	Internal Shading Devices (Max. SCeff)	L. Blinds (0.44)	L. Blinds (0.29)	L. Blinds (0.36)	M. Blinds (0.33)	L. Blinds (0.53)
	Number of Panes (Min.)	1	1	2	2	1
	U-Value, W/(m2-K) (Max.)	4.60	4.60	2.95	2.95	4.60
	Automatic daylight controls on elect. ligh	NO	NO	NO	NO	YES

•
•
•

a) First, some internal shading device is required, equivalent to either medium or light coloured venetian blinds (given the column chosen).

b) Second, the single pane tinted glass (SC_g=0.73) even with venetian blinds (SC_x=0.57 adding medium blinds or SC_x=0.53 adding light coloured blinds) still does not comply without some additional energy efficiency measure.

Thus, the Base Case glazing design does not comply with the requirements of EEBC Table 4-1.

4.1.4.4 Modifications That Comply: The Base Case building does not comply. Now we explore modifications to both the opaque wall and the fenestration that will permit the building design to comply with the Prescriptive Wall Requirements.

Opaque Wall Modifications: The wall complies with the Solar Absorptivity Coefficient requirement but not with the U-Value requirement. Thus, only the U-Value needs to be brought into compliance. This can be accomplished in many ways. However we shall examine a very direct method. In Table D-5, an option for the 150 mm concrete block is to fill the second, empty, cavity with perlite insulation. The calculations to derive this number are shown in Table D-2. As the tables show, the use of perlite in one cavity reduces the overall U-Value for the 150 mm concrete block in-fill section from 3.008 W/m^2-K to 2.135 W/m^2-K. Using this new value, a new weighted average U-Value can be computed for the entire opaque wall, as follows:

$$\text{U-Value}_{tot} = 2.135 \times 767 + 3.507 \times 233$$
$$= 2.455 \ \text{W/m}^2\text{-K}$$

Table D-9: Excerpt from EEBC-94 Table 4-1

Table 4-1 — EXTERNAL WALL PRESCRIPTIVE REQUIREMENTS

Building Type: SMALL OFFICE

Gross Floor Area less than 4,000 sq. metres

Requirement: OTTVw of design shall be <= 61.7 W/m2

Perlite fill allows wall with U = 2.455 to comply

OPAQUE WALL

U-Value, W/sq.m.-K	(Max.)	3.01	<--- For example, 150 mm conc. block with 12 mm rendering both sides, 1 core filled with conc. (no insulating fill)
Solar Absorptivity Coefficient (Ac)	(Min.)	Ac = 0.7	<--- For example, light or white color

Three example fenestration options

WWR	Fenestration Features	FENESTRATION OPTIONS 1	2	3	4	5
From 0.21 to 0.30	Percent of Window Ext. Shaded (Min.)	100%	80%	80%	70%	50%
	Glass Type (Max. SCg of glass)	Refl (0.60)	Refl (0.40)	Tinted (0.58)	Refl (0.40)	Tinted (0.73)
	Internal Shading Devices (Max. SCeff)	L. Blinds (0.44)	L. Blinds (0.29)	L. Blinds (0.36)	M. Blinds (0.33)	L. Blinds (0.53)
	Number of Panes (Min.)	1	1	2	2	1
	U-Value, W/(m2-K) (Max.)	4.60	4.60	2.95	2.95	4.60
	Automatic daylight controls on elect. ligh	NO	NO	NO	NO	YES

The weighted average U-Value is now lower than the maximum allowable U-Value from EEBC Table 4-1, and the wall now complies with the U-Value requirement.

Fenestration Modifications: In Table D-9, two types of modifications to the Base Case fenestration are required to achieve compliance. First, an appropriate interior or integral shading device is needed. Second, either a reflective (or low-e) glazing must replace the Base Case tinted glass, or automatic daylighting controls must be used with the perimeter electric lighting system. Three options have been circled in the table; any one of which will achieve compliance.

a) Replace the tinted glass with single pane reflective glass with a glazing SC_g=0.40. This option will also require the use of light coloured venetian blinds; the combined fenestration shading coefficient for the glass and blind together is SC_x=0.29 (see Table D-5 and section 5.4.3.2). Another combination of glazing and shading device may also be used, so long as the combined $SC_x \leq 0.29$.

b) Replace the tinted glass with double pane reflective (or low-e) glass with a glazing SC_g=0.40, and add medium coloured venetian blinds, to produce a combined fenestration shading coefficient of the glass and blind together is SC_x=0.33 (see Table D-5 and section 5.4.3.2). Another combination of glazing and shading device may be used, so long as the combined $SC_x \leq 0.33$. Note: this option would allow only 70% of the window be externally shaded.

c) Add automatic daylighting controls to the perimeter electric lighting system, and add light coloured venetian blinds to achieve a fenestration shading coefficient for the tinted glass and blind together of SC_x=0.53. Other glazings and shading devices may be used, so long as the combined $SC_x \leq 0.53$.

Additional prescriptive compliance options could be used, for example column 3 in Table D-7. Note that ***all*** four of the requirements within a column of EEBC Table 4-1 must be met in order to comply, including percent external shading, SC_x, fenestration U-value, and any specified daylighting controls.

On the other hand, the wall system performance compliance method requires only that the *overall* system criteria be met; even though various wall components may fail to meet set levels. Thus, the System Performance compliance method is much more flexible than the Prescriptive Method. Since it involves only slightly more compliance effort, the System Performance compliance method is recommended for use whenever additional flexibility is desired.

Also, the Prescriptive Requirements are set at the more stringent edge of each range used. This factor, plus the limited set of trade-offs permitted, make compliance using the Prescriptive compliance path generally more stringent than compliance using the System Performance path.

4.2 Roof - Prescriptive Criteria

The prescriptive criteria for the roof is treated similarly to those for the wall and the WWR is replaced by a Skylight to Roof area Ratio (SRR).

4.2.1 Criteria: The prescriptive roof criteria are specified in Table 4-3 contained in Section 4.5 of the EEBC.

4.2.2 Compliance: To comply, select from EEBC Table 4-3 one of the three roof construction types that most nearly matches the roof construction of your building design. Criteria are given for three construction methods: concrete deck, wood frame, and metal deck. Then, for the construction type you have selected, select one of the two options given in the table. If the construction features of the roof of your building design are very different from the types listed EEBC Table 4-3, then your should use the System Performance method listed in EEBC 4.6.2 when complying with the roof criteria. Within Table 4-3, there are two requirements that must be met for the opaque roof:

a) ***U-Value:*** A MAXIMUM value is listed in EEBC Table 4-3. The U-Value of the roof construction must be less than or equal to the criteria value listed (Note: a minimum weight criteria for each of the three construction types is also listed in the table).

b) ***Solar Absorptivity Coefficient:*** A MAXIMUM value is listed in EEBC Table 43. The Solar Absorptivity Coefficient (A_c) for the roof surface must be less than or equal to the value listed in the table.

Note: Skylights can be considered within the prescriptive roof criteria only if the skylights are installed with automatic daylighting controls for the electric lighting system adjacent to the skylights, per the daylighting credit provided in EEBC 4.7.2. If the building roof has skylights, and automatic daylighting controls are not used, then the Roof System Performance compliance path must be used, per EEBC 4.6.2 and EEBC Eq. 4-4.

4.2.2.1 U-Values: To comply, the U-Value for the opaque roof of the proposed design must be determined. Table D-11 contains a list of U-Values for typical roof construction types in Jamaica. U-Values for both insulated and non-insulated versions of each roof type are listed in Table D-11. If one of the options listed in the does not apply to the roof construction of your building, then the U-Value can be calculated. Table D-11 illustrates the calculation procedure, and an example calculation is shown in section 5.5.4 below.

4.2.2.2 Solar Absorptivity Correction Factor (A_c): To comply, the Solar Absorptivity Correction Factor (A_c) for the surface of the opaque roof of the proposed design must be determined. Table D-4 contains a list of Solar Absorptivity Correction Factors (Ac) for typical roof surface treatments in Jamaica.

If the surface treatment of your proposed roof design has a different solar absorptance value (α) from those listed in Table D-4, interpolation may be used to determine the Ac value. For example, a more expanded list of solar absorptance values (α) are listed on page III.83 of the DOE-2 Reference Manual, Part 1, May 1981, NTIS.

4.2.3 Roof Compliance Examples

Example 1 - No Insulation: For the roof example, the same two-storey office building used for the wall examples is used again. The roof area is 404 m^2. The roof construction is a 150 mm reinforced concrete slab with 25 mm average sand/cement screed, waterproofed with 2 layers of felt, and protected with a gravel surface. The weight of the roof is just over 371 kg/m^2.

Table D-10: Excerpt -- EEBC-94 Table 4-3

Table 4-3: PRESCRIPTIVE REQUIREMENTS FOR ROOFS

Requirement: OTTVR of design shall be <= 20.0 W/sq.m.

		OPTIONS					
		1	2	3	4	5	6
Opaque Portion of Roof		**Concrete Deck**		**Pitched Frame**		**Metal Deck**	
U-Value, W/sq.m.-K	(Max)	1.08	0.91	0.74	0.62	0.74	0.57
Weight, kg/sq.m.	(Min.)	371	371	58	58	34	34
Solar Absorptivity Coefficient (Ac)	(Min.)	0.70	1.00	0.75	1.00	0.70	1.00

Base Case U = 2.61 does not comply!

NOTES:

1 U-Values listed for each type of opaque roof construction are approximately for:
Added R-Value = 0.7 in columns 1, 3, and 5.
Added R-Value = 1.4 in columns 2, 4, and 6.

2 Example Solar Absorptivity Coefficients (Ac): Asphalt, Dark Roof = 1.00, Gravel = 0.70,
Light pebbles = 0.50, Mildew resistant white = .42

3 Skylights: Section 4.7.2 and Table 4-4 may be used in conjunction with this table to include up to indicated pecentages of skylight areas, if daylighting controls are used as specified.

U-Value: From Table D-11, the U-Value of this typical uninsulated roof is 2.61 W/m^2-K. This does not comply with the U-Value requirement for Option 1 or 2 for concrete decks in EEBC Table 4-3.

A_c: The roof has a gravel surface, with a Solar Absorptivity Correction Factor (A_c) = 0.85. This does not comply with Option 1 but does comply with Option 2 for concrete decks in EEBC Table 4-3.

However, since the U-Value for the roof does not comply with either option, this uninsulated roof does not comply.

Example 2 - 25 mm of Insulation: In this example, 25 mm of rigid insulation has been added to the roof construction of the previous example, which is now a 150 mm reinforced concrete slab with 25 mm average sand cement screed, 25 mm rigid insulation, waterproofed with 2 layers of felt, and protected with a gravel surface.

U-Value: From Table D-11, the U-Value of this modestly insulated roof is 1.07 W/m^2-K. This complies with the U-Value requirement for Option 1 for concrete decks in EEBC Table 4-3, but not for Option 2.

A_c: From the Base Case Example above, the roof has a gravel surface, with a Solar Absorptivity Correction Factor (A_c) = 0.85. This does not comply with Option 1. The roof still does *not* comply.

However, if white limestone chips are used, the Ac value would be reduced from 0.85 to 0.50. This is less than the upper limit of 0.70 specified in option 1 of EEBC Table 4-3. Thus, the concrete deck with 25 mm of insulation and surface of white limestone chips *does comply* with Option 1, and thus with the roof prescriptive criteria.

Example 3 - 50 mm of Insulation: In this example, 25 mm more of rigid insulation has been added to 25 mm of insulation of the previous example, for a total of 50 mm of insulation. Now, the roof construction is a 150 mm reinforced concrete slab with 25 mm average sand/cement screed, 50 mm rigid insulation, waterproofed with 2 layers of felt, and protected with a gravel surface.

Table D-11:
R-Values and U-values for Typical Roof Constructions

Construction Element		Uninsulated	25 mm Insulation	50 mm Insulation	D/Tee Flange	D/Tee Webb
Outside air film		0.044	0.044	0.044	0.044	0.044
Gravel or white stone chips		0.009	0.009	0.009	0.009	0.009
2 layers felt		0.049	0.049	0.049	0.049	0.049
No insulation		0.000	-	-	-	-
25 mm rigid insulation		-	0.588	-	-	-
50 mm rigid insulation		-	-	1.176	1.176	1.176
12 mm avg. screed		-	-	-	0.018	0.018
25 mm avg. screed		0.035	0.035	0.035	-	-
150 mm reinforced concrete		0.088	0.088	0.088	-	-
D/Tee flange, 50 mm		-	-	-	0.029	-
D/Tee webb, 355 mm		-	-	-	-	0.203
Inside air film		0.121	0.121	0.121	0.121	0.121
Total R (sum of items)	(sq.m.-K)/W	0.347	0.935	1.522	1.446	1.620
U-Value (1/R-Value)	W/sq.m.-K	**2.884**	**1.070**	**0.657**	**0.692**	**0.617**

U-Value: From Table D-11, the U-Value of this typical concrete deck with 50 mm of insulation roof is 0.657 W/ m^2-K. This complies with the U-Value requirement for *both* Options 1 and 2 for concrete decks in EEBC Table 4-3.

A_c: Since the U-Value complies with option 2, *any* solar absorptivity value is acceptable. To comply with option 1, A_c value must be ≤ 0.7. Thus, use of the white limestone chips would permit this example to comply with Option 1 as well.

Example 4 - Daylighting Credits for Skylights: This example uses the 150 mm concrete deck of the previous example, with 50 mm of rigid insulation and white limestone chips. That solution complied with both prescriptive Options 1 and 2 in EEBC Table 4-3.

This fourth example includes, for Kingston (climate zone A), skylights covering 5.1% of the roof area in skylights. There are 28 skylights, each 0.6 m x 1.2 m, for a total of 20.8 m^2. The floor to ceiling height is 3.66 m. Automatic daylighting dimming controls are to be installed for all fluorescent fixtures within 5 m of the center of the skylight in each direction. The average installed lighting power density on the second floor of the building is 17.2 W/m^2, the design light level is 500 lux. The Visible Light Transmittance of the skylights is VLT< 0.50.

Table D-12: Excerpt from EEBC-94 Table 4-4

Table 4-4: Maximum Percent Skylight Area

Climate Zone	VLT Level	Light Level (lux)	Range of Lighting Power Density (W/m^2) <10.8	10.8-16.1	17.2-21.5	>21.5
			...			
A		300	3.3	4.2	5.1	6.0
&	0.50	500	3.6	4.8	6.0	7.2
B		700	4.2	6.0	7.8	9.6
			...			

In Table D-12, since the daylight area using automatic controls is greater than the minimum area specified in EEBC 4.7.2 (2), the daylighting credits listed in EEBC Table 4-4 may be used. Since the VLT < 0.50, the second section of the table should be used. Since the design light level is 500 lux, the middle row of this section should be used. Since the installed lighting power density is 17.2 W/m^2, the third column should be used.

Thus, 6% is the maximum percent skylight area that can be used, and receive the daylighting credit. Since the 5.1% skylight area to be installed is less than the 6% allowed, this roof example, complies with the Roof Prescriptive Criteria, including the daylighting credit of EEBC 4.7.2.

5 System Performance Criteria

5.1 Introduction

This section discusses the separate system performance methodologies for walls and for roofs. The performance criteria are specified as separate Overall Thermal Transmittance Values for walls ($OTTV_W$) and for roof ($OTTV_R$) While the procedures are very similar for walls and roof, the discussions are presented separately. Each discussion has the same elements:

5.2 Wall Overall Thermal Transmittance Value ($OTTV_W$)

For most cases, the wall prescriptive criteria, covered in the previous section are more stringent than the system performance criteria. The reason is that each set of prescriptive criteria covers a range for each of several variables, and the values are set for the most difficult part of the range - the upper bound. The system performance compliance method provides the user with much more flexibility than the prescriptive methods. To demonstrate this, the same example that was used to demonstrate the use of the prescriptive criteria will be used below to also demonstrate how to achieve compliance using the system performance criteria.

5.2.1 Requirement: The Overall Thermal Transmittance Value ($OTTV_W$) for the exterior walls of buildings shall not exceed the following values for each square metre of wall surface area:

a) 67.7 W/m^2 for large office buildings, with gross conditioned floor area equal to or greater than 4,000 m^2.

b) 61.7 W/m^2 for smaller office buildings, with gross conditioned floor area less than 4,000 m^2.

c) 55.1 W/m^2 for all other buildings.

In general, walls of large office buildings contain more glazed area than walls of small office buildings, which in turn contain more glazed area than walls of other building types (from surveys conducted in the U.S.). Since it is easier to reduce thermal transmittance through opaque walls than through glazed areas, the EEBC-94 wall $OTTV_W$ criteria have been set accordingly.

5.2.2 $OTTV_W$ Compliance Process: Computing the $OTTV_W$ for the external walls of a building is a 2 step process that uses EEBC equations (4-1) and (4-2). First, EEBC equation (4-1) is used to determine the amount of heat gain per m^2 for *each* wall orientation separately. Second, EEBC equation (4-2) is used to determine the overall $OTTV_w$ value for all walls of the building together, calculated as the weighted average of the heat gain per square metre ($OTTV_i$) for all walls of the building.

A microcomputer software spreadsheet template (EEBC-ENV) is provided (on a diskette attached to these guidelines) that performs the 2 step calculation. Figure D-7 shows the input-output screen for the spreadsheet, with all the input areas in italics. The spreadsheet may be used on microcomputers to assist in examining options for compliance with the $OTTV_w$ requirement specified in Section 5.2.1. Versions of the spreadsheet

Figure D-7: Spreadsheet Screen -- Base Case Building

ENVELOPE SYSTEM PERFORMANCE COMPLIANCE SPREADSHEET (EEBC-ENV)

GENERAL	Bldg Name	*Small Office*	Option No.	*BC*		<--Perim. DL credit (Yes?)
	Climate Zone	*K*	<---Input Kingston, Montego, or Mandeville			<--Skylight (Ltg W/sq.m.?)
	Building Type	*SO*	<---Input LO (lge ofc), SO (sml ofc), O (other)			<--Skylight (Ltg lux level?)
	Metric?	*Y*	<---If using Metric units, enter "Yes".			<--Skylight (VLT value?)

September 1994 Version		N	NE	E	SE	S	SW	W	NW	Tot-Avg	ROOF
Tot. Area, Wall (or Roof)	(Sq m.)	*0*	*123*	*0*	*159*	*0*	*120*	*0*	*159*	561	*404*
WINDOWS/SKYLIGHTS		**Single pane, tint, no venetian blinds**					**Average WWR or SRR --->**			**0.27**	**0.00**
Area, Wind. (or Sky.)	(Sq m.)	*0*	*20*	*0*	*68*	*0*	*22*	*0*	*39*	149	*0*
Shading Coeff	(SC x)	*0.00*	*0.73*	*0.00*	*0.73*	*0.00*	*0.73*	*0.00*	*0.73*	0.73	*0*
Ext. Shading	(factor)	*0.00*	*0.30*	*0.00*	*0.90*	*0.00*	*0.75*	*0.00*	*0.90*	0.80	*0*
U-Value	(W/m sq-K)	*0.000*	*5.910*	*0.000*	*5.910*	*0.000*	*5.910*	*0.000*	*5.910*	5.91	*0*
OPAQUE WALLS/ROOFS		**Concrete block, 200 mm, 2nd cavity empty, 12 mm rendering**									
U-value	(W/m sq-K)	*0.000*	*2.798*	*0.000*	*2.798*	*0.000*	*2.798*	*0.000*	*2.798*	2.80	*2.613*
Weight	(kg/sq m.)	*0*	*244*	*0*	*244*	*0*	*244*	*0*	*244*	244	*370.88*
Absorpt. Coeff.	(Ac)	*0*	*0.7*	*0*	*0.7*	*0*	*0.7*	*0*	*0.7*	0.70	*0.79*
Area Daylit	(percent)	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	0	
Window Solar (or Sky.)	(W/m sq.)	**0.0**	**29.7**	**0.0**	**46.5**	**0.0**	**30.1**	**0.0**	**26.4**	**33.6**	**0.0**
Window Cond. (or Sky.)	(W/m sq.)	**0.0**	**9.1**	**0.0**	**23.9**	**0.0**	**10.2**	**0.0**	**13.7**	**14.8**	**0.0**
Op.Wall Solar (or Sky.)	(W/m sq.)	**0.0**	**10.0**	**0.0**	**8.0**	**0.0**	**13.9**	**0.0**	**10.5**	**10.4**	**41.5**
Op.Wall Cond. (or Roof)	(W/m sq.)	**0.0**	**22.1**	**0.0**	**15.1**	**0.0**	**21.6**	**0.0**	**19.9**	**19.4**	**24.7**
OTTV Compliance	(W/m sq.)	**0.00**	**70.87**	**0.00**	**93.55**	**0.00**	**75.78**	**0.00**	**70.52**	**78.25**	**66.19**
OTTV Requirements	(W/m sq.)									**61.70**	**20.00**
										Fails!	*Fails!*

template have been provided for 2 spreadsheet programs, Excel 4 (TM) under Windows 3.1 (TM), and Lotus 123 (TM). While the spreadsheet can be used to calculate compliance using either metric and imperial units, all examples in this appendix are in metric units. Also, all examples in this appendix have used the Excel 4 (TM) version.

In Figure D-7, results of intermediate calculations are shown in shaded sections of the spreadsheet screen (toward the bottom). Also, component totals for each orientation have been converted to W/m^2 units to facilitate the analysis of results. The shaded the column "**Tot-Avg**" contains the sums of total wall areas and window areas for all orientations, the calculation of WWR, and the weighted averages of all other input items.

For presentation consistency, Figure D-7 uses the same Base Case wall inputs for the example building that were used in the prescriptive compliance section (Figures D-4, D-5, and D-6, and data in Section 4.1.4). The example roof shown in this figure is the uninsulated case, from Prescriptive section 4.2.3 above, example 1.

As indicated in the lower right-hand corner of Figure D-7, both the walls and roof *fail* to meet the System Performance criteria. The wall $OTTV_W$ requirement is 61.70 W/m^2. However, the compliance value determined for building's walls is a higher Base Case $OTTV_W$ of 78.25 W/m^2. The roof $OTTV_R$ requirement is 20.00 W/m2. However, the compliance value determined for the building's uninsulated roof is a *significantly* higher Base Case $OTTV_R$ value of 66.19 W/m^2.

The process of achieving compliance using the computer spreadsheet template involves changing the inputs to reflect modifications to the building's walls and roof so that the wall $OTTV_W$ and roof $OTTV_R$ compliance values obtained are both less than the respective criteria. The spreadsheet template uses EEBC eq. (4-1) to calculate an $OTTV_i$ for each of up to 8 possible orientations, N, NE, E, SE, S, SW, W, and NW. The $OTTV_i$ calculated for each orientation is contained at the bottom of the spreadsheet on the line "**OTTV Compliance.**" The spreadsheet template then uses EEBC eq. (4-2) to calculate a weighted average $OTTV_W$; the result is displayed on the line "**OTTV Compliance**" in the column "**Tot-Avg.**" For the roof, the spreadsheet template uses EEBC eq. (4-4) to calculate an $OTTV_R$ that includes both opaque roof and any skylights. A detailed description of the use of the spreadsheet is contained below in Section 5.4.

5.2.3 Calculating the $OTTV_i$ for an Individual Wall:

The Overall Thermal Transfer Value ($OTTV_i$) for each exterior wall section that has a different orientation is determined by EEBC eq. (4-1). The first two terms of the equation, repeated below, are for the opaque wall (first solar, second conduction) and the last two terms are for the fenestration (third is solar, and fourth is conduction).

$$\begin{aligned} OTTV_i = & (TD_{eq}-DT) \times CF \times Ac \times Uw \times (1-WWR)) \\ & + DT \times U_w \times (1-WWR) \\ & + (SF \times CF \times SC \times WWR) \\ & + (DT \times U_f \times WWR) \end{aligned}$$

EEBC Eq (4-1)

Where

$OTTV_i$ = Overall thermal transmittance value for the specific wall orientation under consideration in W/m^2.

A_c = Solar absorptance coefficient for the surface of the opaque wall. Typical values for A_c are given in Table D-4 and are related to the solar absorptivity of the opaque surface.

U_w = Thermal transmittance of the opaque wall, W/m^2-K. Typical values are presented in Table D-5. If a calculation of U_w is desired, the calculation procedure is shown below in Section 5.3.

WWR = Window-to-gross exterior wall area ratio for the wall under consideration. Example calculations are presented in this appendix in sections 4.1.1 and 6.1.1.

TD_{eq} = Equivalent door-out-door temperature difference, in °C, which incorporates the effects of solar gains into the opaque wall under consideration at peak design conditions. Typical values for Jamaica are given in Table D-13.

DT = Temperature difference, in °C, between indoor temperature (using 24.4 °C) and outdoor temperature. Typical values for Jamaica are given in Table D-13.

U_f = Thermal transmittance of the glazing in W/m^2·K. U-Values for commonly used glass is given in Table D-5. These values are extracted from the ASHRAE Handbook of Fundamentals 1985, Chapter 27 (Table 13). The 1989 edition of the ASHRAE Handbook of fundamentals uses a complex procedure which takes into consider-

Table D-13: Temperature Differences (DT) and TDeqs for Walls and Roofs

		Zone A	Zone B	Zone C
		DT (deg C)		
Temperature differences between indoor and outdoor air		9.4	7.8	6.1
Weights of Wall Construction (kg/sq.m.)		TDeq (deg C)		
0 – 122		24.4	23.3	22.2
123 – 195		20.6	19.4	18.3
196 – 342		16.7	15.6	14.4
343 plus		12.8	11.7	10.6
Weights of Roof Construction (kg/sq.m.)	Roof U-Value (W/m2-K)	TDeq (deg C)		
0 - 29	0.00 - 0.57	19.4	17.8	16.1
	0.58 - 2.50	24.6	22.9	21.3
	2.51 plus	29.8	28.2	26.5
30 - 337	0.00 - 0.34	27.8	26.1	24.4
	0.35 - 1.19	33.3	31.7	30
	1.20 plus	38.9	37.2	35.6
338 plus	0.00 - 0.34	30.6	28.9	27.2
	0.35 - 0.80	34.7	33.1	31.4
	0.81 plus	38.9	37.2	35.6

Table D-14: Solar Correction Factors (CF) for 8 Orientations

	N	NE	E	SE	S	SW	W	NW
CF	0.58	0.84	0.96	0.99	1.09	1.2	1.36	0.98

ation values at the centre of glass, edge of glass, frames and mullions. In the Jamaican climate these thermal transmittance refinements have a only minor effect on fenestration performance; thus, the added complexity has been avoided here.

SC_x = Shading coefficient of the fenestration system. Typical values for SC_x are given in Table D-5; these have been extracted from Chapter 27 of the 1985 ASHRAE Handbook (Tables 35, 36, and 39). Manufacturer's data may also be used.

SF = Average hourly value of the solar energy incident on the windows. The value of SF is 372 W/ m^2. The solar factor for windows or portions of windows which are not exposed to direct sunlight between the hours of 8:00 a.m. and 5:00 p.m. solar time, on April 21 through October 21 because of orientation or fixed exterior shading devices, (such as roof overhangs) shall be considered to be 40 for the purpose of inclusion in Equation 4-1. When shading device does not shade the entire window only the shaded portion shall use a SF of 40.

CF = Correction factor to account for the variation in the available solar, due to the orientation of the wall, for the wall section under consideration. Values for CF are given in Table D-14.

5.2.4 Calculating the Overall $OTTV_W$ for the Building: The Overall Thermal Transmittance Value ($OTTV_W$) for the total exterior gross wall area of the building is a weighted average of the $OTTV_i$ computed in section for all of the individual walls. The OTTV is a weighted average of the $OTTV_i$ for each wall section. The OTTVw shall be determined using Equation (4-2), in EEBC-94 Section 4.6.1.3.

$$OTTV = (Ao_1 \times OTTV_1 + Ao_2 \times OTTV_2 + ... + Ao_i \times OTTV_i) / (Ao_1 + Ao_2 + ...Ao_i)$$

EEBC Eq (4-2)

Where

AO_i = Gross wall area for the exterior wall section in m^2. The gross wall area includes all of the opaque wall surface area and the window surface area for the wall section considered.

$OTTV_i$ = Overall thermal transfer value for the wall section, as calculated from EEBC Eq. 4-1.

5.2.5 Daylighting Credit: A given area of glazing usually allows more heat gain to the interior space than an equivalent area of insulated wall. Thus, in daylighting applications, if larger glass areas are used, the higher window-to-wall ratio (WWR) would normally cause a greater level of cooling energy to be used in the space. However, lighting energy savings due to daylighting can be greater than cooling energy penalties from additional glazed surface area may be reduced when the building envelope is carefully designed for daylighting.

A general rule-of-thumb for perimeter zones is that an effective aperture (EA) greater than 0.1 will provide adequate daylight illumination for the perimeter area within 4.6 m of the external wall (see Figure E-1 in Appendix E). Likewise, an EA greater than 0.2 might produce excessive heat gains without additional daylighting benefit, and daylighting/ thermal gain tradeoffs should be carefully examined for EA>0.2. (For purposes here EA is defined as SC x VLT).

The transparent portions of the building envelope should be designed to prevent solar radiant gain above that necessary for effective daylighting. To ensure that the daylighting is effectively used, automatic daylighting controls shall be used to reduce the amount of electric lighting when sufficient daylighting is available.

If automatic daylight controls are provided for those portions of the electric lighting system within 4.6 m of an exterior wall, the $OTTV_i$, calculated using EEBC Eq. (4-1), and the daylighting credit is not claimed in the lighting section for that portion of the wall may be reduced by 30 %. If the daylight credit is claimed in the lighting section, then the $OTTV_i$ maybe reduced by 7.5%. The computer spreadsheet calculates this trade-off. The reduced $OTTV_i$ value shall then be used in the evaluation of EEBC Eq. (4-2).

If the automatic daylight control credit is taken, then the visible transmittance of the fenestration system used for that exterior wall shall not be less than 0.25.

5.3 Roof Overall Thermal Transmittance Value ($OTTV_r$)

5.3.1 Roof $OTTV_r$ Requirements: The Overall Thermal Transfer Value ($OTTV_r$) for the gross area of the roof of a building shall not exceed 20 W/m^2.

5.3.2 Compliance: For a roof without skylights, compliance with the Roof Overall Thermal Transfer Value ($OTTV_r$) shall be determined by EEBC Eq. 4-3. For a roof with skylights, EEBC Eq.4-4 shall be used.

$$OTTV_r = Ac \times U_r \times (TDeq_r - DT) + U_r \times DT$$

EEBC Eq (4-3)

$$OTTV_r = Ac \times U_r \times (TDeq_r - DT) \times (1-SRR) + U_r \times DT \times (1-SRR) + 138 \times SCs \times SRR + U_s \times DT \times SRR$$

EEBC Eq (4-4)

Where

$OTTV_r$ = Overall thermal transmittance value for the roof assembly in W/m^2.

Ac = Solar absorptance coefficient of the opaque portion of the roof. Typical values for Ac are given in Table D-4.

U_r = Thermal transmittance of the roof assembly, including both above and below deck insulation, in W/m^2-K. Typical values for roof constructions are listed in various ASHRAE documents (e.g., the Hand Book of Fundamentals (1985, 1989, etc.), the Cooling and Heating Load Calculation Manual (1979, 1992) or in manufacturer's literature. Typical values are given in Table D-11, and calculation procedures are given in Section 5.4.4.1.

TDeqr = Equivalent indoor-outdoor temperature difference, in °C, which incorporates the effects of solar gains. Typical values are listed in Table D-13.

SRR = Skylight to roof ratio

SF = Solar factor, for horizontal surfaces, the average hourly value of the solar energy incident on the skylights. The value of SF is 435 W/m^2.

5.4 Using the Computer Spreadsheet to Achieve System Performance Compliance

The same building used to illustrate the application of the prescriptive criteria is used here. Figures D-4, D-5, and D-6 show the building elevations and floor plan, and the Base Case data from the prescriptive compliance example (see 4.1.4.1, 4.1.4.2, and 4.2.3.1) are applied to the System Performance method in Figure D-7. As Figure D-7 shows, the Base Case example wall and roof do not comply with the System Performance Criteria for Small Office Buildings. However, simply changing the glass type and adding venetian blinds will permit compliance with the wall criteria, while adding roof insulation will permit compliance with the roof criteria. These modifications that result in compliance are shown in Figure D-8.

The remainder of this section describes in sequence each of the inputs to the spreadsheet for the example data used to achieve compliance.

Figure D-8: Spreadsheet Screen -- Reflective Glass & Venetian Blinds Comply

ENVELOPE SYSTEM PERFORMANCE COMPLIANCE SPREADSHEET (EEBC-ENV)

GENERAL	Bldg Name	*Small Office*	Option No.	*1*		<--Perim. DL credit (Yes?)
	Climate Zone	*K*	<---Input Kingston, Montego, or Mandeville			<--Skylight (Ltg W/sq.m.?)
	Building Type	*SO*	<---Input LO (lge ofc), SO (sml ofc), O (other)			<--Skylight (Ltg lux level?)
	Metric?	*Y*	<---If using Metric units, enter "Yes".			<--Skylight (VLT value?)

September 1994 Version		N	NE	E	SE	S	SW	W	NW	Tot-Avg	ROOF
Tot. Area, Wall (or Roof)	(Sq m.)	*0*	*123*	*0*	*159*	*0*	*120*	*0*	*159*	561	*404*
WINDOWS/SKYLIGHTS		**Single pane, refl (SCg=0.50), med. ven. blinds**						**Avg. WWR --->**		**0.27**	**0.00**
Area, Wind. (or Sky.)	(Sq m.)	*0*	*20*	*0*	*68*	*0*	*22*	*0*	*39*	149	*0*
Shading Coeff	(SCx)	*0.00*	*0.42*	*0.00*	*0.42*	*0.00*	*0.42*	*0.00*	*0.42*	0.42	*0*
Ext. Shading	(factor)	*0.00*	*0.30*	*0.00*	*0.90*	*0.00*	*0.75*	*0.00*	*0.90*	0.80	*0*
U-Value	(W/m sq.-K)	*0.000*	*4.600*	*0.000*	*4.600*	*0.000*	*4.600*	*0.000*	*4.600*	4.60	*0*
OPAQUE WALLS/ROOFS		**Concrete block, 200 mm, 2nd cavity empty**									
U-value	(W/m sq.-K)	*0.000*	*2.798*	*0.000*	*2.798*	*0.000*	*2.798*	*0.000*	*2.798*	2.80	*1.070*
Weight	(kg/sq m.)	*0*	*244*	*0*	*244*	*0*	*244*	*0*	*244*	244	*371*
Absorpt. Coeff.	(Ac)	*0*	*0.7*	*0*	*0.7*	*0*	*0.7*	*0*	*0.7*	0.70	*0.7*
Area Daylighted	(percent)	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	0	
Window Solar (or Sky.)	(W/m sq.)	**0.0**	**17.1**	**0.0**	**26.8**	**0.0**	**17.3**	**0.0**	**15.2**	**19.3**	**0.0**
Window Cond. (or Sky.)	(W/m sq.)	**0.0**	**7.1**	**0.0**	**18.6**	**0.0**	**8.0**	**0.0**	**10.7**	**11.5**	**0.0**
Op.Wall Solar (or Sky.)	(W/m sq.)	**0.0**	**10.0**	**0.0**	**8.0**	**0.0**	**13.9**	**0.0**	**10.5**	**10.4**	**9.3**
Op.Wall Cond. (or Roof)	(W/m sq.)	**0.0**	**22.1**	**0.0**	**15.1**	**0.0**	**21.6**	**0.0**	**19.9**	**19.4**	**10.1**
OTTV Compliance	(W/m sq.)	**0.00**	**56.24**	**0.00**	**68.49**	**0.00**	**60.73**	**0.00**	**56.26**	**60.68**	**19.39**
OTTV Requirements	(W/m sq.)									**61.70**	**20.00**
										Passes!	***Passes!***

Changes to input data

Walls and Roof now comply

5.4.1 General Inputs

5.4.1.1 Bldg Name: Enter a short name to identify the building project. This can be helpful for future identification of printouts of options.

5.4.1.2 Option No: Enter a unique number or letter to identify each compliance option that is being considered for the project. This can be helpful for future reference in identifying multiple compliance options considered for the same project.

5.4.1.3 Climate Zone: Enter the appropriate city for one of three climate zones, ***Kingston*** for zone A, ***Montego*** for zone B, and ***Mandeville*** for Zone C (see Figure D-3). Only the first 2 letters of each city name are required. This choice determines which DT and TD_{eq} values to use.

5.4.1.4 Building Type: Enter the code for one of three choices of building type, ***LO*** for large office, ***SO*** for small office and ***O*** for other buildings. This choice determines which building-type-dependent $OTTV_W$ requirement to apply.

5.4.1.5 Metric?: Enter ***Y*** or ***Yes*** for metric units, or ***N, No,*** or blank for inch-pound units. Note: this input changes the calculation units used by the spreadsheet. However, the unit values of the inputs entered by the user must be changed manually (e.g., an input fenestration U-value of 4.6 in metric units must be multiplied by .176 to obtain the proper U-value of 0.81 in I-P units).

5.4.1.4 Daylighting-related entries: inputs are required for the following four items only if automatic daylighting controls are being used.

a) **Perim. DL Credit (Yes?):** This entry is blank ***except*** if two conditions apply: 1) if automatic controls for perimeter daylighting are being used, and also, 2) if the Lighting Power Control Credit is being claimed (EEBC-94 section 5.4.3) to permit an increase in the installed lighting power allowance. If both conditions apply, then enter ***Y*** or ***Yes***; otherwise, leave blank.

b) **Skylight (Ltg W/sq.m.?):** This entry is blank ***except*** if skylights are being used in the roof, and if credit is being claimed for the use of automatic daylighting controls for lights under the skylighted areas. If these conditions apply, then enter here the W/m^2 in the applicable areas under the skylights. For example, ***17.2*** W/m^2 might be entered for office spaces.

c) **Skylight (Ltg lux level?):** This entry is blank ***except*** if skylights are being used in the roof, and if credit is being claimed for the use of automatic daylighting controls for lights under the skylighted areas. If the above conditions apply, then enter here the most applicable choice from three possible lux levels, ***300***, ***500***, or ***700*** lux (see EEBC-94 Table 4-4). For example, ***500*** lux might be entered for office spaces.

d) **Skylight (VLT value?):** This entry is blank ***except*** if skylights are being used in the roof, and if credit is being claimed for the use of automatic daylighting controls for lights under the skylighted areas. If these conditions apply, then enter here the most applicable choice from two possible VLT levels, ***0.75*** (for 0.75 to 0.50), or ***0.50*** for 0.50 or less) (see EEBC-94 Table 4-4). For example, using a rule-of-thumb that VLT = 2/3 SC for grey and bronze glazings, if SC=0.6, then VLT=0.4, and ***0.50*** might be entered, for a VLT of 0.50 or less.

5.4.2 Tot. Area, Wall (or Roof)

Enter the m^2 of total wall (or roof) area, including the area of both the opaque surfaces and glazed surfaces. (If I-P units are used, then enter the area in ft^2.) Note: since the spreadsheet calculates compliance in W/m^2, the absolute areas of walls and roof are not as important as the relative areas among the various surfaces.

5.4.3 Windows/Skylights

5.4.3.1 Area, Wind. (or Sky.): For each building wall orientation, enter the m^2 of any window area, including the area of the glass, sash and frames. This also includes any glazed doors and clerestory windows that meet the wall criteria. For the roof, enter any skylight area. (If I-P units are used, then enter the area in ft^2.)

The spreadsheet will calculate the weighted average window wall ratio (WWR) for the total building. In the example, this is the average of the 4 orientations and is given by the following equation:

WWR Building = WR1+WWR2+WWR3+WWR4)/4

All dimensions should be clearly noted on the drawing being used or other "take off" sheet, for checking or future reference is needed. This exercise can be time consuming, particularly in complex buildings. A spreadsheet, in which the dimensions of the various constructions in the building envelope are calculated and the Window Wall Ratio Summary recorded, could be extremely useful, particularly if the process will be repeated.

The wall and fenestration areas for the stairwell building and ground are computed and added and the percentage fenestration calculated and recorded for each orientation. For the example building shown in Figures D-4, D-5, and D-6, the WWR works out to be 0.266 (see the column "**Tot-Avg.**" in Figures D-7 or D-8). That is equivalent to the windows being 26.6% of the total wall area.

Skylight Area: If the roof has skylights, then enter the area of the skylights, in m^2, in the rightmost column of the spreadsheet, entitled "**Roof.**" The SRR is calculated by the spreadsheet in the same way as the WWR for the windows and the opaque wall. The example building (see Figure D-5) has about 12 m^2 of skylights, producing a ratio of the area of skylights to gross area of roof gives a SRR of 0.03 as follows.

The roof area	=	404 m^2
Skylight area	=	12 m^2
SRR	=	12 / 404
	=	0.03

A SRR of 0.03 is equivalent to a skylight percentage of 3%. A compliance example is provided below in Section 5.5.5.

5.4.3.2 Shading Coefficient (SCx): For each applicable orientation, enter the shading coefficient of the fenestration, including the glass and associated shading devices. The SCx can consist of the product of 3 types of shading effects:

$$SC_x = SC_g \times SC_{int} \times SC_{ext}$$

SC_g = the shading coefficient of the glazing, that is typically given in the manufacturers' literature (typical examples are provided in Table D-5).

SC_{int} = Internal shading devices, such as venetian blinds or drapes (Table D-5 also provides examples of the impact of internal shading devices upon a range of glazing types).

SC_{ext} = External shading devices, such as external louvered sun screens.

For example, a single pane reflective glass with SC_g = 0.50 with a medium venetian blind (with an effective SC_{int} = 0.84) would together produce:

$$\begin{aligned} SC_x &= SC_g \times SC_{int} \\ &= 0.50 \times 0.84 \\ &= 0.42 \end{aligned}$$

Likewise, the same single pane reflective glass with SC_g = 0.50 with an external unpainted aluminum louvered sunscreen (0.85 w/s ratio, and profile angle of 20^0, for an SC_{ext} = 0.50, per the ASHRAE Handbook of Fundamentals, Ch. 27) would together produce:

$$\begin{aligned} SC_x &= SC_g \times SC_{ext} \\ &= 0.50 \times 0.50 \\ &= 0.25 \end{aligned}$$

Also, external overhangs and fins may be considered separately in the EEBC-ENV spreadsheet, as indicated below.

5.4.3.3 External Shading: For each applicable orientation, enter the annual (April to October) average ratio of the window area that is shaded from the direct rays of the sun. The primary devices that would provide such external shading are overhangs and fins; however, objects such as other buildings or trees could also provide external shading. The percent of window externally shaded is determined on the basis of the architect's judgment at this time. A computer program is being written which will accurately calculate the amount of external shading on the window from 8:00 a.m. to 5:00 p.m. for the relevant seasons. The program will he issued as an addendum to the EEBC-94 code as it is completed and tested.

For the example building, the estimated ratio of window area that is externally shaded from the sun's direct rays are as follows:

NE 0.30 (30% of glass)

SE	0.90	(90% of glass)
SW	0.75	(75% of glass)
NW	0.90	(90% of glass)

This input data is shown on the "External Shading" line in Figures D-7 and D-8.

5.4.3.4 U-Value (Fenestration): For each applicable orientation, enter the U-value of the fenestration. Using the centre-of-glass U-value is considered sufficient, although composite U-values for centre-of-glass, edge-of-glass, and frame may also be used. Table D-5 provides typical centre-of-glass U-values for cases with, and without, internal shading devices.

U-Values may also be obtained from the manufacturers literature. For the example building, the single pane glass selected is a 6 mm single pane glass, with a U-value of 5.91 W/m^2-K without internal shading device and 4.60 W/m^2-K with an internal shading device present.

5.4.4 Opaque Walls/ Roofs

5.4.4.1 U-Value (Opaque Walls): The U-Value for the opaque wall is the weighted average of the areas of the various wall constructions. Ideally these should also be calculated separately and added to give the gross wall area. In the case of the example the gross wall area is 561 m^2 (to check, add the areas shown on the WWR summary sheet and also on the U-Value calculation sheet).

The types of wall construction are reinforced concrete block and reinforced concrete. The U-Values may be calculated by determining from Table D-3 the resistances (R) of all the materials in the construction, adding them and taking the reciprocal of R to give the U-Value. The U-Value for the whole wall is the weighted average of the U-Values for the various constructions of the opaque portion of the wall, but not including the fenestration.

U-Values for common types of wall constructions used in Jamaica are given in Table D-1, and R-values and calculations for typical wall materials used are listed in Tables D-2 and D-3. From Table D-3, the U-value for the example 150 mm concrete block wall is calculated as follows:

$$
\begin{aligned}
R_{tot} &= Rl + R2 + R3 + R4 + R5 \\
&= 0.044 + 0.018 + 0.268 + 0.018 + 0.121 \\
\text{U-Value} &= 1/R_{tot} \\
&= 1/0.468 \\
&= 2.135 \text{ W/m}^2\text{-K}
\end{aligned}
$$

From Table D-3, the U-value for a reinforced concrete frame construction is as follows:

$$
\begin{aligned}
R_{tot} &= Rl + R2 + R3 + R4 + R5 \\
&= 0.044 + 0.018 + 0.084 + 0.018 + 0.121 \\
\text{U-Value} &= 1/R_{tot} \\
&= 1/0.285 \\
&= 3.507 \text{ W/m}^2\text{-K}
\end{aligned}
$$

The areas of the respective wall components are:

Concrete block wall area	= 319.8 m^2
Reinforced concrete wall area	= 91.6 m^2

Thus, the weighted average U-Value for the wall consisting of the two components is:

$$
\begin{aligned}
&= ((319.4 \times 2.135) + (91.6 \times 3.507)) \\
&\quad / (319.4 + 91.6) \\
&= 2.44 \text{ W/m}^2\text{-K}
\end{aligned}
$$

Roof U-Value: The U-Value for the roof is the weighted average of the U-values for areas of the various roof constructions. Ideally these should also be calculated separately and added to give the gross roof area. In the case of the example the gross roof area is 404 m^2. For the Base Case example building, there is only one type of roof construction, a 150 mm reinforced concrete slab with 25 mm average sand/cement screed, and waterproofed with 2 layers of felt and protected with gravel.

The U-Values are calculated by determining, from tables the resistances (R) of all the materials in the construction, adding them and taking the reciprocal of R to give the U-Value. The U-Value for the roof is the weighted average of the U-Value for the various constructions but not including the fenestration.

R-values and U-values for common types of roof constructions used in Jamaica are given in Table D-11. For example, the U-value for the Base Case uninsulated roof is calculated as follows:

$$R_{tot} = Rl + R2 + R3 + R4 + R5 + R6$$
$$= 0.044 + 0.009 + 0.049 + 0.035 + 0.088 + 0.121$$
$$\text{U-Value} = 1/R_{tot} = 0.347 = 2.884 \text{ W/m}^2\text{-K}$$

Likewise, the U-value for the same roof with 50 mm of insulation added is calculated as follows:

$$R_{tot} = Rl + R2 + R3 + R4 + R5 + R6 + R7$$
$$= 0.044 + 0.009 + 0.049 + 1.176 + 0.035 + 0.088 + 0.121$$
$$\text{U-Value} = 1/R_{tot} = 1.522 = 0.657 \text{ W/m}^2\text{-K}$$

5.4.4.2 Weight: Enter the weight of each square metre of external surface of the opaque wall, in kg/m^2. The weight of a square metre of 150 mm thick concrete block wall is about 195 kg/m^2, while the weight for a 150 mm thick concrete block wall is about 244 kg/m^2.

5.4.4.3 Absorptance Coefficient (A_c): Enter the absorptance coefficient for the type and colour of wall or roof surface. Table D-4 contains A_c values for several typical coloured surfaces.

5.4.4 Area Daylighted

If automatic daylighting controls are used to reduce the electric energy used for lighting within the 4.6 m of the perimeter zones next to the external walls, enter the percent of the area for each orientation that is controlled by the automatic controls. For example, if all of the northeast perimeter zone is controlled for daylighting, then enter ***100*** under the **NE** column, whereas if only 75 percent of the southeast perimeter zone is controlled for daylighting, then enter ***75*** under the **SE** column.

For areas under skylights, enter the percent of the potentially daylighted area under the skylights that is controlled by automatic daylighting control devices. (Several examples for perimeter and skylight situations are provided in Appendix E.)

5.5 Examples of Additional System Performance Trade-offs and Features

An important feature of the System Performance envelope compliance path is the great flexibility possible in making trade-offs among envelope features. Compliance can be achieved in many different ways.

The EEBC-ENV computer spreadsheet enables evaluation of trade-off and options to be done very quickly. Because of this, the envelope spreadsheet can be considered as a very simplified envelope energy design tool.

This section demonstrates several different options for complying with the EEBC-94 envelope System Performance requirements. The Base Case example building, as shown in Figure D-7, is used as the starting point for each of the options.

5.5.1 Using Daylighting within Perimeter Zones:

The base building example, as modified in Figure D-9, is used as the starting point. In the EEBC-ENV computer spreadsheet, credit may be taken for the use of automatic daylighting controls for electric lights within the perimeter zone adjacent to the windows.

Perimeter daylighting. For this example, assume that all electric lighting in 3 of the perimeter zones (100 percent within 4.6 metres of the external wall) is to be controlled with multiple step daylight sensing dimming controls (See EEBC Table 5-2). Due to a constraint in the SE perimeter zone, only 75 percent of the lights in that zone are to be controlled for daylighting.

While these controls will substantially reduce lighting energy use, the lighting system already complies with the EEBC lighting requirements, and no additional credit will be taken within the lighting section for the use of these controls. Thus, the 30% credit can be used for the envelope compliance, per EEBC 4.7.1.

The EEBC-ENV computer spreadsheet calculates the 30% credit if the user inserts the percentage of perimeter lighting for each perimeter zone that is automatically controlled. The user supplies this data in the row entitled "**Area Daylighted** (percent)."

As can be seen in the row entitled "Area Daylighted" Figure D-9, 100% of the electric lights in 3 zones and 75% in the SE zone is designated as automatically controlled for daylighting. This results in a substantial reduction in energy flux from the modified base case. Daylighting is an effective energy efficiency strategy.

Note: in the upper right portion of the EEBC-ENV spreadsheet there is an input box with the following text to its right: "<—Perim. DL credit (Yes?)." This box should be used only if two conditions exist: 1) perimeter daylighting controls are being used; and, 2) credit is being taken for the use of these controls in EEBC 5.4.3 "Lighting Power Control Credits" to allow additional lighting power to be installed. If a "*Yes*" is inserted in this box, the envelope daylighting credit in the EEBC-ENV envelope spreadsheet is set to 7.5% instead of 30%, per EEBC 4.7.1. In the example in Figure D-9, if this entry were input as "*Yes*," the building design would still comply with the envelope requirements, but just barely. In that case, the compliance value would be 61.22 W/m^2, just less than the criteria value of 61.70 W/m^2. (The EEBC-ENV spreadsheet may be used to verify this).

For the roof, 12 m^2 of skylight area has been added in Figure D-9, representing an SRR = 0.03, or about 3% of the roof area in skylights. Acrylic domes are used, with SC = 0.60 and U = 5.2. The roof with skylights added no longer complies with the roof $OTTV_R$ criteria. A solution to this will be sought in the next example.

5.5.3 Combined Use of White Walls and Roof, Daylighting, and Low-E Glazing: This example demonstrates the *combined* impact of using several energy efficiency strategies together. Using the same Base Case building example as before, three sets of changes are made:

a) The walls and roofs are changed from light to white (A_c from 0.70 to 0.50), as per the information in section 5.4.4.3 above;

b) Daylighting controls are used for electric lighting in perimeter areas and under skylights, as in the previous example in Figure D-9; and,

c) Double pane low-emissivity (low-e) glazing is used

Figure D-9: Spreadsheet Screen -- Daylighting & Light Venetian Blinds

ENVELOPE SYSTEM PERFORMANCE COMPLIANCE SPREADSHEET (EEBC-ENV)

GENERAL Bldg Name	*Small Office*	Option No.	*2*		<--Perim. DL credit (Yes?)
Climate Zone	*K*	<---Input Kingston, Montego, or Mandeville			<--Skylight (Ltg W/sq.m.?)
Building Type	*SO*	<---Input LO (lge ofc), SO (sml ofc), O (other)			<--Skylight (Ltg lux level?)
Metric?	*Y*	<---If using Metric units, enter "Yes".			<--Skylight (VLT value?)

September 1994 Version		N	NE	E	SE	S	SW	W	NW	Tot-Avg	ROOF
Tot. Area, Wall (or Roof)	(Sq m.)	*0*	*123*	*0*	*159*	*0*	*120*	*0*	*159*	561	*404*
WINDOWS/SKYLIGHTS		**Single pane, tint, light ven. blinds**				**Average WWR or SRR --->**				**0.27**	**0.03**
Area, Wind. (or Sky.)	(Sq m.)	*0*	*20*	*0*	*68*	*0*	*22*	*0*	*39*	149	*12*
Shading Coeff	(SC x)	*0.00*	*0.53*	*0.00*	*0.53*	*0.00*	*0.53*	*0.00*	*0.53*	0.53	*0.6*
Ext. Shading	(factor)	*0.00*	*0.30*	*0.00*	*0.90*	*0.00*	*0.75*	*0.00*	*0.90*	0.80	*0*
U-Value	(W/m sq-K)	*0.000*	*4.600*	*0.000*	*4.600*	*0.000*	*4.600*	*0.000*	*4.600*	4.60	*5.200*
OPAQUE WALLS/ROOFS		**Concrete block, 200 mm, 2nd cavity empty, 12 mm rendering**									
U-value	(W/m sq-K)	*0.000*	*2.798*	*0.000*	*2.798*	*0.000*	*2.798*	*0.000*	*2.798*	2.80	*1.070*
Weight	(kg/sq m.)	*0*	*244*	*0*	*244*	*0*	*244*	*0*	*244*	244	*370.88*
Absorpt. Coeff.	(Ac)	*0*	*0.7*	*0*	*0.7*	*0*	*0.7*	*0*	*0.7*	0.70	*0.70*
Area Daylighted	(percent)	*0*	*100*	*0*	*75*	*0*	*100*	*0*	*100*	93	
Window Solar (or Sky.)	(W/m sq.)	**0.0**	**21.6**	**0.0**	**33.8**	**0.0**	**21.9**	**0.0**	**19.2**	**24.4**	**7.7**
Window Cond. (or Sky.)	(W/m sq.)	**0.0**	**7.1**	**0.0**	**18.6**	**0.0**	**8.0**	**0.0**	**10.7**	**11.5**	**1.5**
Op.Wall Solar (or Sky.)	(W/m sq.)	**0.0**	**10.0**	**0.0**	**8.0**	**0.0**	**13.9**	**0.0**	**10.5**	**10.4**	**9.0**
Op.Wall Cond. (or Roof)	(W/m sq.)	**0.0**	**22.1**	**0.0**	**15.1**	**0.0**	**21.6**	**0.0**	**19.9**	**19.4**	**9.8**
OTTV Compliance	(W/m sq.)	**0.00**	**42.50**	**0.00**	**58.52**	**0.00**	**45.68**	**0.00**	**42.17**	**47.63**	**28.02**
OTTV Requirements	(W/m sq.)									**61.70**	**20.00**
										Passes!	*Fails!*

New fenestration SC_x *Perimeter daylighting* *Skylights added (3%)*

in place of the single pane tinted glazing with light venetian blinds (SC_g = 0.40, SC_x = 0.30, VLT = 0.50, U = 1.76).

As might be expected, the combined compliance results for the walls are striking. The $OTTV_w$ compliance results for the walls, at 32.54 W/m^2, are only 54% of the thermal transmittance results of the $OTTV_w$ criteria, at 61.70 W/m^2. These new compliance results are only 42% of the thermal transmittance of the original Base Case.

The wall results in Figure D-10 indicate that it is possible to design buildings with $OTTV_w$ results that are *far* better than the EEBC requirements. The roof results show that adding daylighting controls can bring the building's roof into compliance. An alternative measure would have been to increase roof rigid insulation levels from 25 mm to 50 mm. Doubling the level of roof insulation would have produced an $OTTV_R$ compliance value of 19.77 W/m^2. The choice of alternatives will depend upon design objectives and costs.

The wall and roof energy efficiency measures just cited can produce buildings that are highly energy efficient. Such strategies can be used in combination to permit buildings to use additional amounts of glazing area. This can be seen in the next example.

5.5.4 Combined Compliance Strategies for a Building with 50% Window Glass and 15% Skylights: This example demonstrates that it is possible to comply with the $OTTV_w$ and $OTTV_r$, requirements and still design buildings with substantial glazed areas for windows and skylights. In this example, the modified base building is used as a starting point, but the

Figure D-10: Spreadsheet Screen -- Low-e Glass, Daylighting, & White Walls

ENVELOPE SYSTEM PERFORMANCE COMPLIANCE SPREADSHEET (EEBC-ENV)

GENERAL	Bldg Name	*Small Office*	Option No.	3	
					<--Perim. DL credit (Yes?)
	Climate Zone	*K*	<---Input Kingston, Montego, or Mandeville	17.2	<--Skylight (Ltg W/sq.m.?)
	Building Type	*SO*	<---Input LO (lge ofc), SO (sml ofc), O (other)	500	<--Skylight (Ltg lux level?)
	Metric?	*Y*	<---If using Metric units, enter "Yes".	0.50	<--Skylight (VLT value?)

September 1994 Version		N	NE	E	SE	S	SW	W	NW	Tot-Avg	ROOF
Tot. Area, Wall (or Roof)	(Sq m.)	0	123	0	159	0	120	0	159	561	404
WINDOWS/SKYLIGHTS		**Dbl pane low-e, med. ven. blinds**					**Average WWR or SRR --->**			**0.27**	**0.03**
Area, Wind. (or Sky.)	(Sq m.)	0	20	0	68	0	22	0	39	149	12
Shading Coeff	(SCx)	0.00	0.30	0.00	0.30	0.00	0.30	0.00	0.30	0.30	0.60
Ext. Shading	(factor)	0.00	0.30	0.00	0.90	0.00	0.75	0.00	0.90	0.80	0.00
U-Value	(W/m sq-K)	0.000	1.760	0.000	1.760	0.000	1.760	0.000	1.760	1.76	5.200
OPAQUE WALLS/ROOFS		**Concrete block, 200 mm, 2nd cavity w/ perlite**									
U-value	(W/m sq-K)	0.000	2.798	0.000	2.798	0.000	2.798	0.000	2.798	2.80	1.070
Weight	(kg/sq m.)	0	244	0	244	0	244	0	244	244	371
Absorpt. Coeff.	(Ac)	0	0.5	0	0.5	0	0.5	0	0.5	0.50	0.7
Area Daylighted	(percent)	0	100	0	75	0	100	0	100	93	100
Window Solar (or Sky.)	(W/m sq.)	0.0	12.2	0.0	19.1	0.0	12.4	0.0	10.9	13.8	0.0
Window Cond. (or Sky.)	(W/m sq.)	0.0	2.7	0.0	7.1	0.0	3.0	0.0	4.1	4.4	0.0
Op.Wall Solar (or Sky.)	(W/m sq.)	0.0	7.1	0.0	5.7	0.0	9.9	0.0	7.5	7.4	9.3
Op.Wall Cond. (or Roof)	(W/m sq.)	0.0	22.1	0.0	15.1	0.0	21.6	0.0	19.9	19.4	10.1
OTTV Compliance	(W/m sq.)	0.00	30.90	0.00	36.49	0.00	32.83	0.00	29.65	32.54	19.39
OTTV Requirements	(W/m sq.)									61.70	20.00
										Passes!	Passes!

New SC_x and U for low-e glass

Daylighting for perimeter and skylights

WWR is increased from 0.27 to 0.50 (or, windows from 27% to 50% of total wall area), and the SRR is increased from 0.03 to 0.15 (skylights from 3% to 15% of total roof area). To achieve this increase in glazed area, a combination of envelope features was sought that would comply with the EEBC-94 criteria. The following wall strategies were used:

a) The walls were kept a light colour ($A_c = 0.70$)

b) The roof colour was changed from light to white (A_c from 0.70 to 0.50), as in the example in 5.6.1 above.

c) Daylighting controls are used for electric lighting in perimeter areas and under skylights, as in the previous example (in 5.5.3 above). External shading is added to the skylights.

d) Low-e glazing is used in place of the single pane tinted glazing with venetian blinds, as in the previous example (in 5.5.3 above). As in the previous example, a combined $SC_x = 0.30$ is used. For an actual project, the value of the SC for the glass and blind combination should be sought from the manufacturer.

Wall measures: This combination of wall measures achieves a compliance value of 40.28 W/m², that is far less than the $OTTV_W$ criteria maximum allowable of 61.70 W/m². Even if all of the considerable external shading were removed from the design, compliance would still be achieved (but barely, at 61.68 W/m2).

Daylighting with Skylight: EEBC 4.7.2 provides for a credit if automatic daylight controls are used to control *all* of the electric lights within the designated area under the skylights. As can be seen in the roof column in Figure D-11, 100% of the electric lights in the required areas under the skylights are automatically controlled for daylighting. This is designated by the "100" in the roof column in the row entitled **"Area Daylighted (per-**

WWR=0.5, new SC_x & U for low-e glass & med. blinds

Figure D-11: Spreadsheet Screen -- Compliance at WWR = 0.50 and SRR = 0.15

ENVELOPE SYSTEM PERFORMANCE COMPLIANCE SPREADSHEET (EEBC-ENV)

GENERAL Bldg Name	*Small Office*	Option No. 3		<--Perim. DL credit (Yes?)
Climate Zone	*K*	<---Input Kingston, Montego, or Mandeville	*17.2*	<--Skylight (Ltg W/sq.m.?)
Building Type	*SO*	<---Input LO (lge ofc), SO (sml ofc), O (other)	*500*	<--Skylight (Ltg lux level?)
Metric?	*Y*	<---If using Metric units, enter "Yes".	*0.50*	<--Skylight (VLT value?)

September 1994 Version		N	NE	E	SE	S	SW	W	NW	Tot-Avg	ROOF
Tot. Area, Wall (or Roof)	(sq m.)	0	123	0	159	0	120	0	159	561	404
WINDOWS/SKYLIGHTS		**Dbl. pane low-e (@0.40), med. ven. blinds**					**Average WWR--->**			**0.50**	**0.15**
Area, Wind. (or Sky.)	(sq m.)	0	62	0	80	0	60	0	80	282	61
Shading Coeff	(SCx)	0.00	0.33	0.00	0.33	0.00	0.33	0.00	0.33	0.33	0.60
Ext. Shading	(factor)	0.00	0.30	0.00	0.90	0.00	0.75	0.00	0.90	0.74	1.00
U-Value	(W/m sq-K)	0.000	1.760	0.000	1.760	0.000	1.760	0.000	1.760	1.76	0.295
OPAQUE WALLS/ROOFS		**Concrete block, 200 mm, 2nd cavity empty, white colour**									
U-value	(W/m sq-K)	0.000	2.798	0.000	2.798	0.000	2.798	0.000	2.798	2.80	0.657
Weight	(kg/sq m.)	0	244	0	244	0	244	0	244	244	371
Absorpt. Coeff.	(Ac)	0	0.5	0	0.5	0	0.5	0	0.5	0.50	0.5
Area Daylighted	(percent)	0	100	0	100	0	100	0	100	100	100
Window Solar (or Sky.)	(W/m sq.)	**0.0**	**41.6**	**0.0**	**24.8**	**0.0**	**37.1**	**0.0**	**24.5**	**31.0**	**10.1**
Window Cond. (or Sky.)	(W/m sq.)	**0.0**	**8.4**	**0.0**	**8.4**	**0.0**	**8.3**	**0.0**	**8.4**	**8.4**	**0.2**
Op.Wall Solar (or Sky.)	(W/m sq.)	**0.0**	**4.2**	**0.0**	**5.0**	**0.0**	**6.1**	**0.0**	**4.9**	**5.0**	**3.1**
Op.Wall Cond. (or Roof)	(W/m sq.)	**0.0**	**13.1**	**0.0**	**13.1**	**0.0**	**13.2**	**0.0**	**13.1**	**13.1**	**5.7**
OTTV Compliance	(W/m sq.)	**0.00**	**47.13**	**0.00**	**35.85**	**0.00**	**45.29**	**0.00**	**35.64**	**40.28**	**19.16**
OTTV Requirements	(W/m sq.)									**61.70**	**20.00**
										Passes!	Passes!

White walls and perim. daylighting *SRR=0.15, ext. shading & 50 mm insul.*

cent)." Additional data is required to properly consider the daylight credit for skylights. Entries must be provided for:

a) Lighting power in W/m^2 (*17.2* is entered);
b) Illumination level in lux (*500* is entered);
c) Visible light transmittance of the skylights (*0.50* is entered for the VLT)

Each of these data items has been entered in the cells listed in the upper right portion of the EEBC-ENV spreadsheet. For an actual building design, the actual lighting power to be installed should be used, and the design illumination level should be used. The power and illumination values in EEBC Tables 5-5 or 5-7 may be used, if the exact levels are not known. The VLT values should be obtained from the skylight manufacturer.

For the roof analysis, one additional feature has been added. External shading above the skylights has been added that blocks 60% of the direct sun rays under peak conditions. This is indicated by:

d) the "0.6" entry in the "**Ext. Shading**" row in the "**Roof**" column.

The use of the daylighting credit for skylights results in a reduction of overall load, that is credited by a reduction in the thermal flux considered. This results in a substantial reduction in energy flux.

Wall and Roof Results: These results indicated that current technologies leave ample room for aesthetic expression and for use of extensive amounts of glazed surfaces in building designs that meet the EEBC-94 wall criteria. However, one must use a reasonable combination of energy-efficient envelope strategies. From the above examples, important strategies include the use of daylighting controls, high performance glazing, and a reasonable combination of internal and external shading devices on the glazing and skylights.

6 More Envelope Calculation Details (Selected Topics)

In this section, more detailed explanations are given for window wall ratio, external shading and internal shading. Also, brief mention is made of the Whole-Building Annual Energy Analysis, as this method involves an analysis of the whole building and not just the envelope.

6.1 Window-to-Wall Ratio (WWR)

Five ranges of WWR are presented in the table of the prescriptive criteria, with the ranges moving from relatively little window area with WWR<0.10 (less than 10%) to large amounts window area with 0.40 <WWR≤ (41% to 50%). The requirements for each range are determined from the system performance requirements using eq. (4-1) in Section 4 of the Code. Within the table, the requirements are set using the upper bound of WWR in each range, namely, 0.10, 0.20, 0.30, 0.40 and 0.50. This means that the prescriptive criteria are more stringent for most WWRs than the system performance criteria. As WWR increases (relatively more glass area on the building) more effort must be used to reduce the solar gain through the larger glass area.

6.1.1 WWR Calculation Procedure: WWR is the total window area divided by the total wall area. The gross exterior wall area is defined as the gross area of exterior walls separating a conditioned space from the outdoors or from unconditioned spaces as measured on the exterior above grade. It consists of the opaque wall including between floor spandrels, peripheral edges of flooring, window areas including sash, and door areas (excluding vents and grills).

Parapets are not included in wall area but basement walls above grade are included if they enclose air-conditioned space. If the basement/semi-basement is open, then the U-Value of the roof/floor slab must be less than or equal to the U-Value for the walls. The total area of fenestration is measured using the rough opening, including the glass or plastic, sash, and frame. A few examples of calculating WWR for a building with different wall configurations are presented below:

a) Building with glass on all four sides
b) Building with glass on two sides
c) Building with two-party walls (adjacent to next buildings)
d) Building with three-party walls

6.1.1.1 Glass on All Four Sides: The building is a two-story square, freestanding office building has the same dimensions on all four elevations. The building is 30 m on each side, with 3.3 m floor-to-floor height.

Windows form a continuous strip on all sides from 0.76 m to 2.13 m high, or covering 1.37 m of the 3.3 m floor-to-floor dimension. Therefore the WWR for the building is as follows:

Total wall area	=	30 m width x 3.3 m fl-fl height x 4 elevations x 2 floors
	=	792 m^2
Total window area	=	30 m width x 1.37 m window height x 4 elevations x 2 floors
	=	329 m^2
WWR	=	329 m^2 / 792 m^2 = 0.41

6.1.1.2 Glass on Two Sides: A rectangular one story store has 9 m frontage and is 15 m deep. It has a floor to roof height of 11 m. The store has continuous windows in front from 0.3 m to 3 m high and 2 small windows in back, but no windows on either side. Therefore, the WWR for the building is as follows:

Total wall length	=	(9 m front + 9 m back + 15 m side x 2)
	=	66 m
Total wall area	=	66 m total length x 4 m height
	=	264 m^2
Front window area	=	9 m width x 2.75 m high
	=	24.75 m^2
Rear window area	=	1 m wide x 0.6 m high x 2 windows
	=	1.2 m^2
Total window area	=	25.95 m^2
WWR	=	25.95 m^2 / 264 m^2
	=	0.1

6.1.1.3 A Building With Two-Party Walls: Buildings with party walls, or walls in direct contact with the walls of other buildings, are common in Jamaica. The portions of walls that are party-walls are NOT included in the OTTV calculations, since they are assumed to be protected from thermal stress and sum. This impacts on the way in which the WWR calculations are done.

If in the previous example, the two 15 m long side walls were party-walls, then the side walls are excluded entirely from the calculations. The procedure is done as follows:

Total wall length	=	9 m front + 9 m back
	=	18 m
Total wall area	=	18 m total length x 4 m height
	=	72 m^2
Front window area	=	9 m x 2.75 m high
	=	24.75 m^2
Rear window area	=	1 m wide x 0.6 m high x 2 windows
	=	1.2 m^2
WWR	=	25.95 m^2/72 m^2
	=	0.36

6.1.1.4 A Building With Three-Party Walls: This represents a very unusual situation, But it is presented here to show the concept. Note the previous example has been changed so that the rear wall is now also a party wall. The only wall exposed to the outside air is the front wall. Now, all three party-walls are excluded from the WWR calculations. The procedure is done as follows:

Total wall length	=	9 m front
Total wall area	=	9 m total length x 4 m height
	=	36 m^2
Front window area	=	9 m x 2.75 m high
	=	24.75 m^2
WWR	=	24.75 m2/ 36 m^2
	=	0.687

6.1.1.5 Special Procedure for Buildings With Party-Walls: Two types of adjustments may be used with the system performance compliance method for buildings with party walls:

a) If the total area of a building's party-walls exceeds 50% of the total wall area (including party-walls and walls exposed to outside air), then the $OTTV_W$ calculated by the System Performance method for the walls exposed to the outside air may be multiplied by 0.7 in order to meet the $OTTV_W$ requirement. The above "two party-wall" example, with two 9 m walls exposed to the outside air and two 15 m party-walls, meets this criterion.

b) If the total area of a building's party-walls exceeds 75% of the total wall area (including party-walls and walls exposed to outside air), then the $OTTV_W$ calculated by the System Performance method for the walls exposed to the outside air may be multiplied by 0.5 in order to meet the $OTTV_W$ requirement. The above "three party-wall" example, with 9 m walls exposed to the outside air and two 15 m side party-walls and a 9 m rear party-wall, meets this criterion.

6.2 External Shading

External shading devices help in reducing solar gain through fenestration. The percent external shading of the fenestration is a variable in the OTTV equation. This value is based on judgement of the building designer. However, a computer program is being written which will determine the exact percentage for each facade between 8:00 a.m. and 5:00 p.m., daily, for one year. The program will be made available when completed and tested.

6.3 Internal Shading Devices

Internal, or integral, shading devices are not required. However, they are a cost-effective means of reducing solar heat gain. Typical devices are horizontal or vertical venetian blinds and drapes. These shading devices are also good for glare control. Because they need to be manually set, their effectiveness can be reduced if not properly operated. This can become a problem in energy management which could be difficult to solve without the cooperation of people using the space.

6.4 Future Refinements to Envelope System Performance Method

The envelope system performance method provides reasonable guidance for a broad range of building envelope energy efficiency features. Future updates to the method might use parametric energy simulations to generate regression equations to: 1) refine the relative impact of solar and conduction loads; 2) further integrate daylighting credits; and 3) further integrate external shading by overhangs and fins.

6.5 Whole-Building Annual Energy Analysis

The prescriptive and system performance methods for complying with the code have been dealt with in detail. However, for those who wish the Whole Building Energy Cost Budget Method may be used, as in Section 12 of the Code.

For purposes of calculating compliance with the annual energy budget method, the fenestration U-value may either consider only the centre-of-glass or may also include edge-of-glass and frame effects. For example, the U-values in Table D-5 have been derived from the 1985 ASHRAE Handbook of Fundamentals. In more recent versions of the ASHRAE Handbook of Fundamentals (e.g., the 1989 version, Chapter 27, Table 13) the fenestration U-Value takes into consideration the edge of glass and frame effects, for either the "R" (residential) or "C" (commercial) column, depending on window size. The thermal transmittance of fenestration assemblies is thus corrected to account for the presence of sash, frames, edge effects, and spacers in multiple-glazed units.

7 References

ASHRAE, *Handbook of Fundamentals*, ASHRAE, Atlanta, GA, 1985, 1989, and 1993 versions.

Cumper, J. and S. Marston, *Energy and Economic Analyses in Support of the Jamaican Energy Efficiency Building Code*, Jamaican report submitted to ESMAP, Washington, DC, 1992.

DOE-2.1D Documentation, *at JBS.*

McPherson, E.G., ed., *Energy-Conserving Site Design,* American Society of Landscape Architects, Washington, DC, 1984.

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Appendix E:
Daylighting

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1 Daylighting Design for Energy Efficiency E-1

2 Envelope and Daylighting E-4

3 Integrating Daylight and Electric Light E-6

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Commentary

Appendix E is intended to provide guidance in the use of daylighting to comply with requirements of the EEBC standard. Key resources are identified, basic concepts are introduced, compliance procedures are explained, and actions required for compliance are emphasized. Also, a number of references are cited, for those readers interested in further exploration of this subject.

Various energy simulation programs such as DOE-2, ASEAM 2.1, and ASEAM 2D may be used to comply with the whole-building analysis methods discussed in Appendix C. The cited programs include analyses of daylight benefits that include estimates of energy reductions due to daylighting for the cooling system, as well as for the electric lights.

1 Daylighting Design for Energy Efficiency

1.1 Benefits

Used in conjunction with modern automatic controls, daylighting can be one of the most effective energy strategies to implement within contemporary buildings.

a) It can save up to 65% of annual, electric lighting-energy in spaces where used (Fig.E-1);

b) It can reduce a building's peak cooling load by up to 15% thus allowing cooling system to be downsized, which results in first-cost savings (Fig.E-2); and,

c) It can save up to 20% of total building energy use in cooling climates as exist in Jamaica (Fig. E-1). But, magnitude of savings depend on the installed lighting-power (Fig. E-2).

Daylighting is therefore an attractive strategy to implement and even more so considering that it can also improve the quality of a building's internal environment; thus,

d) Improving the productivity of its occupants; and,

e) Increasing rentals, or value of the building.

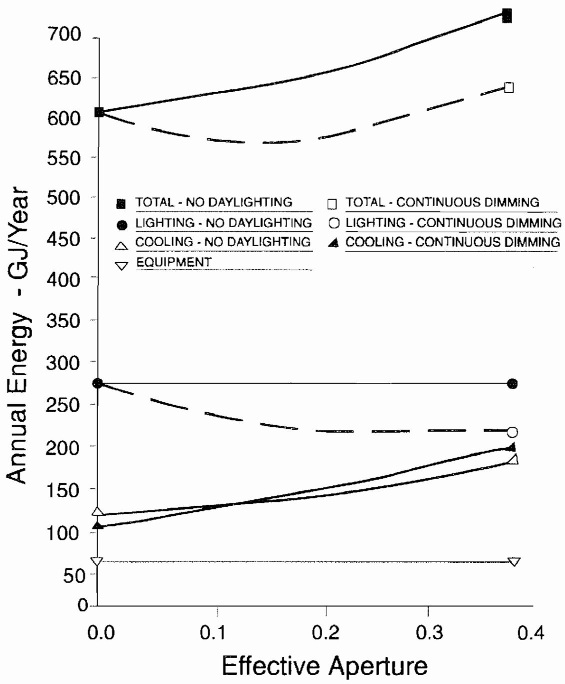

Figure E-1: Annual energy-requirements with and without daylighting.

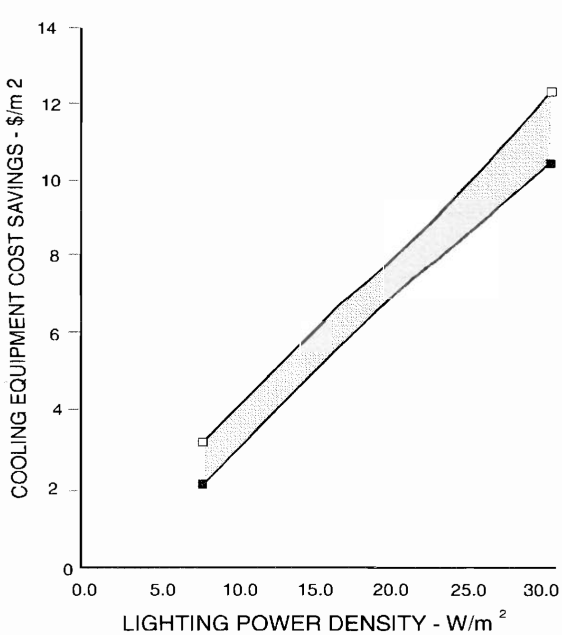

Figure E-2: Potential cost-savings on cooling system with use of daylighting.

1.2 Factors to Consider

Daylighting is less effective in reducing total energy use in buildings operated over substantial nighttime hours (as hotels & hospitals). But to take advantage of potential benefits, two key factors must be considered:

a) Adequate daylight must be provided at the work surface; and,

b) Controls must be provided for electric light to assure their reduced use with the availability of adequate levels of daylight.

1.3 Principles of Daylighting Design

A building's thermal and visual environments are chief concerns of daylighting design, and as such, the effectiveness of daylighting in climates such as Jamaica's depend on two factors:

a) The control of solar heat gains; and,

b) The reduction of contrasts between indoor lighting-levels and that outdoors.

1.3.1 Control of Solar Heat Gain. To control solar heat gain, three key factors must be addressed:

a) Selected glazing must reduce the transmission of solar radiation more than visible transmission where external shading is not provided;

b) Adjustable shading must be provided to reduce transmission of solar radiation when the level of daylight illumination is unacceptable (see Fig. E-3); and,

c) Daylight must be distributed as uniformly as is possible within a building.

1.3.2 Reduction of Contrasts. Benjamin Evans' *Daylight in Architecture* outlines five basic concepts to reduce contrasts in brightness which promote uniform distribution of light within a building; namely,

a) Avoid use of direct sunlight and skylight;

b) Use direct sunlight only sparingly in noncritical task areas;

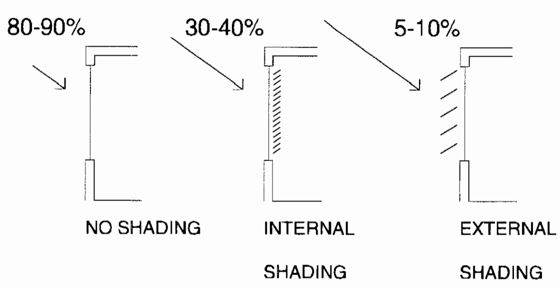

Figure E-3: Solar-heat transmission and location of shading.

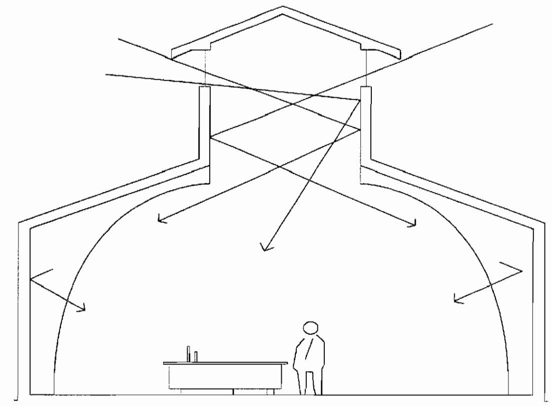

Figure E-5: Daylight admitted high in room bounced off walls.

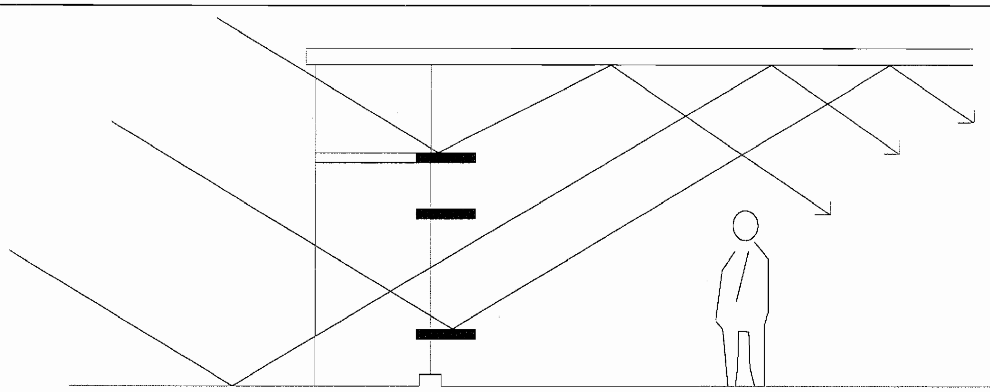

Figure E-4: Light bounced off surrounding surfaces

c) Bounce daylight off surrounding surfaces;

d) Admit daylight high above floor level; and,

e) Filter daylight with use of vegetation and shading devices.

Figures E-4 and E-5 demonstrate some of these important daylighting concepts.

1.4 Integrating Daylight and Electric-Light

The use of daylight and electric-light must however be coordinated that each supplements the other while a threshold level of illuminance is maintained within the daylighted area.

To integrate daylight and electric light, luminaires within a daylighted area must be controlled independent of non daylighted areas; and, luminaires must be controlled as daylight conditions permit (Fig. E-6).

Manual on-off switches are the most basic of controls used in daylighting but, in practice, these are frequently under-utilized. So, integration of daylight and electric light is frequently achieved with the use of automatic daylighting controls.

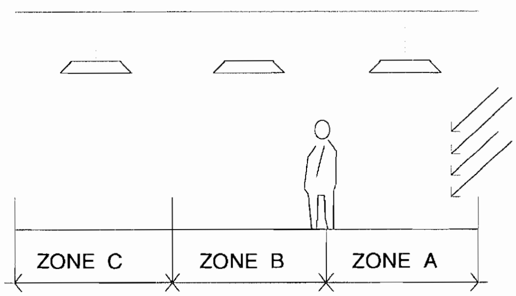

Figure E-6: Zonal control of electric-light.

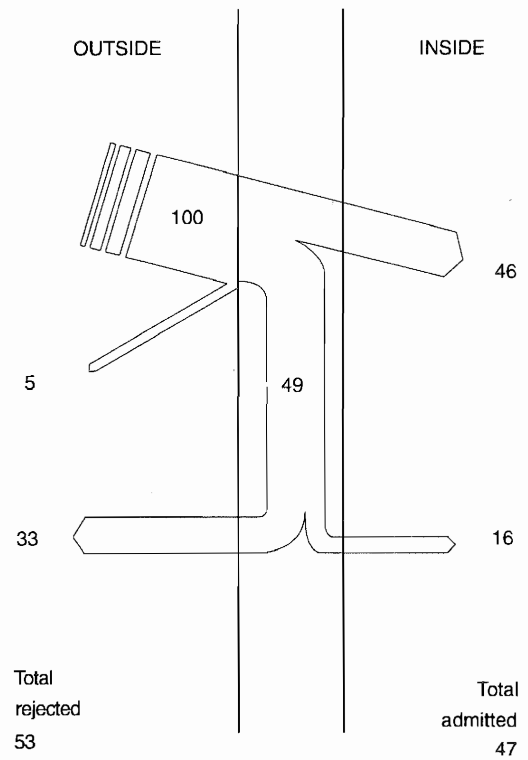

Figure E-7: Transmission characteristics of bronze, "antisun" float glass.

2 Envelope Design and Daylighting

2.1 Type of Glazing

Glass types used for buildings are considered either ordinary or special, solar control glasses being one type of special glass which is designed specifically to reduce solar heat gains. But, solar control glasses can reduce daylight transmission more significantly than heat-gain. So, it is advisable that both thermal and visual properties of glass types be examined before making a selection.

Specification of glazing should therefore be made only after consulting data provided by the respective glazing manufacturer, or generic data provided in reference books as the *ASHRAE: Handbook of Fundamentals.* Grey and bronze-tinted glazing, for example, can reduce daylight by 50% more than the reduction of solar heat gain. But, commercially available blue-green glazing can reduce daylight transmission 10% less than it reduces solar heat gain. And, new glass coatings prove even more effective in this respect.

2.2 Shading Devices

Shading devices can be classified as being either operable or fixed. With proper window management, the former can be more effective as potentially greater control can be exercised over the transmission of both sunlight and excessive levels of daylight.

Position of a shading device relative to its glazing is however important to the effective reduction of solar heat gain. The external placement of a shading device, for example, best utilizes the natural ability of glass to resist heat transfer so that less heat is transferred into a building. But placing the same device indoors prevents heat from escaping outdoors. So, for cooling-dominated climates such as Jamaica's, external shading is the

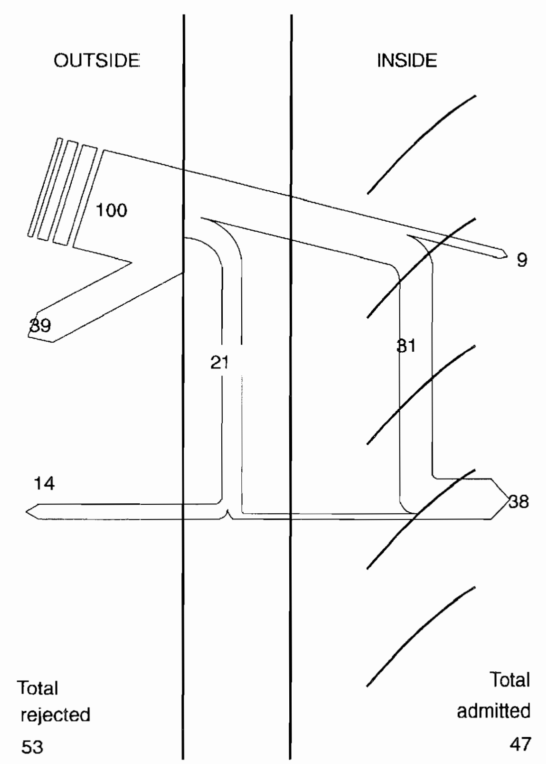

Figure E-8: Transmission characteristics of clear float with light-coloured venetian blinds.

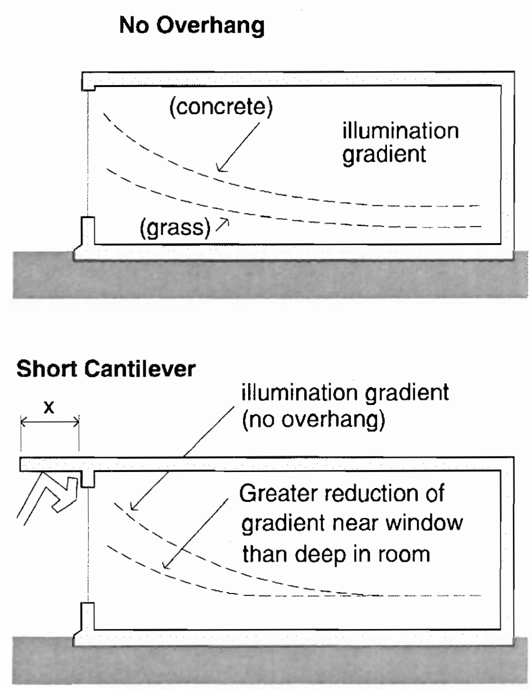

Figure E-9: Distribution of daylight transmitted through windows.

preferred option (see Fig. E-3). However, internal shading devices can also be effective, especially when good management of the internal shade is used. With poor window management (shades deployed when they ought not be), fixed external shades may therefore provide better solar-control than internal placement of operable shades. References as the *Architectural Graphic Standards* should be consulted for information on designing shading devices for solar control, reduction of glare, etc.

The combined effects of glazing and shading devices should be examined as a system, both as to comfort and energy benefits and as to cost. For example, Figures E-7 and E-8 compare the differences in transmission characteristics between a tinted glass with no shading device and a clear glass with an internal shading device.

2.3 Windows and Skylights

The distribution of daylight transmitted through windows is characteristically three to four times brighter near a window than to the back of a room. The pattern of distribution for windows, and skylights, however depends on the orientation, shape, and location of their apertures as well as visible transmittance of the glazing, presence of shading devices, or the lack thereof.

2.3.1 Distribution of Daylight with Windows. Narrow openings higher in a space permit greater pen-

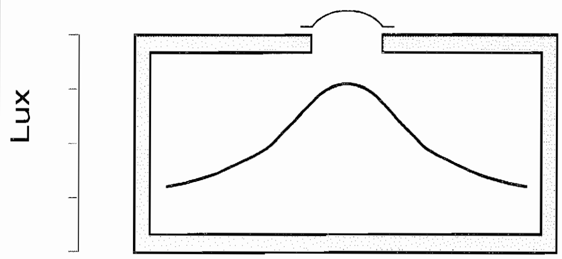

Figure E-10: Distribution of daylight transmitted through skylights.

etration and uniformity of daylight within the space. Overall lighting levels are however reduced with the presence of horizontal overhangs. But, illuminance near the window is reduced more than that to the back of the room. So, the distribution of daylight is, in effect, improved in the presence of overhangs. This is demonstrated in Figure E-9, which shows a more uniform daylighting gradient if an overhang is present. In general, the effect of overhangs on daylighting is positive, for the slight reduction in overall illumination is more than offset by the reduction of glare and the improved uniformity of the daylighting distribution.

Windows however allow effective penetration of daylight only up to depths three to five times their floor-to-ceiling height. Increasing window head-heights to the level of the ceiling, or above, therefore allows daylight to penetrate much further than would otherwise have been expected.

Orienting windows either east or west should nevertheless be handled with great care, as solar heat-gain may prove unacceptable. Proper external shading is very important for east or west windows. Southern orientations will provide bright but variable lighting levels; and orientation to the north will provide diffuse light of uniform lighting levels, throughout the course of a day, thus providing the best daylighting conditions available.

2.3.2 Distribution of Daylight with Skylights. Skylights permit more uniform distribution of daylight within a room than windows, by virtue of their orientation towards the brightest portions of sky for most of the day (Fig. E-10). However, skylights should be shaded to keep solar heat-gain within acceptable limits, especially during the period of peak, design cooling-load.

The size of skylights will impact their proper spacing. Small skylights should be placed no further than the height of a room from each other to provide even illumination; and large skylights (over 2.8 m^2) in area should be placed no further than twice the room's height from each other. And any light-wells (beneath skylights) should be widely sloped away from the skylights to soften contrast between the light-well and ceiling.

3 Integrating Daylight and Electric Light

3.1 Methods of Integration

Various methods exist to integrate daylight and electric light. In the article "A Comprehensive Approach to the Integration of Daylight and Electric Light in Buildings" for instance, Eliyahu Ne'eman classifies integration methods relevant to building-types. Five methods (adopted from his article) are described in Table E-1 (overleaf).

Furthermore, the use of automatic daylighting controls facilitates what Eliyahu Ne'eman terms the Dynamic Integration of Daylight and Electric Light (DIDEL). And with DIDEL, daylight should be used to its maximum (and electric light to its minimum) to create an efficient and visually pleasant environment.

3.2 Daylighting Zones

Within a building however, areas similarly illuminated may represent independent lighting zones. The size of these zones depend on the sky conditions (at the time), and fenestration design as it affects distribution of daylight within a building (mentioned in section 2.3 of this text).

Table E-1
Methods of Integrating Daylight and Electric Light

NUMBER	1a	1b	2a	2b	3	4	5
SPACE INTER-RELATIONSHIP	Single-space integration	Single-space integration	Single-space integration	Single space integration	Inter-space integration	Transitional integration	Outdoor integration
ROLE OF DAYLIGHT	Dominant light source for at least part of the space	Dominant light source for entire space	To add qualityto lighting of space	Background lighting and supplement to electric light	Dominant source in peripheral rooms	Gradation of light intensities indoors and out	Dominant source during the daytime
ROLE OF ELECTRIC LIGHT	Zonal supplement to poorly daylit areas	Supplement to daylight on dull and cloudy days	General and task lighting	General and task lighting	Dominant source in inner rooms	Exclusive source in windowless buildings	Exclusive source during the night
SIZE APERTURE	Large windows	Large skylights	Small windows	Small skylights	Large windows		
DIRECTIONAL PROPERTY OF DAYLIGHT	Side: admitted through vertical outer walls	Above: admitted through skylights on roof	Side: admitted through vertical outer walls	Above: admitted through skylights on roof	Side: admitted through vertical outer walls		
DIRECTIONAL PROPERTY OF ELECTRIC LIGHT	Above: fixtures on ceiling	Above: fixtures on ceiling	Above: fixtures on ceiling	Above: fixtures on ceiling	Above: fixtures on ceiling	Above: fixtures on ceiling	
SPECTRAL PROPERTY OF ELECTRIC LIGHT	Important: critical for accurate colour judgement	Important: critical for accurate colour judgement	Important: good colour rendering source required	Important: good colour rendering source required	Important: critical for accurate colour judgement	Important: good colour rendering source required	Prime importance for TV coverage
EXAMPLES OF SUITABLE USE	Schools, small offices, and workshops	Factories, and museums	Public bldgs, operating theatres, large landscaped offices & factories	Public buildings, large or small factories	Public bldgs, offices, and deep-plan hospitals	Underground structures, & large factories	Sport stadia, and swimming pools
BENEFITS	Visual comfort, optimal energy-savings; subjective well-being	Visual comfort optimal energy-savings; subjective well-being	Low cost of construction, and less exposure to outside noise	Low cost of construction, and less exposure to outside noise	Improved visual comfort for occupants moving from area to area	Elimination of "visual shock" when entering or leaving the building	Uninter-rupted visual transition from daylight to electric light

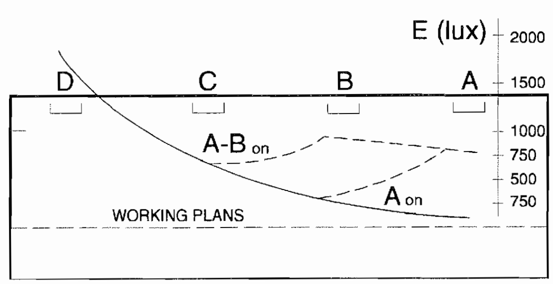

Figure E-11: Daylight penetration and electric light supplement.

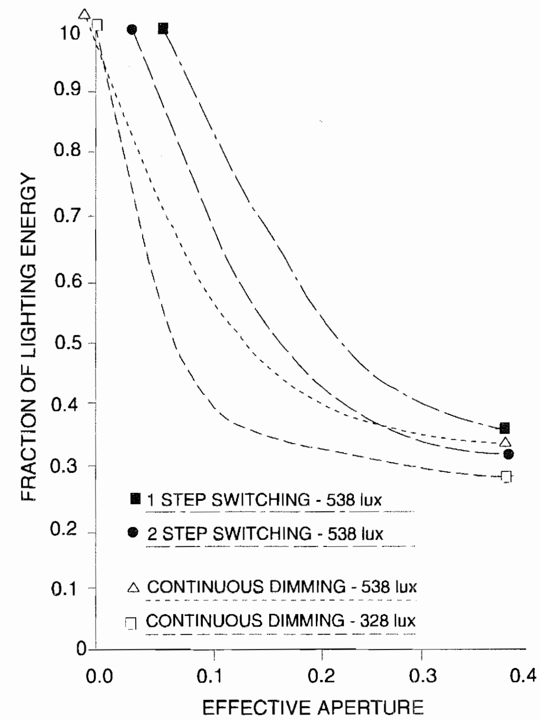

Figure E-12: Daylighting with windows and use of electric lighting in perimeter zones.

3.2.1 Internal Lighting-Levels. Interior lighting levels may be determined with use of either hand-calculation methods (such as lumen or daylight-factor) or use of microcomputer programs (such as DAYLIGHT, CADLIGHT, and MICROLITE).

If the building design budget permits, a model should also be built at a scale no smaller than 1:25; and reflectance of internal surfaces and furniture should be accurately reproduced. Illuminance should then be measured at various points within the model using a photometer. Such a scale model can be an extremely valuable tool for assessing the qualitative aspects of the proposed daylighting design for the building. Further information on building and analyzing such models can be found in Benjamin Evans' *Daylight in Architecture,* and elsewhere.

3.2.2 Establishing Daylight Zones. In *Daylighting: Design and Analysis,* Claude L. Robbins recommends three lighting zones for rooms irrespective of orientation, as long as contrast between the zones does not exceed a brightness ratio of 1:3. And, automatic controls should be installed within each zone to switch or dim the luminaires within them as daylight conditions permit (see Fig. E-11).

3.3 Lighting Controls

Automatic daylighting controls dim or switch luminaires consistent with the level of daylight illumination available such that a specific design illuminance can be maintained.

Luminaires within a particular daylight zone must however be connected via a common electrical circuit to its respective control. And, this is equally true for use of manual controls, as each zone within a room must be controlled independent of the others.

3.3.1 Dimming Controls. In the presence of low levels of daylight illuminance, dimming controls are more effective than switching controls, but they are more expensive; and some are available without off-switches which allows luminaires and their controls to consume energy even when electric light is completely imperceptible. Figure E-12 indicates relative lighting energy savings from dimming versus switching controls.

3.3.2 Switching Controls. Switching controls are however more effective with high levels of daylight illuminance. But when activated abrupt changes in lighting-levels may occur that disturb occupants of the building.

In *Daylighting: Design and Analysis* however, Claude L. Robbins states that these controls are available in two- through five-step switching sequences. Two-step (or on/off) switching can only switch luminaires on or off. The use of these controls are therefore recommended only where marked changes in illumination can be tolerated and daylight illumination is consistently high.

With use of multiple circuits however, each circuit can be progressively turned off as rising levels of daylight permit until all circuits are able to be turned off. And, the partial use of electric light results in a smooth transition between daylight and electric light compared to the single-circuit option.

3.3.3 Installing Photocells. Photocells should nevertheless be well placed within each zone to accurately monitor their average illuminance, that luminaires within them can be effectively controlled. In zones adjacent to windows for example, photocells are typically placed two-thirds the depth of the zone in from the window.

Care should therefore be taken in locating photocells within a zone, and manufacturers specifications on this matter should be followed. Claude L. Robbins' *Daylighting: Design & Analysis* should also be consulted for further information on the topic .

3.3.4 Manual Controls. Manual controls permit two-step switching control where occupants, and not photocells, determine when luminaires are to be turned on or off.

To be effective, at least two lighting zones must exist and switches must be conveniently located to facilitate ease of use. But ultimately, it is the conscientious use of these controls that determine their effectiveness. So, occupants must turn off luminaires as daylight illumination permits.

3.4 Luminaires

In table E-1, two factors concerning luminaires are obviously important to integrate daylight and electric light, namely:

a) The directional properties of electric light relative to that of daylight; and,

b) The spectral properties of electric light.

3.4.1 Directional Properties of Electric Light. Daylight is typically admitted through vertical windows and electric light down from ceilings. So, the directional properties of each is understandably different.

Effective integration of both therefore requires occupants to be unaware, or at least unconcerned, whether interior space is lit by daylight or not. Indirect lighting systems are therefore preferred for daylighting design, as light diffused by reflection off textured surfaces loses most of its directional qualities. Luminaires are therefore suspended from ceilings and their light bounced off light-coloured surfaces to make the directionality of their light less distinct.

3.4.2 Spectral Properties of Electric Light. Again, the ability to distinguish between daylight and electric light is important if both are to be successfully integrated. Electric light should therefore have colour appearance and rendering similar to that of daylight.

Data on the spectral distribution of luminaires is available from literature of the respective manufacturers, or from other guides on lighting. And, a number of luminaires have spectral properties sufficient to integrate them with daylight. The efficient types of fluorescent lamps are one such example.

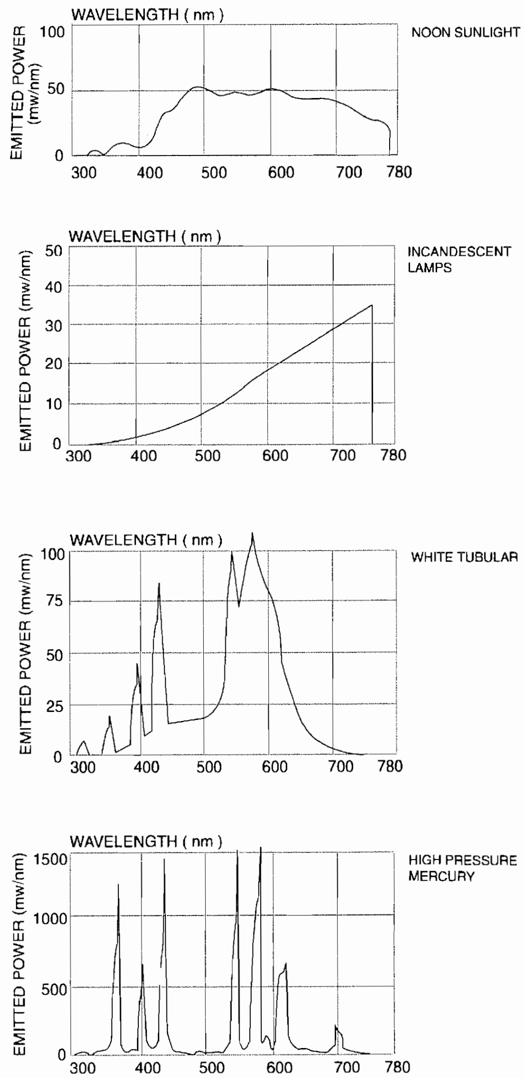

Figure E-13: Distribution of power over light spectrum.

"Deluxe" lamps are highly recommended for their superior colour-rendering properties. But, "tri-phosphor" lamps should be used with caution, as its colour distortion may prove unacceptable.

4 COMPLIANCE PROCEDURES

4.1 Basic Requirements for Daylighting Credit

The EEBC does not require the use of daylighting as part of compliance. Rather, use of daylighting controls for electric lights are encouraged via credits on other envelope or lighting requirements (e.g., amount of glazing or lighting power allowed). These credits are provided in recognition of the ability of daylighting to save energy.

Compliance procedures have been established to make the installation of daylighting more attractive.

Basic requirements provide no daylighting credits, but the basic requirements must be followed if daylighting credits are to be earned under the code. And, basic requirements are specified separately for envelope and lighting systems.

4.1.1 Envelope Credits. There are no basic requirements in EEBC section 4.4 that pertain to daylighting. But, there are air leakage requirements directly applicable to windows and skylights (EEBC 4.4.2 and 4.4.4 respectively).

4.1.2 Lighting Credits. Illumination levels recommended for the design of electric lighting in EEBC section 5.4 (tables 5-5 & 5-7) are the same recommended for use of automatic daylighting controls.

These controls are consequently expected to reduce lighting power as the design illuminance is exceeded. And, their photoelectric sensors shall be capable of reducing lighting power by 50% or more in the presence of sufficient daylight. Credit may be obtained for sensors if more than 50% of the illumination from the luminaire is within the daylighted area. No daylight sensor shall receive credit for controlling an luminaire

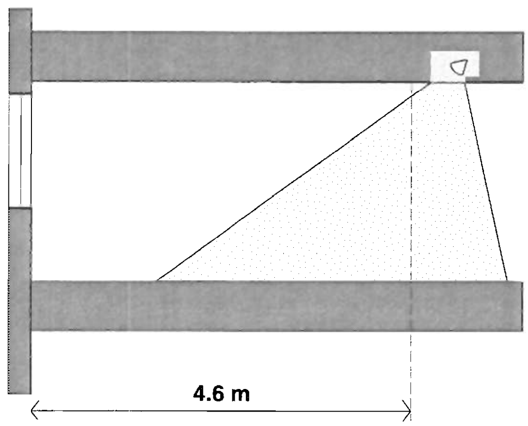

Figure E-14: Illumination of daylit floor-area by luminaire outside the area.

if less than 50% of the illumination is within the daylight zone in which, or near which, it is located (see Fig. E-14).

Daylighting controls may be centralized. In fact, EEBC 5.4.2.2 and EEBC 5.4.3 describe credits provided to reduce the required number of controls and increase connected lighting power (CLP) of controls respectively. But, sensors shall not control over 1,500 W of CLP.

Section 4.3.2 of this appendix describes EEBC credits that directly apply to daylighting.

4.2 Prescriptive Requirements for Daylighting Credit

4.2.1 Envelope Credits. Credits provided under EEBC prescriptive requirements of the envelope section are applicable firstly to walls (where daylight is transmitted through vertical windows), and secondly to roofs (daylight being transmitted through skylights). Further discussion of these credits is therefore presented under separate headings below.

4.2.1.1 Walls: EEBC Tables 4-la through 4-lc contain wall options for code compliance. For daylighting credit, daylighting controls must be provided to control luminaires to a depth of 4.6 m in from the external wall providing daylight. And where daylight sensors are provided, these must be placed within the space occupied by luminaires described above.

4.2.1.2 Roofs: EEBC table 4-2 contains roof options for code compliance. However, no explicit mention is made of daylighting.

But, EEBC section 4.7.2 states that credits are provided on satisfaction of the following conditions:

a) The percentage of gross roof are occupied by skylights shall not exceed the value specified in EEBC table 4-3; and,

b) Lighting system used in the daylighted area beneath skylights shall use automatic daylighting controls.

These conditions being satisfied, credits under option 5 of EEBC table 4-2 shall apply to daylighting. The area of skylights (specified in EEBC table 4-3) can however be increased if external shading is provided for the skylights at least during the period of peak design cooling-load (EEBC section 4.7.2.1).

4.2.2 Lighting Credits. Prescriptive requirements for lighting credit are found in EEBC section 5.5. However, no explicit mention is made of daylighting.

Credits are nevertheless provided for use of daylighting controls listed in EEBC table 5-2. And, the adjusted lighting power (ALP) defined in EEBC section 5.4.3.1, can be substituted for the connected lighting power (CLP) in EEBC section 5.5.2.

Compliance shall therefore be achieved when the ALP does not exceed the building's interior lighting power allowance (ILPA) determined from EEBC equation 5-3, for the area of building using the controls.

4.3 System Requirements For Daylighting Credit

4.3.1 Envelope Credits. System performance requirements for daylighting credit are provided individually for walls and roofs EEBC section 4.5. Further description of these credits is therefore presented under separate headings below.

4.3.1.1 Walls: For wall credits, daylight is assumed to be transmitted through vertical windows (as opposed to light transmitted through skylights).

Credit is provided for use of both manual and automatic controls. The floor area considered to receive adequate daylight must however be determined as defined in Section 4.3.2 of this appendix. And, windows must provide adequate illumination.

Windows with effective aperture (EA) 0.10 or more are considered adequate for this purpose; EA being defined as:

$$EA = WWR \times TVIS \qquad \text{Eq.(E-1)}$$

where,

WWR = Window-to-wall ratio

TVIS = Visible transmittance

Window height must however be 0.9 m or higher and window head must be over 1.2 m above the finished floor level.

Conditions being met, OTTV calculated for walls along the daylighted floor area can be reduced by 30%, if Lighting Power Control Credit (LPCC) has not been taken; or 7.5%, if LPCC has been taken. The daylighted floor area is described below in section 4.3.2 of this appendix.

4.3.1.2 Roofs: Daylight credit for roofs are provided only where conditions of EEBC section 4.7.2 are met, that is:

a) Percentage of gross roof area occupied by skylights shall not exceed the value specified in EEBC Table 4-3; and,

b) Electric-light over daylighted area shall be regulated by automatic daylighting controls.

If the above two conditions are met, then the area of skylights should be neglected in the calculation of the OTTV, as described in EEBC equation 4-3 for the roof area.

4.3.2 Lighting Credits. Lighting credits are only provided where conditions for envelope credit have been met. In which case, two credits are applicable, namely:

a) the use of more lighting power; or,

b) the use of fewer lighting controls

Both credits are contained in the basic requirements of EEBC section 5.4. But, credit shall only apply to luminaires having 50% or more of their visible light output focused on the daylighted floor area.

Credits to Increase Lighting Power: Maximum levels of connected lighting-power (CLP) are specified by EEBC section 5.6. However, credits are provided for use of daylighting controls that permit CLP to be increased even further.

These credits, termed Power Adjustment Factors (PAF), are listed in EEBC table 5-2, and are used in EEBC equation 5-1 to calculate the Lighting Power Control Credits (LPCC).

The values for PAF are however conservative, as continuous dimming and stepped controls have been found to reduce annual, lighting energy by over 50% (refer to Fig. E-12). So, a whole building analysis (as outlined in Appendix C and EEBC section 12) should be undertaken if larger credits are desired.

Credit To Reduce Lighting Controls: EEBC section 5.4.2.1 specifies the minimum number of lighting control points to install within a building. With the use of automatic daylighting controls, this number can however be reduced in accordance with EEBC section 5.4.2.2. and Table 5-1.

Floor Area Daylighted Through Windows: To receive wall credits, width of daylighted floor-area shall be considered on a cumulative basis along the length of each window. Those windows admitting daylight plus 0.6 m wide portions of wall either side of these windows

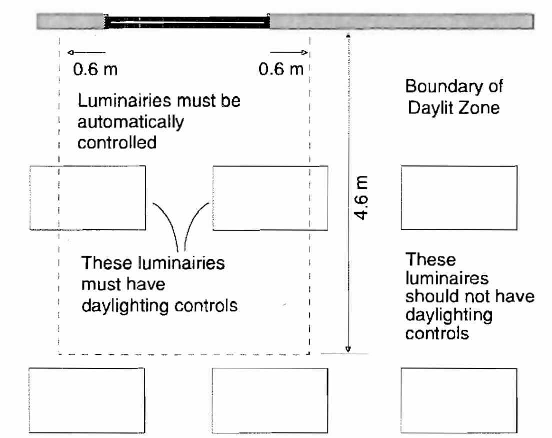

Figure E-15: Daylit floor-area and placement of automatic daylighting controls within them.

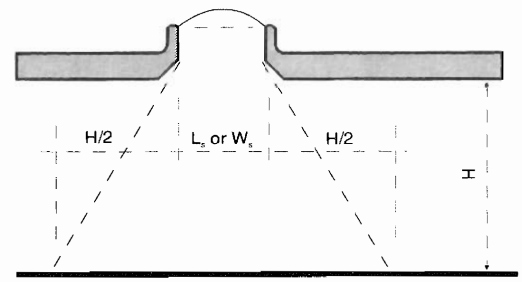

Figure E-16: Skylights and the dimensions of daylighted floor-area.

(Fig. E-15). And, depth of daylighted floor-area shall be considered 4.6 m providing no opaque, floor-to-ceiling partitions are installed within that depth.

Floor Area Daylighted Through Skylights: Where roof credits are applicable however, daylighted area shall be determined from the equation:

$$A_{dl} = (L_s + H) \times (W_s + H) \qquad \text{Eq. (E-2)}$$

where,

A_{dl} = Daylighted floor area
L_s = Length of skylight
W_s = Width of skylight
H = Height of light-well (floor to lowest point).

Fig. E-16 shows the dimensions for calculating the daylighted floor-area from skylights.

Overlapping daylit areas: Where overlapping daylighted areas exist, overlapping areas shall be considered a single space, daylighted areas being accounted for only once in the calculations (see Fig. E-17).

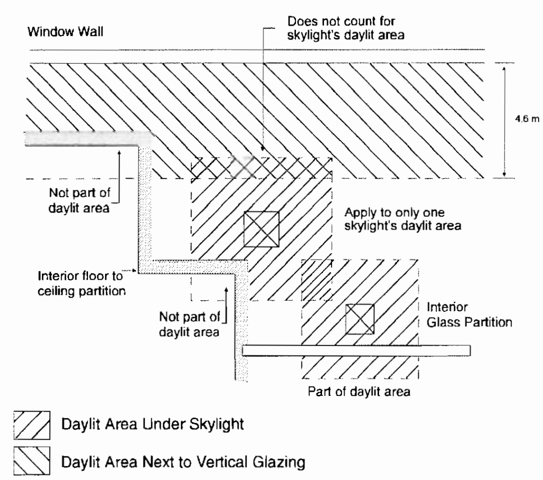

Figure E-17: Daylighted floor-area with overlapping daylighted areas.

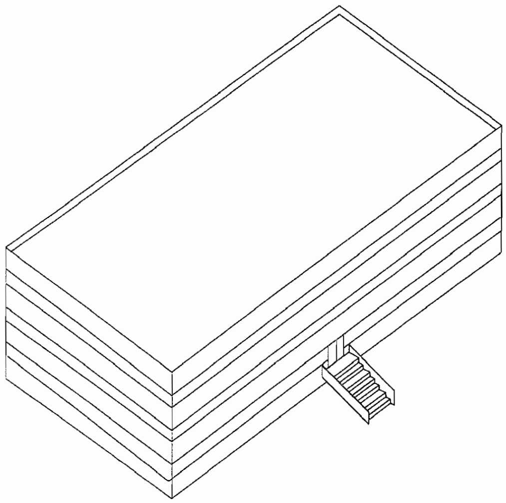

Figure E-18: Three-storey office building in Kingston, Jamaica.

5 Calculation Procedures

Situation 1:

A three-storey building, located in Kingston, is 36 m long by 18 m wide: larger sides being oriented north and south (Fig. E-18). Strip windows are used throughout: floor-to-floor height is 3.7 m; and external walls have OTTV's of 45.6, 62.5, 68.0, and 80.0 W/m^2 clockwise: from north to west.

The building has an installed lighting power of 20 W/m^2 and daylighting is to be used that EEBC performance requirements may be satisfied.

According to EEBC section 4.6.1, Overall Thermal Transfer Value (OTTV) for exterior walls shall be determined by the EEBC equation 4-2 as follows:

$$\text{OTTV} = (Ao_1 \times \text{OTTV}_1 + Ao_2 \times \text{OTTV}_2 + \ldots + Ao_i \times \text{OTTV}_i)/(Ao_i + Ao_2 + Ao_i)$$

[EEBC Eq. 4-2]

where,

Aoi = Gross wall area for the ith exterior wall, m^2

OTTVi = Overall Thermal Transfer Value for the ith exterior wall, W/m^2

OTTV can therefore be calculated for walls described above as follows:

$$\text{OTTV} = [(45.6 \times 399.6) + (62.5 \times 199.8) + (68.0 \times 399.6) + (80.0 \times 199.8)]/[(399.6 \times 2) + (199.8 \times 2)]$$

$$= 61.4 \text{ W/m}^2$$

OTTV should however not exceed 57 W/m^2. But when daylighting is used, EEBC section 4.7.1 states that OTTV for the wall providing daylight can be reduced by 7.5% (when LPCC is claimed). And in this case, all external walls provide daylight; so OTTV can be calculated:

$$\text{OTTV} = 61.4 \times (1 - 0.075) = 56.8 \text{ W/m}^2$$

And, from EEBC section 5.5.2 Connected Lighting-Power (CLP) should not exceed the Interior-Lighting Power Allowance (ILPA) determined from EEBC equation 5-3 as follows:

$$\text{ILPA} = \text{ULPA} \times \text{GLA}$$ [EEBC Eq. 5-3]

where,

ULPA = Unit Lighting Power Allowance determined from EEBC table 5-5, W/m^2

GLA = Gross Lighted Area, m^2

In this case for example,

ULPA = 17 W/m^2, and

GLA = 648 m^2

Therefore,

ILPA = 17 x 1944 = 33048 W

CLP = 20 x 1944 = 38880 W

The building will therefore not comply with EEBC standard. But according to EEBC section 5.4.3.1, Lighting Power Control Credits (LPCC) are provided for the use of daylighting controls. And, these credits are determined from equation 5-1 in EEBC, that is:

$$LPCC = (CLP)_{dl} \times PAF \quad \text{[EEBC Eq. 5-1]}$$

where,

LPCC = Lighting Power Control Credit, W

$(CLP)_{dl}$ = Connected Lighting Power in area that uses daylight controls, W

PAF = Power Adjustment Factor determined from EEBC table 5-2

$(CLP)_{dl}$ is then reduced by LPCC as follows:

$$ALP = (CLP)_{dl} - LPCC$$

where,

ALP = Adjusted Lighting Power, W

And according to section 4.3.1 of this appendix, daylit floor-area for which this credit is provided has a depth of 4.6 m in from the wall for which daylighting credits have been provided.

In this instance, daylighting credit can be applied to all external walls. Therefore, the floor area A_{dl}, for which lighting credit is applicable, can be calculated as follows:

$$A_{dl} = 1{,}944 - 3\,[(36 - 4.6 \times 2) \times (18 - 4.6 \times 2)]$$
$$= 1{,}944 - 707.52$$
$$= 1{,}236.48 \text{ m}^2$$

And in EEBC table 5-2, PAF = 0.25 for use of multiple-step daylighting controls. Therefore,

$$(CLP)_{dl} = 20 \times 1{,}236.48$$
$$= 24{,}729.6 \text{ W}$$

$$LPCC = 24{,}729.6 \times 0.25$$
$$= 6{,}182.4 \text{ W}$$

and,

$$ALP = 24{,}729.6 - 6{,}182.4$$
$$= 18{,}547.2 \text{ W}$$

CLP for the core of the building, $(CLP)_{el}$, is then calculated as follows:

$$(CLP)_{el} = 20 \times 707.52$$
$$= 14{,}150.4 \text{ W}$$

And for the building as a whole,

$$CLP = ALP + (CLP)_{el}$$
$$= 18{,}547.2 + 14{,}150.4$$
$$= 32{,}697.6 \text{ W}$$

The building's CLP is therefore less than ILPA previously calculated. So, the building now exceeds EEBC performance requirements for both external walls and lighting.

Situation 2:

A five-storey building is to be located in Kingston (See Fig. E-19). The proposed building is square: constructed as defined in situation 1: with 1,337 m^2 of floor space per storey; window head 3.05 m above floor-level; and installed lighting-power of 20.5 W/m^2.

The building has a 10.7 m, square courtyard: so OTTVs become 44.6, 60.6, 66.2 and 77.5 W/m^2 clockwise, from north to west. And, daylighting is proposed to comply with EEBC performance requirements.

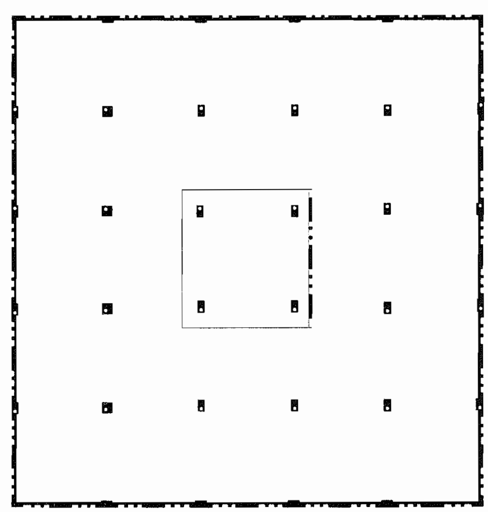

Figure E-19: Typical floorplan of the five-story building in Kingston.

Overall Thermal Transfer Value (OTTV) for exterior walls shall be determined by the EEBC equation 4-2, as follows:

$$OTTV = (Ao_1 \times OTTV_1 + Ao_2 \times OTTV_2 + ... + Ao_i \times OTTV_i)/(Ao_i + Ao_2 + ... + Ao_i) \quad \text{[EEBC Eq. 4-2]}$$

where,

Ao_i = Gross wall area for the ith exterior wall, m^2

$OTTV_i$ = Overall Thermal Transfer Value for the ith exterior wall, W/m^2

For the building described above, the building's external dimensions are 38.1 x 38.1 x 18.5 m high and those of the courtyard 10.7 x 10.7 x 18.5 m high, so Ao_i and OTTV are calculated as follows:

$$Ao_i = (38.1 \times 18.5) + (10.7 \times 18.5) = 902.8 \; m^2$$

$$OTTV = [(44.6 \times 902.8) + (60.6 \times 902.8) + (66.2 \times 902.8) + (77.5 \times 902.8)] / (902.8 \times 4) = 62{,}225 \; W/m^2$$

Now for large buildings, OTTV of vertical walls should be at least 63 W/m^2 to comply with EEBC section 4.6.1.1. So, this building already complies with the requirement and does not have to be modified.

For EEBC section 5.5.2, Connected Lighting-Power (CLP) should however not exceed the Interior-Lighting Power Allowance (ILPA) determined from EEBC equation 5-3 as follows:

$$ILPA = ULPA \times GLA \quad \text{[EEBC Eq. 5-3]}$$

where,

ULPA = Unit Lighting Power Allowance deter mined from EEBC table 5-5, W/m^2

GLA = Gross Lighted Area, m^2

In this case for example,

ULPA = 17 W/m^2,

GLA = 1,337 x 5 = 6,685 m2

Therefore,

ILPA = 17 x 6,685 = 113,645 W

CLP = 20.5 x 6,685 = 137,042.5 W

So, the building will not comply with EEBC section 5.5.2. But, EEBC section 5.4.3.1 states that Lighting Power Control Credit (LPCC) is provided for the use of daylighting controls. And, these credits are determined from equation 5-1, as follows:

$$LPCC = (CLP)_{dl} \times PAF \quad \text{[EEBC Eq. 5-1]}$$

where,

LPCC = Lighting Power Control Credit, W

(CLP) = Connected Lighting Power in area that uses daylight controls, W

PAF = Power Adjustment Factor determined from EEBC table 5-2

$(CLP)_{dl}$ is then reduced by LPCC as follows:

$$ALP = (CLP)_{dl} - LPCC$$

where,

ALP = Adjusted Lighting Power, W

And according to section 4.3.1 of this appendix, daylit floor-area for which this credit is provided has a depth of 4.6 m in from the wall for which daylighting credits are provided (see Fig. E-20).

In this instance, daylighting credit can be applied to all external walls. Along the outer most walls, floor area (A_{dl}), for which daylighting credit is applicable, can therefore be calculated as follows:

$$A_{dl} = 5\{(38.1)^2 - [38.1 - (4.6 \times 2)]^2\} = 3{,}082 \; m^2$$

But along walls facing the courtyard, A_{dl} must be calculated according to section 4.3.1 (d) of this appendix, as follows:

$$A_{dl} = (L_s + H) \times (W_s + H)$$

where,

L_s = Length of skylight
W_s = Width of skylight
H_s = Floor-to-ceiling height

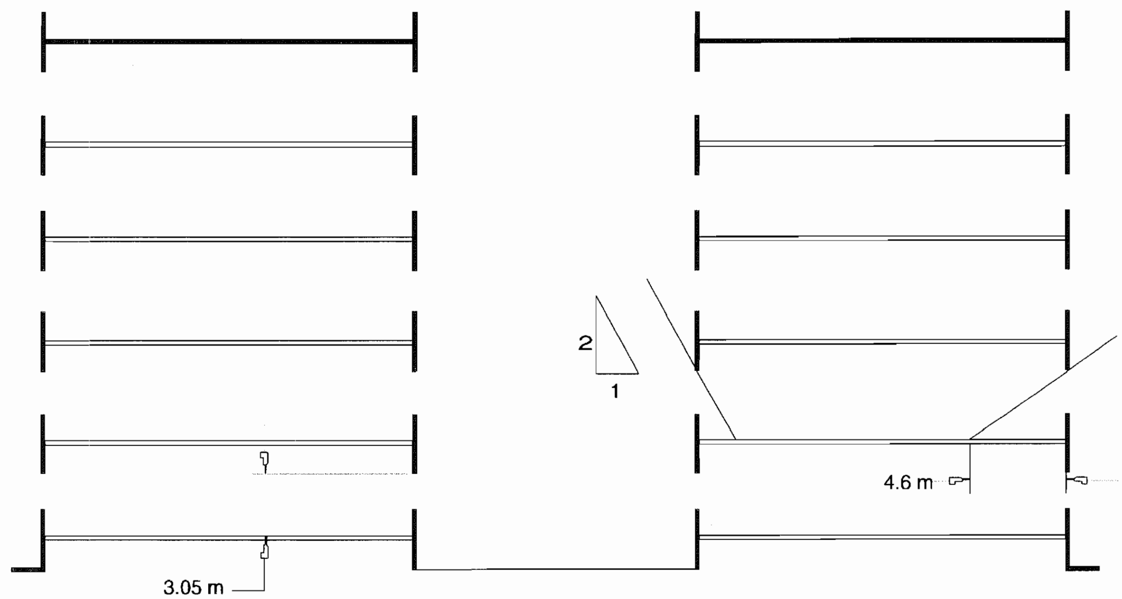

Figure E-20: Section through courtyard of five-storey office building.

The dimensions of the skylight, in this case, should however be taken as that of the courtyard. And, height of the light-well should be taken as that of the window head above the floor-level. But, the area of the courtyard should not be considered as part of A_{dl}. So, A_{dl} in this case should be calculated as follows:

$$A_{dl} = 5[(10.7 + 3.05)^2 - (10.7)^2] = 372.86\ m^2$$

And the summation of areas for which daylight credits are provided (YA_{dl}) can be determined as follows:

$$YA_{dl} = 3{,}082 + 372.86 = 3{,}454.86\ m^2$$

So,

$$(CLP)_{dl} = 20.5 \times 3{,}454.86 = 70{,}824.68\ W$$

And in EEBC table 5-2, PAF = 0.35 for use of continuous dimming controls. Therefore,

$$LPCC = 70{,}824.68 \times 0.35 = 24{,}788.64\ W$$

$$ALP = 70{,}824.68 - 24{,}788.64 = 46{,}036.04\ W$$

The portion of the building for which daylighting credit is not provided (A_{el}) is however determined as follows:

$$A_{el} = (1{,}337 \times 5) - 3{,}454.86 = 3{,}230.14\ m^2$$

And, the Connected Lighting Power, $(CLP)_{el}$ is calculated as follows:

$$(CLP)_{el} = 20.5 \times 3{,}230.14 = 66{,}217.82\ W$$

For the building as a whole, CLP is therefore determined as follows:

$$CLP = ALP + (CLP)_{el} = 46{,}036.04 + 66{,}217.82 = 112{,}253.86\ W$$

The building's CLP is therefore less than ILPA previously calculated. So, the building complies with EEBC performance requirements for external walls and lighting.

6 References

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Appendix F: Lighting

Contents of this Appendix

1 Introduction F-1
2 Basic Lighting Requirements F-5
3 Interior Lighting Power Allowances (ILPA) - Prescriptive Path F-16

Commentary

This section of the compliance guidebook describes compliance with the energy saving requirements for lighting systems and lighting equipment in buildings.

To specify the minimum requirements for lighting systems and controls. The intention is to set minimum design parameter for lighting systems. More efficient lighting systems should be used where possible, as considerably more savings in energy are possible than those obtained from meeting the minimum design parameters established in the EEBC-94.

1 Introduction

1.1 Benefits

The electric lighting used within a building can be a major part of the building's total energy use, especially if excessive lighting power is installed in the building and then its use over time is poorly controlled. Results from the energy and economic analysis conducted of potential energy efficiency measures, including those measures required by the EEBC, give an indication of the energy and cost benefits of some key energy-related lighting measures.

Figure F-1 shows the percentage reduction in total building energy use as a result of applying each lighting measure to a Base Case five-story large office building that represents the current Jamaican construction practice in the early 1990's. For comparative purposes, the same scale for percentage of total building energy reduction is used as in Figure D-1 in the Appendix on Building Envelopes measures.

These result also demonstrate an important side-benefit of more efficient lighting systems -- as less energy is used for lighting, less heat is given off by the lighting into the interior of the building. Thus, less air-conditioning energy is needed to withdraw that heat from the building. In each result shown in Figure F-1, some of the energy reduction has resulted directly from the lighting measures used, and additional energy reduction has resulted from the reduced load on the air-conditioning system.

The figure shows the benefits from improved efficiency in 4 types of lighting measures: fluorescent lamps, ballasts, troffers and lenses, and daylighting. The base case lighting includes 40W T12 1200 mm lamps, standard loss magnetic core ballasts (one ballast per lamp), and a standard troffer with prismatic lens. Daylighting controls are not used in the base case design.

Figure F-1 demonstrates that more efficient lighting equipment and systems can cause a profound improvement in the energy efficiency of a typical office building:

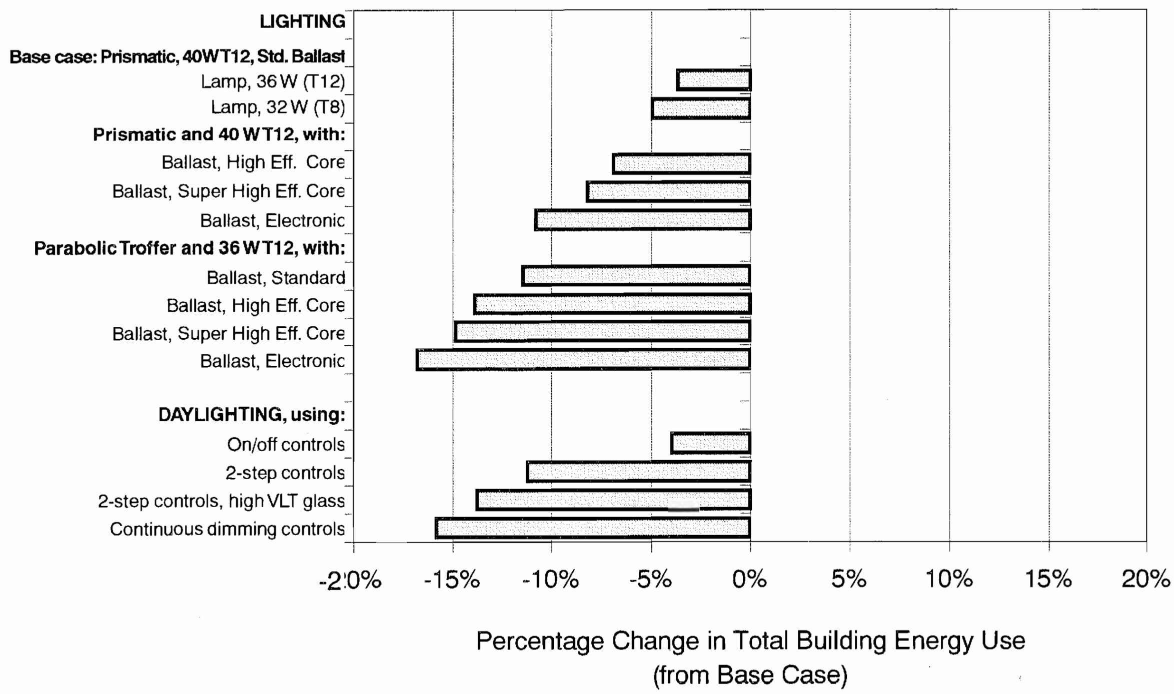


Figure F-1: Impacts of Energy Strategies for Lighting Systems (Large Office)

a) Simply using more efficient fluorescent lamps can reduce the total energy used by the entire building by 3% - 5%.

b) Use of higher-efficiency ballasts is even more striking, with total energy reductions for the building in the range of 7% - 11%.

c) Note that use of one ballast per lamp has been the norm in Jamaica, and the use of one ballast to serve multiple lamps has not been examined here. This would produce even further savings.

d) Another highly effective strategy is switching from a standard troffer with prismatic lens to an open cell parabolic troffer. This measure by itself can reduce total building energy use by some 12%. In combination with high-efficiency ballasts, the parabolic troffer can reduce total building energy use by 15% -17%. However, it is a more expensive option.

e) Daylighting is also a very effective energy-efficiency strategy. The analyses performed indicate that daylighting can reduce total building energy use by 4% - 6%, depending upon the control strategy adopted.

Daylighting depends on the use of controls on the lighting system. Simple on/off switches are low cost, but only reduce energy 4% - 5%. Use of either two-level switching or continuous dimming controls will produce energy savings in the 10% - 15% range. Continuous dimming controls are more effective, but also are more expensive.

The energy and economic analysis to evaluate the impacts of the EEBC also examined the relative economic benefits of each of the lighting measures. Figure F-1 shows an example of the economic output for the separate lighting and daylighting measures from a national economic perspective, where increasing net present value (NPV) represents increasing economic benefit. The figure shows that the lighting and daylighting measures examined are clear winners, with most strategies being highly cost-effective. The highly cost-effective results for the measures including the parabolic troffer

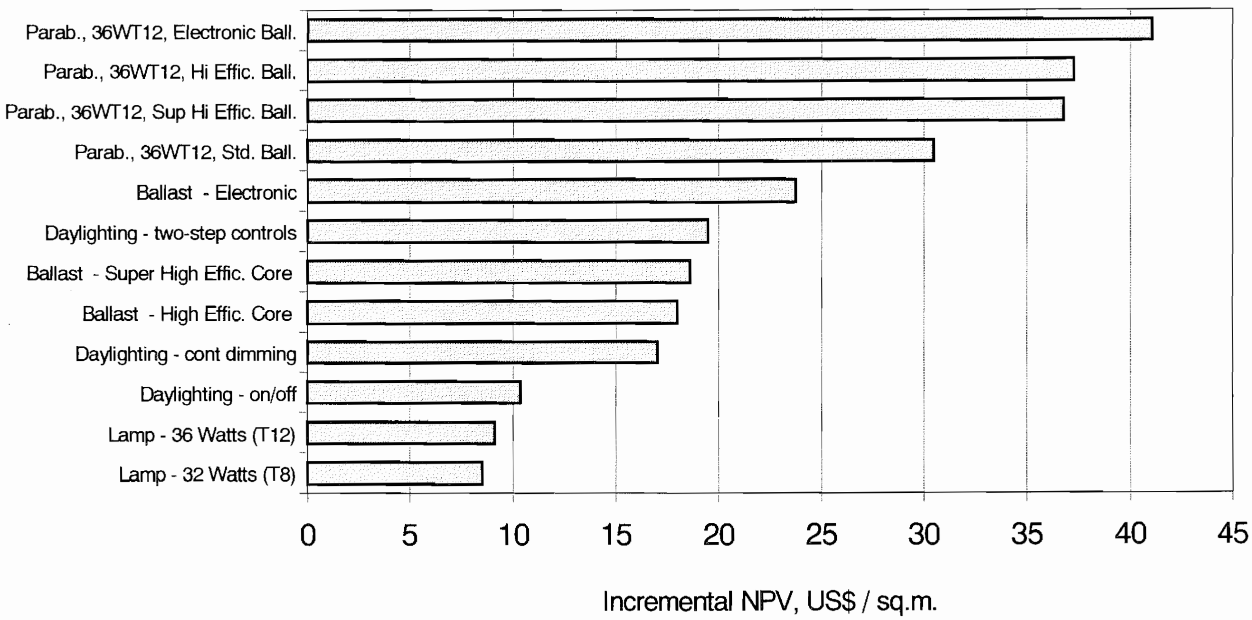


Figure F-2: National Economic Perspective Results for Lighting Measures

assume that fewer fixtures are required than for the prismatic troffers.

Project resource limitations precluded conducting the logical next step of iteratively adding successive measures in descending order from most cost-effective to least cost-effective until the combined incremental NPV hits zero. This procedure could precisely define an economically optimal point for the lighting measures, from a national perspective. The energy and economic analysis performed also showed that lighting measures were also highly cost-effective from a private owner financial perspective.

1.2 Organization of Lighting Requirements

Lighting requirements are included for the interior spaces and the exterior surrounding areas of buildings including roads, grounds and parking that are energized through the building electrical service.

The organization of the lighting sector of the Code is illustrated in Figure F-3, where compliance is achieved by following by first meeting compliance with the basic requirements (EEBC 5.4). Then compliance must be met with either the prescriptive path (EEBC 5.5) or the system performance path (EEBC 5.6).

In addition, there is yet another alternative path; that of achieving compliance using the whole building energy budget and energy cost budget methods (EEBC 12.0). The whole building compliance option (EEBC 12.0) is another compliance path which may be used for any building, especially those of innovative designs. The basic requirements (5.4) are mandatory and are used in conjunction with this path. The intention is eventually to adopt the whole building compliance route for all buildings larger than 4,000 m^2 of floor area.

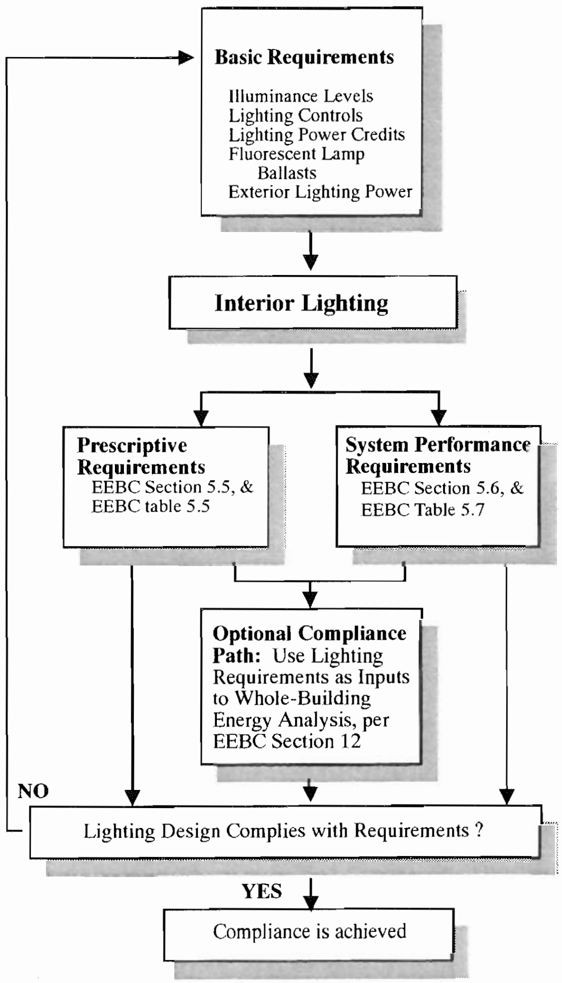


Figure F-3: Lighting Compliance Paths

The requirements of the lighting section of the Code are intended to: (1) set limits to the maximum lighting power allowed for lighting systems of buildings, based on the space activities; and, (2) to achieve efficient use and control of the energy needed.

To assist in meeting these goals, one basic and two other requirements are given with recommended illuminance levels derived from the Illuminating Engineering Society of North America (IESNA) and CIBS:

Basic requirements give recommended illuminance levels and controls to turn off the lighting systems.

Prescriptive requirements, intended for buildings with defined primary occupancies, for example, a standard office or hotel building. A Unit Lighting Power Allowance (ULPA) in W/m^2 is specified for the primary occupancy space and the total Interior Lighting Power Allowance (ILPA) is determined by the product of the ULPA and the gross area of the space. Thus the maximum interior lighting power allowed, using the prescriptive requirements, is determined by:

$$ILPA = ULPA \times GLA \qquad \text{Eq. (5-3)}$$

The system performance path provides a more flexible, but more detailed, approach that deals with the illumination requirements and general spatial characteristics of the different space functions within a building. A base unit power density (Pb) in (W/m^2) is specified in Table 5-7 for each particular space activity.

In the system performance path, the Lighting Power Budget (LPB) of each space is determined by the product of the unit base power density and the area of the space. The results is then multiplied by an area factor of the space. The area factor is based on the spatial geometry, and is obtained from charts displayed in EEBC-94, Figure 5-1, Area Factor.

The Interior Lighting Power Allowance (ILPA) for the building is evaluated by summing the Lighting Power Budget (LPB) for each space. For spaces that are not defined or listed, a nominal 2.15 W/m^2 may be used, and multiplied by the area of the unlisted space. Thus, from Eq. 5-5 EEBC, $ILPA = LPB_1 + LPB_2 + LPB_n + (2.15\ W/m^2 \times A_u)$, where A_u is an area of unlisted space.

1.3 Compliance

First it is necessary to determine whether the prescriptive or system performance requirement is applicable. If the building is to be used primarily for one main activity, then the prescriptive requirement path may be used and the ILPA is evaluated by the product of the ULPA and the gross area as illustrated on Form LTG-2 in Appendix M. Compliance is to ensure that Connected Lighting Power (CLP) of the lighting system is equal or less than the ILPA.

Similarly, if the building has various space activities, the system performance method is used. For example, an office building has three types of space activities; from EEBC Table 5-7 each activity type has a different illuminance level and a different unit power base density:

Illuminance	lux	Pb (W/m²)
Reading, typing and filing	500	17.2
Drafting	750	33.4
Accounting	750	26.9

The lighting power budget for each space activity above is determined by EEBC equation 5-4:

$$LPB = Pb \times area \times area\ factor$$

For example, an accounting area of 100 m^2 and a room height of 2.75 m will have an area factor of about 1.1, from EEBC Figure 5-1. Thus, the LPB for the accounting area is:

$$\begin{aligned} LPB &= 26.9\ W/m^2 \times 100\ m \times 1.1 \\ &= 2959\ W \end{aligned}$$

The sum of the LPB values for all three space activities (EEBC Eq. 5-5) gives the Interior Lighting Power Allowance for the office building.

Compliance is achieved if the total of all connected lighting load including ballast losses is equal or less than the ILPA as determined by EEBC 5-5. To assist in complying with the requirements of the Code, there are forms developed with guideline information to be completed based on the size of the building and the interior base lighting power allowance. Forms SB/LTG-1 andSB/LTG-2 relate to buildings less than 1,000 m^2 while Forms LTG-1 and LTG-2 are for buildings greater than 1,000 m^2.

1.4 Exemptions

There are three types of exemptions to the lighting requirements as follows:

a) Specialized space functions (dwelling houses, theatrical production, etc.)
b) Special requirements (emergency lighting high risk security areas, etc.)
c) Certain exterior areas (athletics, processing manufacturing, etc. facilities)

2 Basic Lighting Requirements

Compliance with these requirements is mandatory in all compliance paths even if the whole-building compliance option (EEBC 12.0) is used. There are five main types of Basic Requirements

a) Illuminance levels (EEBC 5.4.1)
b) Lighting Controls (EEBC 5.4.2)
c) Lighting Power Credits (EEBC 5.4.3)
d) Fluorescent Lamp Ballasts (EEBC 5.4.4)
e) Exterior Lighting Power (EEBC 5.4.5)

2.1 Illuminance Levels

Recommended illuminance levels (in lux) are listed in the EEBC. These recommended levels are included for guidance only, and compliance is NOT mandatory. The recommended levels have been derived from the recommendations of the Illuminating Engineering Society of North America (IESNA) and the Chartered Institution of Building Services Engineers (CIBSE).

The recommended illuminance levels are listed in two locations in the EEBC. EEBC Table 5-5 recommends illuminance levels for a few building types and general space types, that are identified for use with the prescriptive method. EEBC Table 5-7 recommends illuminance levels for over 100 specific types of lighting space types, that are identified for use with the system performance method. In these tables, recommended illuminance levels for each building type and/or space are associated, for information purposes, with the minimum lighting power requirements of the EEBC.

2.2 Lighting Controls

The function of lighting controls is to provide adequate amount of light where and when it is needed at each space or task area throughout the building. The energy consumed by the lighting load is a function of the amount of lighting power that is installed and the time that the power is used to provide light.

A number of EEBC controls requirements affect the time of use (e.g., manually operated wall switches, programmable timers with local area overrides, occupancy sensors and daylight sensors). Some control options are provided within the EEBC to reduce electric power for lighting (e.g., dimming controls and lumen maintenance). Other control options are provided that permit reducing BOTH the power used and the time of use (e.g., daylight sensing, continuous dimming, programmable timing, and lumen maintenance controls).

Controls Requirements: There are eight lighting control requirements as follows:

a) Minimum number of control points (EEBC 5.4.2.1)
b) Minimum number of controls (EEBC 5.4.2.2)
c) Control for task lights (EEBC 5.4.2.3)
d) Duplicate controls (EEBC 5.4.2.4)
e) Control accessibility (EEBC 5.4.2.5)
f) Hotel room master switch (EEBC 5.4.2.6)
g) Exterior lighting controls (EEBC 5.4.2.7)
h) Office & school daylight zone switching (EEBC 5.4.2.8)

Compliance is mandatory for each of the eight listed requirements, if applicable to the building.

However, of the eight requirements listed above, only the first two will apply to almost every building. These two specify the minimum number of controls and control points that must be installed in each space to ensure efficient operation of the lighting system.

The other six requirements will apply only in special circumstances or for selected building types. The third, fourth and fifth requirements indicate how the controls are to be installed in certain situations. The sixth, seventh and eight requirements apply to specific building types or situations.

Requirement 1 - Minimum Number Of Control Points For Each Space:

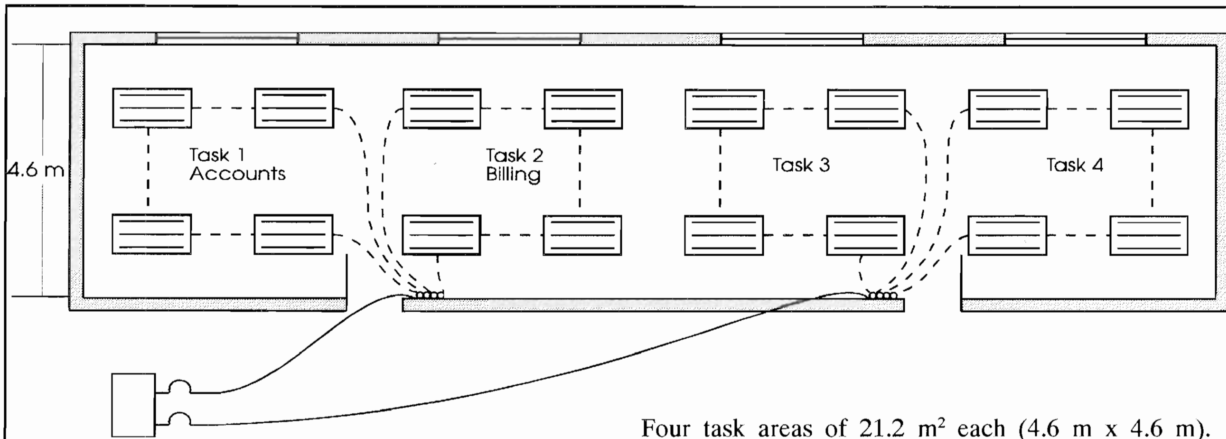
Each space that is enclosed by walls or by ceiling-height partitions shall be provided with a minimum of one manually operated on/off control capable of turning off all the lights, within that space. The control should be located by the exit door if possible. In addition to this control, one other control shall be provided for each principal task location assigned an area of 14 m^2 or more.

The intent is to ensure that a sufficient number of controls are installed to turn off the lighting in unused spaces while allowing the lighting to be used in nearby spaces. This can be a major way of saving energy. For example, in an office building, twenty five percent (25%) of the spaces could be unoccupied at a given time during the day. If the lights in these spaces can be turned off, this could result in great savings in energy. For spaces with more than one task, the task area need not exceed fifty percent (50%) of the total area of the spaces.

Requirement 2 - Minimum Number of Controls:

The use of certain manual and automatic control devices may reduce the number of control points required, as indicated in EEBC Table 5-1. However, the minimum number of controls required shall not be less than one for each 1500 W of Connected Lighting Power (CLP), including ballasts.

However, a reduction in the number of control points is allowed if any of the following controls are used for the lighting system: occupancy sensors, programmable timers and three level step control (including off) a preset dimming are equivalent to two (2) control points, while four level step control (including off) or preset



Four task areas of 21.2 m² each (4.6 m x 4.6 m). Minimum of 4 switches required, one for each task area (& additional switches for lighting near windows). For minimum number of control points, see EEBC 5.4.2.1; for minimum number of controls see EEBC 5.4.2.2.

Figure F-4: Controls for Task Areas

dimming and automatic or continuous dimming controls, are equivalent to three (3) control points.

Requirement 3 - Clarification Concerning Task Lights:

Controls provided for task areas, if readily accessible, may be mounted as part of the task lighting luminance. This is a clarification and not a new requirement. It indicates that controls that are present on task lighting fixtures may be included in the total number of lighting controls counted for compliance, if they are accessible easily. This clarification is listed in EEBC 5.4.2.3.

Requirement 4 - Clarification Concerning Duplicate Controls :

In controls requirements 1 and 2, above, the control of the same lighting system from more than one location shall not be credited as additional control points, since multiple control for the same light fixture is more a convenience than an energy saving strategy. However, lighting control requirements for spaces which must be used as a whole may be controlled by a lesser number of control points but not less than one control point for each 1500 W of connected lighting power, or a total of three control points, whichever is greater. Examples of such spaces include public lobbies of office buildings, hotels and hospitals, retail and department stores, warehouses and storerooms and service corridors under centralized supervision. Lighting in such places shall be controlled in accordance with the work activities. This clarification is listed in EEBC 5.4.2.4.

Requirement 5 - Clarification concerning Control Accessibility:

All lighting controls should be located to be readily accessible to personnel occupying or using the space. However, exceptions apply for: lighting controls centralized in remote locations for: spaces which must be used as a whole; automatic controls; programmable controls; controls requiring trained operators; controls for safety hazard and security. This clarification emphasizes the obvious that all lighting controls should be accessible to the occupants, preferable by the exit door, to switch off the lighting system. The exceptions indicate cases in which alternative remote centralized controls are available to function, just as effectively, as an alternative to the local controls. This clarification is listed in EEBC 5.4.2.5.

Requirement 6 - Controls for Hotel and Motel Guestrooms:

EEBC 5.4.2.6 is a special controls requirement that applies only to motel and motel guestrooms. It specifies that the guestrooms (excluding bathrooms) shall have one or more master switches at the main entry doors that will turn off permanently wired lighting fixtures and switched receptacles. This switch may be activated by the insertion and removal of the room key. For multiple room hotel suites, switches at the entry of each room, in lieu of the switch at the main door will be acceptable to meet these requirements. For rooms at resort hotels, with frequent access from two doors, master switches may be installed at both main door and patio door. The intent is to encourage the guest to turn off all the lighting in the hotel room from the door on leaving the room unoccupied. This is a widely adopted strategy for energy conservation. In some countries, not only the lighting but all the room services including setback of the air conditioning system are linked to a switch, by the door, that can be activated only by the room key or card.

Requirement 7 - Exterior Lighting Controls

EEBC 5.4.2.7 specifies a special controls requirement that applies only to exterior lighting. Exterior lighting not intended for twenty four (24) hour continuous use shall be switched automatically by timers, photocell or a combination of timer and photocells. Timers shall be of the automatic type or otherwise capable of adjustment for seven (7) days and for seasonal daylight schedule variations.

Photoelectric controls for external lighting have been in use for several years; they are the most common way of automatically controlling outdoor lighting. Timers or a combination of both control devices are available to perform more complex operations automatically on twenty four (24) hours, seven (7) days schedule. The specification for the timer shall include either spring or battery backup power for four (4) hours to maintain continuity of the schedule switching.

2.3 Lighting Power Control Credits (LPCC)

This section provides trade-offs between lighting controls and the amount of installed lighting power allowed. Rather, This is not a new requirement, but rather the provision of credits when several different types of automatic lighting controls are used. The credits allow more lighting power to be installed, as automatic controls will reduce the time of usage of the installed lighting power. This is possible as energy = power x time. If the time of usage is reduced significantly, then advantage can be taken of an increase in power and still save energy. The credit is shown in EEBC Table 5-2. The credit can be substantial and varies from five percent (5%) to forty- five percent (45%) of the connected lighting power allowed by the EEBC Code.

This credit can be used to reduce the connected lighting power so as to comply with the Interior Lighting Power Allowance (ILPA).

The Lighting Power Control (LPCC)

$$LPCC = CLP \times PAF \qquad \text{EEBC Eq. (5-1)}$$

where,

CLP = Connected Lighting Power for those luminaires controlled by the automatic control device in watts.

PAF = Power Adjustment Factor

The resultant Adjusted Lighting Power (ALP)

$$ALP = CLP - LPCC$$

Equation 5-1 in EEBC 5.4.3.1 shows how the Lighting Power Control (LPCC) is applied to the 'Connected Lighting Power (CLP)' to be installed in the building so as to derive the 'Adjusted Lighting Power (ALP)' for those spaces where the controls are used. Also, see Sections 3 and 4 of this appendix, below.

2.3.1 Power Adjustment (PAF): The automatic control for which PAF credits may be obtained include:

a) Daylight sensing
   1) Continuous dimming
   2) Multiple step
   3) On/off
b) Programmable timing
c) Lumen Maintenance
d) Occupancy sensor
e) Combination of the above

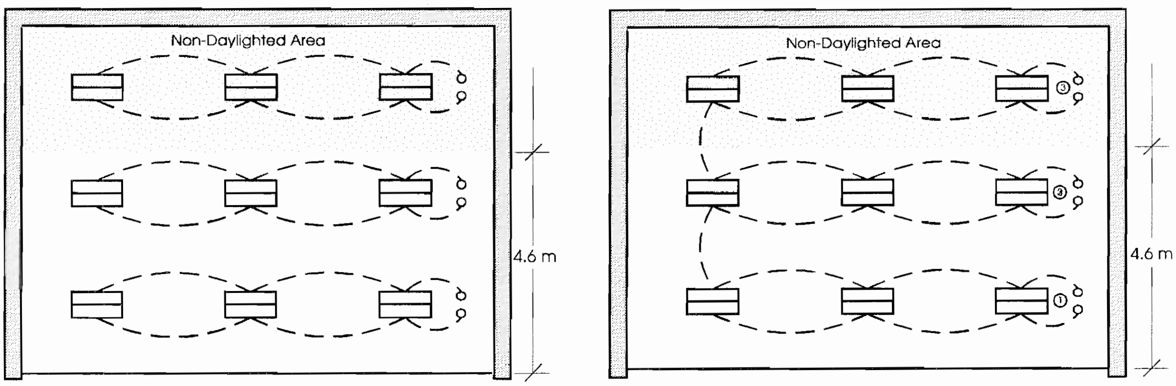


Figure F-5: Manual Switching Arrangements to Utilize Daylighting

Diagram showing the application of daylight saving switches and sensors in offices.

For example, the credits for three controls combined, continuous dimming sensing, lumen maintenance, and occupancy sensor is forty five percent (45%).

This credit, while substantial, is still conservative. For example, it is possible to achieve an energy reduction in perimeter zones of fifty percent (50%) or more from the use of continuous dimming daylight sensing controls by themselves.

2.3.2 PAF Credits for Daylight Sensing Controls: In areas near windows or skylight, natural daylight can be used to satisfy partially, the lighting requirements. The sole use of daylight will not provide the lighting requirements of spaces in a building as it is not available in the evenings and during continually changing seasons and sky conditions. However, daylighting can be manually switched (see Figure F-5) or it can be linked with the electric lighting system by using a photosensitive device to adjust the outputs of the artificial lighting system based on the amount of prevailing daylight.

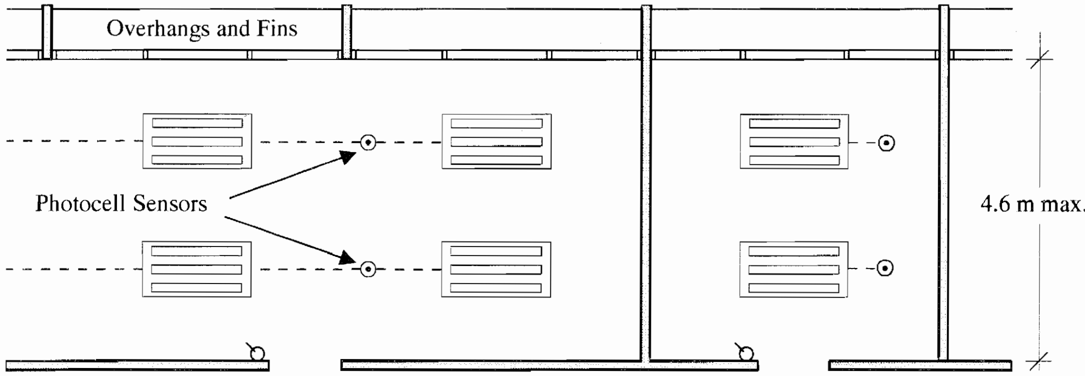
The photo-sensor control is a photo-relay mounted facing horizontally outward and connected in the lighting circuit, so that when daylight illumination on the photo-relay exceeds a threshold the relay switches off the light circuits. The photo relay is essentially a thermal device with thermal inertia which tends to reduce the frequency of hunting or cycling when the daylight level is near the switching point. An adjustable deadband is incorporated with photo-relay so that lighting will be switched off when the daylight illuminance on the photo sensor exceeds some level, but will not be restored until the daylight drops considerably below the switch-off threshold.

Switched-based daylighting controls may annoy some building occupants and should be used with caution especially in spaces where visual performance is important. Photo-sensors with dimming control devices are more acceptable. These are usually placed inside the building envelope at a representative portion of the area to be controlled.

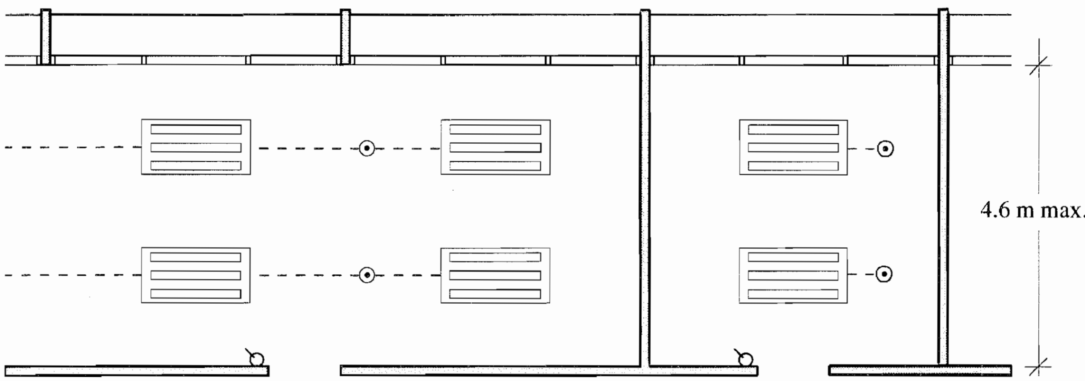
Diagrams (a), (b) and (c) in Figure F-7 show how daylight saving sensors are used to obtain credits for reducing the Connected Lighting Power (CLP). Examples on the next page illustrate how the Adjusted Lighting Power (ALP) is calculated.

For example, consider the use of automatic control devices for lighting in space of a typical office building 36.6 m x 18.3 m wide. The general office space comply with the ULPA of 17.2 W/m^2 except a perimeter area extending 4.6 m from the outer wall along the length of the building. This area is 4.6 m by 36.6 m or 168 m^2.

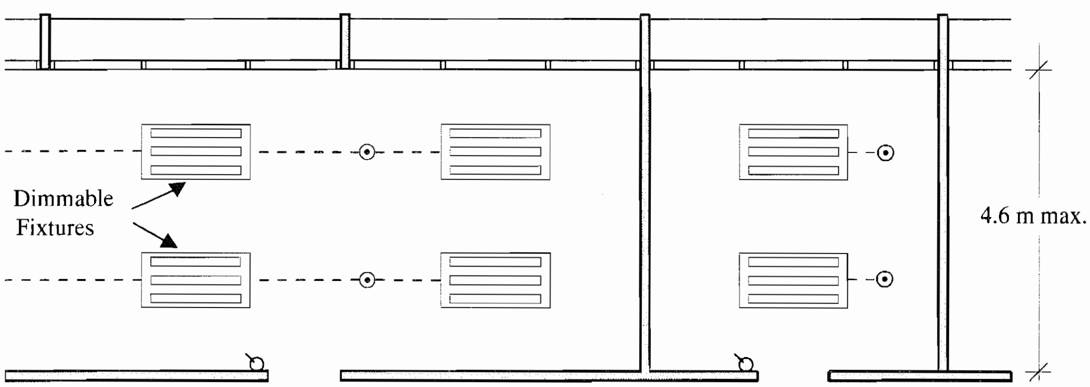
The Architect/Client wishes the space to be illuminated with a type of light fixture that gives a Connected Lighting Power (CLP) of 3200 watts or 19.0 W/m^2. However, the prescriptive requirement for the interior



Daylight Sensing Controls, ON/OFF (PAF = 0.15)



Daylight Sensing Controls, Multiple Step Dimming (PAF = 0.25)



Daylight Sensing Controls, Continuous Dimming (PAF = 0.35)

FIGURE F-6: Daylighting Controls

Lighting Power Allowance (ILPA) is 17.2 W/m^2 x 168 m^2, or 2890 watts, and the desired solution does not comply.

The lighting engineer, being familiar with the Code, notes that there is adequate window aperture along the 36.6 m side of the building. He decides to obtain a credit and reduce the Connected Lighting Power (CLP) for this area, and he explores three options.

First, the simplest automatic on/off daylighting switch is selected. The Power Adjustment Factor for this device from EEBC Table 5-2 is PAF = 0.15, as shown in Figure F-6.

a) The Lighting Power Control Credit (LPCC) would be 3200 x 0.15, or 480 watts.
b) The Adjusted Lighting Power (ALP) is 3200 - 480, or 2720 watts.
c) This meets the ILPA requirements of 2890 watts.

Second, if a daylight-saving, multiple-step dimming device were selected, the Power Adjustment Factor (PAF) from EEBC Table 5-2 is 0.25.

a) The Lighting Power Control Credit (LPCC) is 3200 x 0.25, or 800 watts.
b) The Adjusted Lighting Power (ALP) is 3200-800, or 2400 watts.
c) This is much less than the value of 2890 watts of ILPA requirement. Thus another option has been found that complies.

Third, if a continuous dimming device were used, then the PAF is 0.35 (Table 5-2).

a) Then the LPCC would be 3200 x 0.35, or 1120 watts.
b) The Adjusted Lighting Power (ALP) is 3200 - 1120, or 2080 watts.
c) Again, this is less than the maximum value of 2890 watts (CLP) required by the Code.

In practice, the least first cost device that meets the building design requirement would most likely be chosen to comply with the Code requirements.

The Power Adjustment Factors developed in Table 5-2 are considered conservative values for daylighting application in Jamaica. For example, analysis will indicate that both continuous dimming and stepped controls can reduce annual lighting energy used by over fifty percent (50%) as compared with the conservative values of an adjustment factor of 0.35 shown in the Table 5-2 for continuous dimming, and 0.25 for multiple stepped dimming. On account of this, a variant of the continuous dimming device with say, occupancy sensor and lumen maintenance, should be considered for the maximum energy savings if the control device is cost effective.

2.3.3 PAF Credits for Programmable Timers:

Programmable timers shall have:

a) Separate override control for each space that is required to be switched independently, as every room of more than 9.3 m^2 to 13.9 m^2 in an area.
b) Capable of programming at least two daily schedules of one for week days, and the other for weekends. However, where the building is utilized for different schedule Saturday and Sunday, then additional programming schedules shall be provided.
c) Capable of temporary override by the occupants using a switch located in the room or by a telephone link or other means that use communication networks. The timer shall be arranged to return automatically to the original schedule.
d) The programmable timers are connected so that the mandatory manually operated on/off control for each 13.9 m^2 prevail including the provision for two level illumination by turning off lighting separately, that is nearest to the window areas. The power adjustment factor (PAF) allowed for this device is 0.15 and the expected energy savings is about 40%. Programmable timers which schedule the operation of the building lighting system is accomplished with only switching devices, and it should prove to be less expensive than other control methods.

The example shown in Figure F-7 illustrates a method of scheduling with a programmable timer. The reduction of the lighting level in areas by one third and two thirds at different times, is achieved with a split-wired system. This allows different zones to be switched to one of three light levels according to the task requirement.

2.3.4 PAF Credits for Lumen Maintenance Controls: Lumen Maintenance controls use a photo cell which detects the actual illuminance level in the space and adjusts the lighting system output to the required lux or footcandle level. Figure F-8 shows a diagram of a typical lumen maintenance system. With new lighting installations, the savings resulting from adjusting the input watts downward is on the order of 30%, as shown in Figure F-8. Then, as the lamps and hardware age the input watts must be increased to maintain the same illumination level. Lumen output declines with age, resulting in an increased light loss factor. For a new system that uses lumen maintenance, the initial 30% excess light output is not necessary. This is reduced and maintained at the correct luminance level by dimming, offering a corresponding saving in input energy to the light fixtures.

A lumen maintenance system with an energy monitor would determine the most economic time to relamp the system as the energy use will be at a maximum when the lamps are old. In general lumen maintenance is possible only with dimming controls. However, the photo electric control arrangement is much simpler than that for daylighting. On account of this, it is worthwhile incorporating lumens maintenance control as part of any dimming application for daylighting so as to reap the maximum benefit.

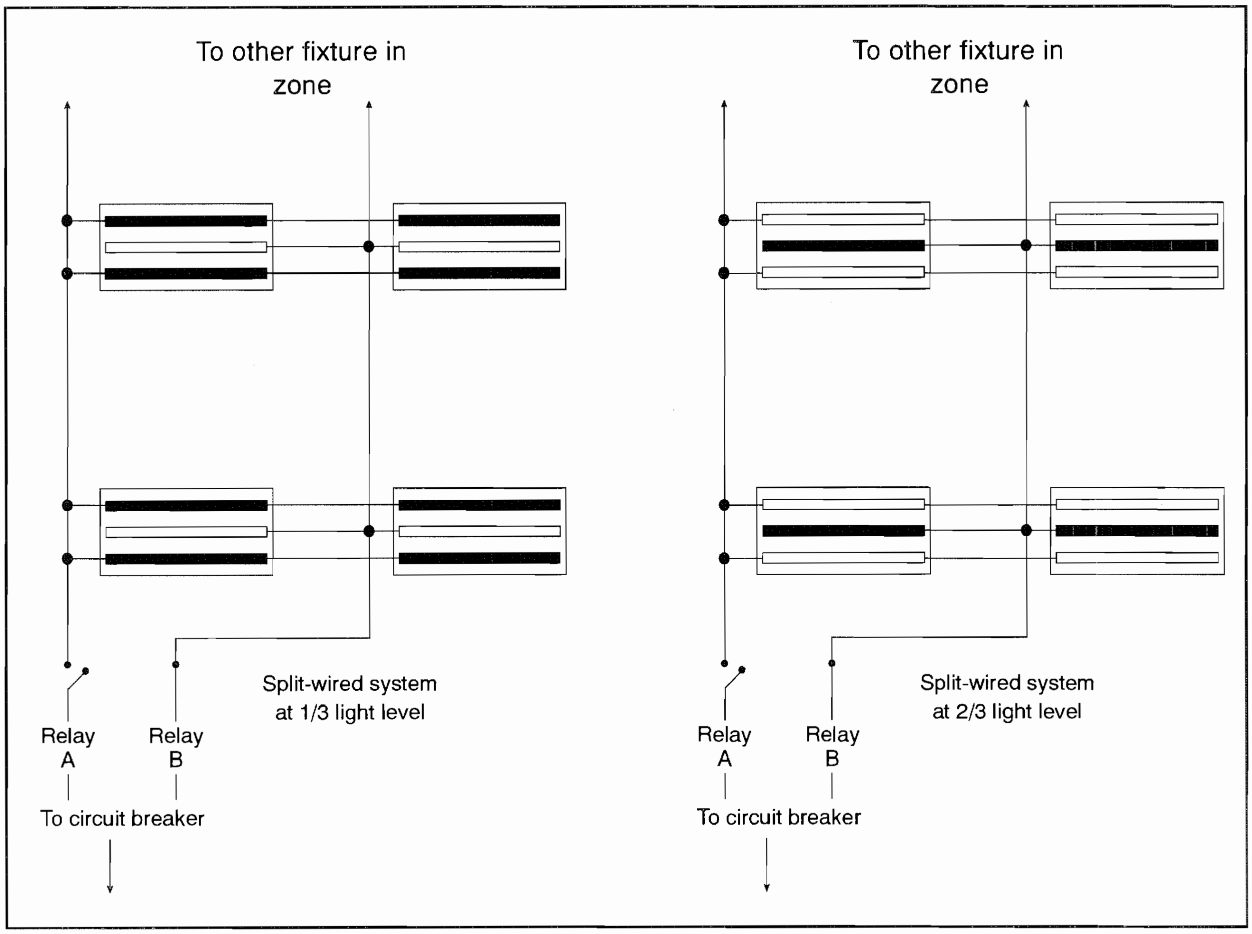


Figure F-7: Split-Wired Lighting Circuit Scheduling

With wiring configuration showing the ballasts feeding, the outer lamps in groups multi-ballasted fixtures, are wired to one relay, while the inner lamps are wired to another relay.

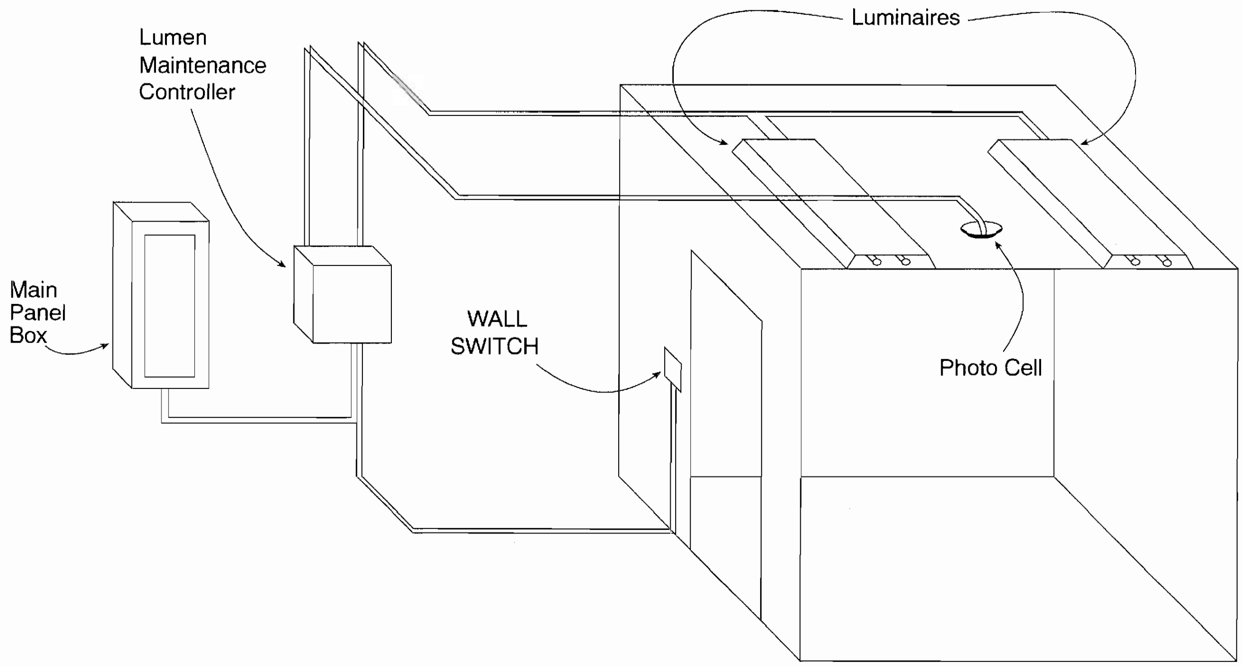
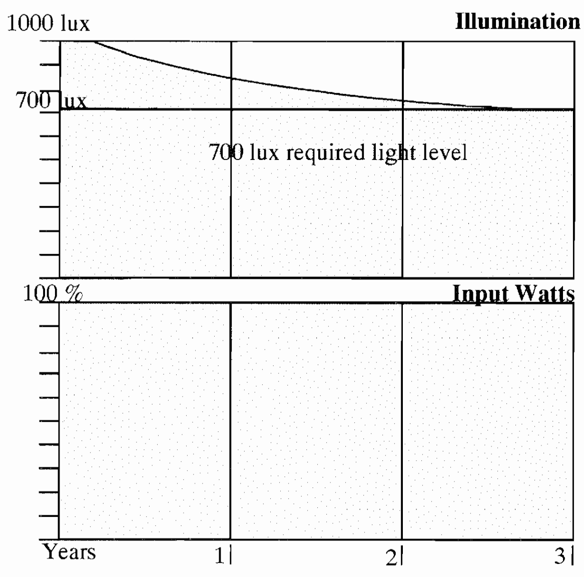
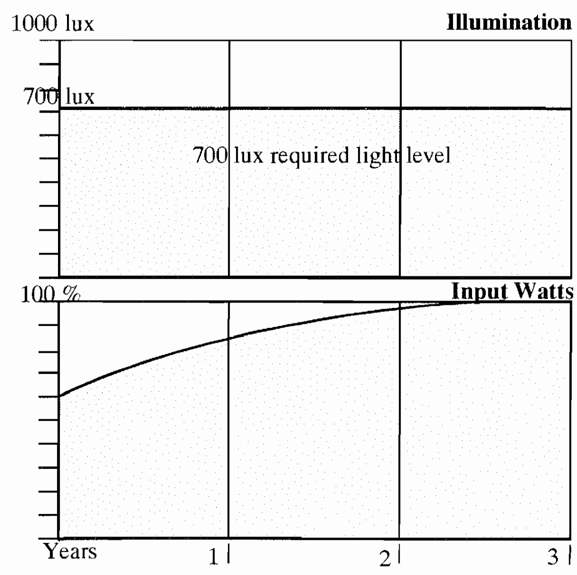


FIGURE F-8: Diagram of a Lumen Maintenance System



Standard fluorescent lighting showing 100% input watts over life of lamp,and declining illumination



Fluorescent lighting with lumen maintenance showing initial 30% reduction in input watts, with gradual increase in inputs watts over life of lamp

FIGURE F-9: Lumen Maintenance Benefits

2.3.5 PAF Credits for Occupancy Sensors: Occupant detectors use ultrasonic detection or infrared-sensing technologies to detect the absence or presence of a person in the space being monitored and switch the lights off or on accordingly. Appropriate location would be one and two persons in enclosed offices, conference rooms, retail store supply rooms and infrequently used areas in industrial settings. Most occupancy sensors will detect occupants only within an area of about 9 m^2 to 23 m^2 and should be used according to their limitations.

2.4 Fluorescent Lamp Ballast Requirements

There are three (3) separate requirements for ballasts used with fluorescent lamps as follows:

a) Ballast efficacy factor limit
b) Power factor limit
c) Tandem wiring specifications if twin ballasts are available These are described in sequence below.

2.4.1 Ballast Efficacy Factor: Fluorescent lamp ballasts shall have the following characteristics to meet or exceed the minimum Ballast Efficacy Factor (BEF) shown in Table 5-3 of EEBC-94.

a) Operate at nominal input voltage of either 110, 220 or 240 volt 50 Hz. with a maximum lamp operating current of less than 1000 milliamperes.
b) Designed for use in starting circuits at temperature above 4.4 °C.
c) Used to operate one of the following lamp types:
   1. One or two 1200 mm nominal 40 watt, rapid start lamp
   2. One or two 1200 mm nominal 36 watts slim line lamps
   3. One or two 1600 mm nominal 70 watts slim line lamps
d) Not specifically designed for use with dimming controls.

The Ballast Efficacy Factor (BEF) = BF/Power Input where Ballast Factor (BF) is the ratio of a lamp's light output using a reference ballast of the appropriate rating to that of the lamps rated light output. Most ballast factors are less than one, although new ballasts designs can have BF greater than one. Power input is the total wattage of the combined lamps and ballasts.

The intention is to eliminate the use of the standard inefficient magnetic core ballast with a loss of 12 to 13 watts when used with a 1200 mm 40 watt fluorescent lamp, and replace it with either:

a) A high efficient core ballast with a loss of 7 watts;
b) A super high efficient core ballast with unit loss of 3.7 watts;
c) An electronic high frequency ballast with unit loss of 3 watts

The high frequency electronic ballast has other advantages such as no flickering with low loss of about 6 watts for a twin unit. They are available at a comparatively higher cost of about 4.5 times the cost of the standard ballast, although the relative cost should decline in the near future.

The Ballast Efficacy Factor (BEF) applies to specific lamp ballast combination which has been determined for the nominal 40 watt 1200 mm fluorescent lamp. BEF limits for the 36 watt 1200 mm and the 70 watt 1800 mm used locally have not been determined with any degree of consistency.

The manufacturer or supplier of the light fixture should provide information needed for compliance in the form of a certificate stating that the Ballast Efficacy Factor (BEF) complies with the Codes requirement.

2.4.2 Ballast Power Factor: Power Factor of all ballasts shall be 0.9 or greater with the exception of dimming ballasts, circline and compact fluorescent lamps, and low voltage high intensity discharge lamps of 100 watts or less. Notwithstanding these exceptions, the application of power factor correction should be considered where possible by adding a suitably sized capacitor to the lamp circuit.

Compliance would entail the provision of a copy of a certificate from the manufacturer or supplier that the applicable ballast controls have the degree of power factor correction.

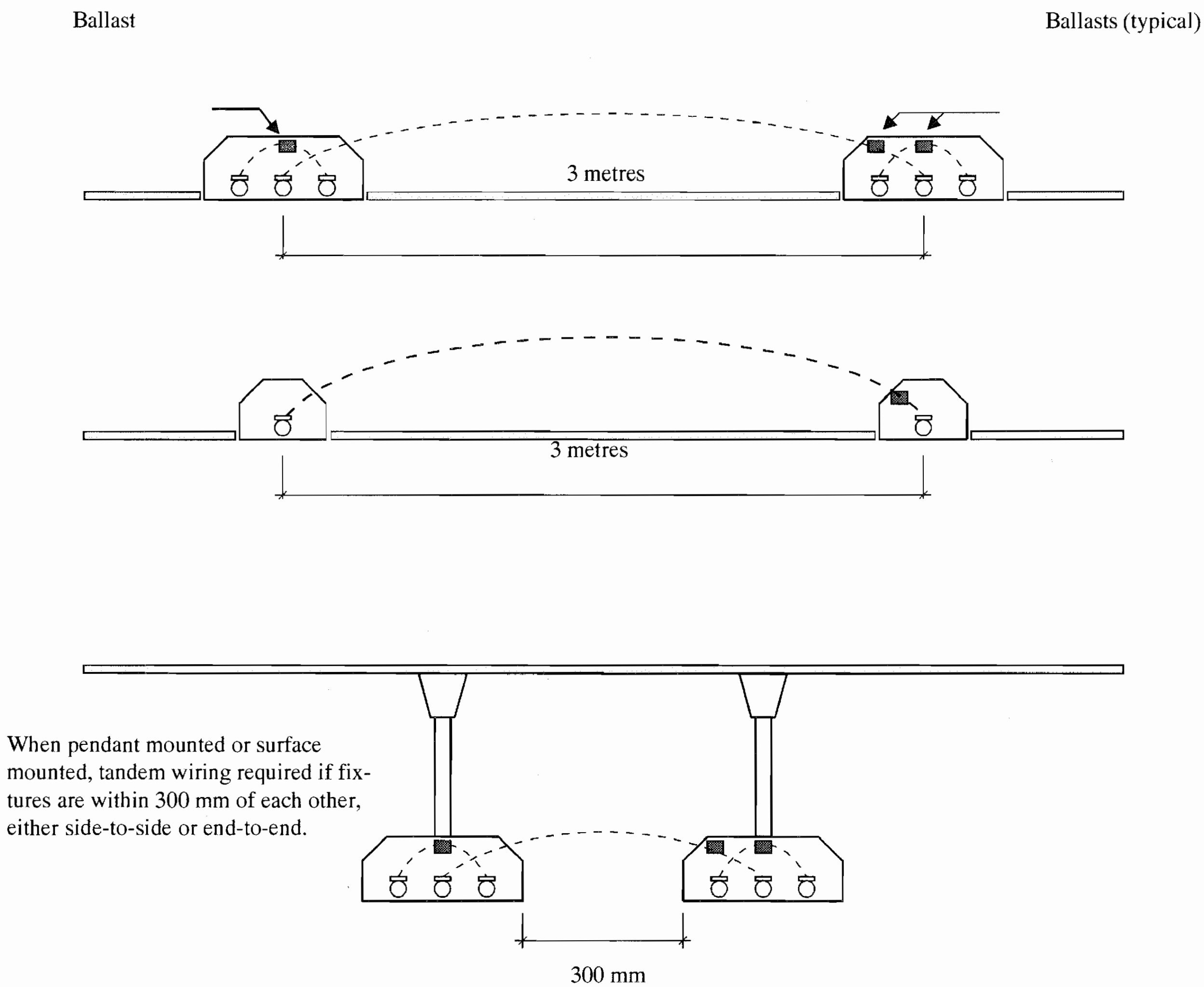


FIGURE F-10: Tandem Wiring Requirement Examples

2.4.3 Tandem Wiring: this is where a twin ballast unit controls a single lamp in one luminaire and an adjacent single lamp in another luminaire in one or three lamp fixtures. Tandem wiring is required under the following two conditions where one-lamp and three-lamp fluorescent fixtures are used. First, if fixtures are recessed mounted and are within 3 m centre to centre. Second, if fixtures are pendant or surface mounted and are within 0.3 m centre to centre. Figure F-10 shows three different examples of applivable tandem wiring requirements.

Twin lamp ballast units: preference should be given to the use of twin lamp ballast units, if they are available, in place of single ballast units as one twin unit should be more efficient than two single units. Tandem wiring is not required if three-lamp ballast units are used with three-lamp fittings.

3.5 Building Exterior Lighting - Power Allowances

The exterior lighting power to be installed shall not exceed the Exterior Lighting Power Allowance (ELPA) listed in EEBC Table 5-4 (EEBC 5.4.5). The items covered in Table 5-4 include entrances, building exterior facades, and outdoor areas such as storage areas, driveways and parking lots. The intention is to set reasonable limits to the electrical power used for external lighting and encourage the use of efficient lamp systems. There are no recommended illuminance levels given in the code, only the various allowable watts per m^2 and watts per linear m. Also, trade-offs are not permitted between power allowances for buildings interiors and exteriors (EEBC 5.4.5.1).

To comply with the requirements, the suggested approach is to prepare a design for each area using the recommended illuminance levels in the appropriate IES Journal Appendix and cross check that the watts per m^2 is equal or less than the Code's requirement. If the allowable watts per m^2 exceeds the Code's requirement, use an efficient lamp system.

3 Interior Lighting Power Allowances (ILPA) - Prescriptive Path

This is essentially one of the main requirements of the EEBC. It states the maximum watts per m^2 of lighting power allowed for the interior of a building, based on the primary occupancy for which the building is intended. The Interior Lighting Power Allowance (ILPA) for the whole building is then evaluated using equation 5-3 (page 14 of the Code) as follows:

ILPA = ULPA x GLA EEBC Eq. (5-3)

where ULPA is the maximum unit lighting allowance for the major lighting activity.

GLA = the gross lighted area in m^2.

3.1 Requirements

To determine the maximum allowed lighting power, use the following procedure:

a) Select from Table 5.5 the appropriate Lighting Power Allowance (ULPA) based on the primary occupancy, then use equation 5-3 of the Code to determine the ILPA for the total building.

b) Where 10% of the gross lighted area of the building is intended for multiple space activities, other than the primary occupancy, then the unit lighting power allowance for each separate type of occupancy (of more than 10% of gross lighted area) should be used and summed to obtain the ILPA.

c) EEBC 5.5.3, allows an adjustment for building sizes as listed in EEBC Table 5-6. An increase of 15% in ILPA is allowed for areas less than 900 m^2 and an increase in ILPA of 25% is allowed for areas less than 190 m^2. These increases recognize the difficulty of designing comparative efficient systems for smaller spaces/buildings which tend to require more lighting on a square metre basis. Example for small spaces, the required number of light fixtures may be evaluated at 1.5 fittings. In practice 2 units would be installed to increase adversely the CLP of the building. Similarly, the purchasing power and expertise to obtain more efficient equipment is not readily available. The percentages listed in EEBC Table 5-6 have been extracted from ASHRAE Standard 90.1-1989.

To elucidate the process, the interior lighting power allowance (ILPA) is calculated below for 3 example buildings.

Prescriptive Compliance Example 1: Two Storey Building—Mixed Office & Retail Uses

A two storey building consisting of two floors with dimensions 36.6 m x 18.3 m is used as follows, with the appropriate ULPA for each space activity from EEBC Table 5-5 and 5.7

Activity	lux	Area (m^2)	ULPA (W/m^2)	ILPA (W)
(1) Retail	500	600	21.5	12900
(2) Storage 10%	100	67	3.2	214
(3) Office	500	670	17.2	11524
Total		1337		24638

Thus, the total ILPA requirement for the building is 24,638 W, for an average of 24,648 / 1337 m^2, or 18.4 W/m^2 for the building. Compliance forms LTG-1 and LTG-2 have been developed, as shown in Appendix M, to record the details and evaluate the ILPA for the whole building.

Note: If the building were less than 1000 m^2 in area, then alternate small building compliance forms would be used (SB/LTG-1 and SB/LTG-2). The small building forms require less information and are simpler to use.

Prescriptive Compliance Example 2: Three Storey Building - Mixed Office and Retail Use

The building 36.6 m long by 18.3 m wide is to be used as offices on the two top floors and a retail store on the ground floor. The procedure for compliance with the prescriptive requirements of a typical 3 storey mixed use building is as follows.

Having identified the primary use, the next step is to look at Table 5-5 of the Code to find the recommended illuminance level and the corresponding unit lighting power allowance ULPA. This is found to be:

a) Office Buildings 400 to 500 lux candles and 17.2 W/m^2 for the ULPA.
b) Retail Merchandising 500 lux candles and 21.5 W/m^2 for the ULPA.

These values are entered on the Form LTG-2 as 500 lux recommended and 500 lux designed. The ULPA for spaces of similar activities is entered on the form with the gross lighted area which when multiplied together gives the ILPA for the practical space, that is 23040 for the office spaces and 14400 for the retail merchandising space. Summing the ILPA for each space gives the total ILPA for the building as 37,440 watts.

Prescriptive Compliance Example 3: Hotel

The procedure would be similar for another type of building as say hotels/motels as follows:

a) All areas of guestrooms and corridors are treated together with an illuminance level of 50 lux and evaluated at a projected installed lighting power of 12.9 W/m^2.
b) All public areas are grouped with a recommended illuminance level of say 150 lux and evaluated at 11.8 W/m^2.
c) All banquet and exhibit areas at an illuminance level of 300 to 500 lux evaluated at 21.5 W/m^2

The gross area for each space activity is multiplied by the ULPA. The sum of the interior lighting allowance for all the separate spaces is calculated to give the total ILPA for the hotel/ motel building.

3.2 Compliance with Prescriptive Requirements

The total connected power for all lighting circuits including ballast losses (CLP) shall not exceed the value for ILPA as determined by EEBC equation 5-3.

Where 10% or more of the gross lighted area is used for other activities, that is, different from the primary use, a separate or weighted average of the unit lighting power allowance should be used and summed to determine the ILPA.

Compliance will involve completing a design using the recommended illumination levels and selecting light fixtures whose total input watts or Connected Lighting Power (CLP) is less than the total ILPA as stipulated in article 5.5.2 of the code.

3.2.1 Compliance Example for the 3 Storey Building Example: Where the standard recessed troffer light fixture is used with twin 40WT12, 1200 mm tubes and prismatic diffusers, the evaluated Connected

Lighting Power (CLP) for the three storey building under consideration is 50,184 watts compared with a design ILPA of 37,440 from Form LTG-l, in Appendix L. This means that the CLP of the building is too high and does not comply with the prescriptive requirements.

The solution is to consider more efficient light fixtures with much lower ballast losses and higher lumens output for the lamp. Examining the details, on ballast losses obtained from the manufacturer publication on the ballasts, the standard ballast loss for a 40 W/ T12 1200 mm tube delivering 2800 lumens used locally is 13 watts compared with 7.6 watts for a low loss and 3.7 for a super low loss used with a 36 watt T8 lamp, delivering 3200 lumens.

On account of the higher lumens output of the T8 lamp, an evaluation of the number of light fixtures required indicate that a total of 456 standard light fixtures are required compared with 480 fixtures with higher efficient lamps and ballasts combination, for all areas of the typical three storey building.

The input watts of a 1200 mm x 600 mm three (3) lamp fixture with low loss ballast and T8 high efficient tube is 125.4 watts compared with 153 watts of the standard version. The total Connected Light Power (CLP) of the efficient lighting system is 125.4 watts x (48 x 6) or 36115 watts for the whole building. This is less than the ILPA of 37,440 watts. The building therefore, complies with the prescriptive requirement.

3.2.2 Construction Modification And New Solution: During construction of the building, the proposed tenant for the retail store requests additional lighting of 2000 watts in the display area, thus increasing the calculated CLP from 36,115 to 38,115 watts.

When the information is entered on Form LTG-2, the total Connected Lighting Power (CLP) for the building is 37,615 watts. This exceeds the Interior Lighting Power Allowance (ILPA) by a mere 175 watts. However, to comply with the requirements, a programmable timing device with a PAF of 0.15, is selected to schedule the switching off of the particular display light load at specific times.

The Lighting Power Control Credit (LPCC) - (1500 x 0.15) is 225 W. Entering this credit on form LTG-2 and subtracting from the adjusted total Connected Lighting Power (CLP) for the building is 37,390 watts which complies with the prescriptive requirement.

3.2.3 Compliance Note: Some current office designs that use the standard four 40 watt tube 1200 mm x 600 mm recessed troffer with prismatic diffuser on a grid pattern will not meet the ILPA requirement of the Code.

The previous exercise using the standard T12, 3 tube fixtures and ballasts, demonstrated that the CLP would not meet the Code's requirement. This is because the standard ballast used is basically an inefficient device with 25% of the input watts (39/153) dissipated in heat, as against 18% for the high efficiency ballast and 9-1/2 % for the super low loss ballast.

There is however, a higher initial cost for the low loss ballast of about 2-1/2 times greater than the standard ballast and 4-1/2 times for the super low loss ballast. Notwithstanding, because of the high cost of electrical energy, it can be shown that the simple pay back period for using high efficiency ballast in place of the standard inefficient ballast is about 1.3 years.

In general, there are several ways of modifying the features of the lighting system to reduce the Connected Lighting Power (CLP) to equal or better the Interior Lighting Power Allowance (ILPA) as follows:

a) Using low loss and super loss ballast as mentioned above, to give reduced input wattage to the fixtures of 18% and 24% respectively on the standard ballast.

b) Using the new T8, 26 mm fluorescent tube with higher efficiency and colour rendering in place of the standard T12 38 mm tube.

c) Use light fixtures with large-cell parabolic reflective/ louvre design giving good glare control and directs the light downward onto the task area. This means improved luminaire efficiency with higher coefficient of utilization requiring a smaller number of fixtures for the same task.

LIGHTING CALCULATION SHEET

CLIENT: ______________________ DATE: ______________

PROJECT: ______________________ FILE: ______________

LOCATION: ______________________ CALC.BY: ______________

		(a)	(b)	(c)
1.	Length		36.6 m	
2.	Width		9.1 m	
3.	Area		333 m^2	
4.	Height		2 m (2.74 m ceiling)	
5.	Room Ratio		333 / (2 x (36.6 + 9.1)) = 3.64	
6.	Proposed fitting		1200 mm x 600 mm recessed troffer with prismatic diffuser	
7.	Lamp watts and type	40 T12	3200 T8 36W	3200 T8 36W
8.	Luminous output per lamp	2800	3200	3200
9.	No. of lamps per fixture	3	3	3
10.	Illumination required	50	50	50
11.	Reflectance factor – ceiling – wall – floor	% 50 % 50 % 50		
12.	Utilization factor	0.45	0.47 x .98 = 0.45	0.45
13.	Maintenance factor	0.85	0.85	0.85
14.	Area per fitting $\frac{(8x9x12x13)}{10}$	64	74	74
15.	No. of fittings $\frac{(3)}{(14)}$	56	48	48
16.	Watts loss per ballast	13	7.6	3.7
17.	No. of ballasts per fixture	3	3	3
18.	Total ballast losses (watts) per fixture (16x17)		39	22.8 11.1
19.	Total input watts per fixture (7 x 9 + 18)	153	125.4	116.1
20.	Total watts per space (19x15)	8568	5517	5108
	Watts per sq. metre	25.6	16.5	15.3

(a) 1200 mm x 600 mm recessed troffer with 3 No. T12 tubes and 3 std. ballasts
(b) 1200 mm x 600 mm recessed troffer with 3 No. T8 tubes and 3 low loss ballasts
(c) 1200 mm x 600 mm recessed troffer with 3 No. T8 tubes and 3 super low ballasts

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Appendix G:
Electric Power and Distribution

Contents of This Appendix

1 Introduction G-1
2 Metering G-1
3 Transformers G-2
4 Electrical Motor Efficiency G-2

1 Introduction

The purpose of this section is to define the basic requirement for electrical power and distribution systems applicable to all building electrical systems, except emergency systems.

2 Metering

The intention is to make provisions at the design stage where it is least costly to implement measures for monitoring the energy performance of the building.

The opinion is that if metering facilities are provided, then greater interest will be taken to adopt and maintain energy conservation practices.

2.1 Basic Requirements

There are essentially two basic requirements, and both concern metering.

a) The first is the provision of metering facilities to check the electrical consumption in buildings where the connected electrical service is greater than 250 kVA.

The electrical power feeders for each facility for which check metering is required shall be subdivided in accordance with the following suggested categories:

1) Lighting and receptacle outlets.
2) VAC systems and equipment
3) Service Water Heating (SWH) systems, elevators and special or other occupant equipment of more than 20 kW as kitchens, printing equipment
4) Computer rooms with special power requirements.

Exception: Where the electrical load is ten percent (10%) or less on a feeder, it may be connected to another usage category.

b) The second basic requirement is that feeders for each category shall contain provisions for portable or permanent check metering facilities.

2.2 Compliance

The metering facility would consist of :

a) A voltmeter with line selector switch, and an ammeter with line selector switch. These two sets of meters are installed on the main incoming service to monitor the voltage and current taken from the utility service.
b) Watt hour meters in each of the sub-circuit feeders to each of the four (4) suggested categories mentioned in EEBC 6.4.1.1.

For large installations, current transformers are necessary to operate the watt hour meter and these devices are installed at the time of manufacture of the switchgear.

On account of this, the metering facilities of each sub-circuit category would be a permanent feature. For smaller installations where the cost of providing fixed check metering facilities cannot be justified, the socket bases for plug-in watt hour meters should be incorporated in the sub-feeder for each category. With this arrangement, one plug-in watt hour meter could be bought and used to monitor when necessary, the performance of each sub-circuit category. It should be noted that a suitable way of bridging out the current section of the watt hour meter socket is necessary when the meter is not in place. The alternative is to use a portable watt hour meter.

The suggested grouping of the load is based on current practice of monitoring separately the two (2) major categories, lighting and air conditioning loads. The feeder to the computer rooms are placed in a separate category as this is nearly always fed from a dedicated service.

Form ELEC-l of EEBC-94 should be completed indicating that the requirements have been met based on the suggested approach mentioned above. A copy of this form is included in Appendix M.

3 Transformers

3.1 Requirements

If the total capacity of transformers, excluding utility-owned, exceeds 300 kVA, a calculation of the total estimated annual operating cost of the transformer losses shall be made, based on estimated hours of transformer operation at projected part-load and full-load conditions, and the associated transformer core and coil losses. The calculation procedure is contained in Compliance Form ELEC-2 included in Appendix M.

3.2 Comments

First, it is necessary to fill in the transformer details as serial No., rating, rated temperature rise, cooling medium and most important, the rated no-load transformer loss (%) and the rated full-load coil losses (kW). This information, if not stamped on the plate, should be available on the drawings provided at the time of purchase. The other part of the form is completed using the no-load and full-load losses to evaluate the cost of the estimated annual transformer losses.

3.3 Compliance

The appropriate transformer section of Form ELEC-2 should be completed for all transformers rated over 300 kVA used for building services.

4 Electrical Motor Efficiency

4.1 Requirements

The requirement states that all permanently wired polyphase motors of 0.37 kW or more serving the building and expected to operate more than 500 hours per year, shall have a minimum nominal full-load efficiency no less than the values shown in EEBC - 94 Table 6-1.

The motors applicable are nominal 1000, 1500 and 3000 r.p.m 50 Hz. in open, drip proof or totally enclosed fan cooled (TEFC) enclosures. Other types of motors are exempted from the efficiency requirements of the Code.

Motors of differing horse power from those listed shall have an efficiency greater than that of the next lower motor horse power.

4.2 Comments

Motors loads as pumps or as used in a wide variety of equipment for residential and commercial buildings, and industrial process, account for the major use of electricity in most countries. The smaller sized polyphase alternating current, induction motor of 0.75 kW or greater is used for many applications and may account for an estimated seventy five (75%) of the motor energy use (Lovins et al., 1989).

On account of the great potential for energy savings with motor loads, most manufacturers produce two versions of motors - a standard efficiency motor and a high efficiency motor. The high efficiency type cost about ten to thirty percent (10-30%) more than the standard with a average of about fifteen percent (15%) more for the large size motors, but reduces energy use by two to fifteen percent (2-15%) dependent on motor size (Stout & Gilmore 1989).

However, as a year's operating cost of a motor often exceeds the purchase price, a small increase in operating efficiency would pay quickly for the added cost of the higher efficient motor.

In general, it can be shown by others who researched this field, that high efficiency motors are cost-effective whenever the annual operating hours exceed 1600 hours approximately. (A.D Little & Rhode Island Analysis).

The strategy to adopt locally, especially as our energy cost is generally higher than in most countries, is to determine when the operating hours are in excess of 1600 hours per annum and consider using high efficiency motors. A cost analysis study may be necessary to convince the Client that this is the way to save annual operating cost. However, to protect the slightly increased investment cost, the control equipment should be provided with protecting devices as a phase monitor to disconnect the motor from the incoming supply when phase failure, under voltage and phase reversal condition exist. It may be prudent also to include thermal protection into the motor windings as a backup to the standard over current device.

4.3 Compliance

Compliance Form ELEC-1 in Appendix M should be completed to indicate that the motor efficiency is not less than the minimum value stated in EEBC Table 6.1. For transformers with capacity in excess of 300 kVA, Compliance Form ELEC-2 in Appendix M should be completed.

References

References listed in this appendix were cited in a paper by Steve Nadel, "Efficiency Standards for Lamps, Motors, And Lighting Fixtures," ACEEE Proceedings, Vol. 7, Asilomar, 1990.

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Appendix H: Ventilating and Air-Conditioning (VAC) Systems and Equipment

Contents of this Appendix

1 Introduction H-1
2 Ventilation & Air-Conditioning Systems......... H-2
3 Prescriptive Requirement................................ H-8
4 Ventilating & Air Conditioning Equipment... H-10

Commentary

This section of the compliance guidelines discusses the requirements for both ventilation and air-conditioning (VAC) systems and equipment. The requirements for VAC systems is contained in EEBC Section 7, while the requirements for VAC equipment are listed in EEBC Section 8. Compliance forms are provided in Appendix M.

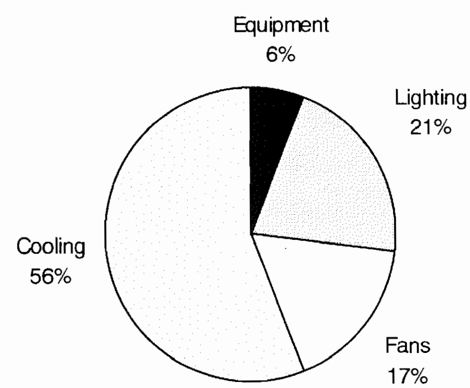


Figure H-1: Energy End Use Mix for a Typical Large Office

1 Introduction

1.1 Impacts of VAC Systems and Equipment

The design and selection of the VAC systems and equipment can have a major impact on the energy efficiency of a building design. In the type of climate experienced in Jamaica, energy for cooling and fans can require a major portion of the energy consumed by a building. For example, Figure H-1 shows the apportionment of energy end uses in a large office building with construction characteristics typical of recent construction practice in Kingston. By far the largest consumers are cooling system and the fans together.

The EEBC-94 determines both basic and prescriptive requirements for the VAC systems. On the other hand, only basic requirements are contained in the equipment section. Compliance with basic requirements is mandatory in all cases of VAC systems. Prescriptive requirements are also mandatory unless they are supplanted by a more energy-efficient solution using the whole-building compliance path contained in EEBC section 12.

Per EEBC section 7, for VAC systems the EEBC code:

a) Requires a detailed load calculation to be done for each application.
b) Prohibits the use of some types of systems except under certain circumstances.
c) Insists on at least one automatic temperature control per system.
d) Defines insulation thickness on cold pipes.
e) Indicates minimum specifications for fan system design.

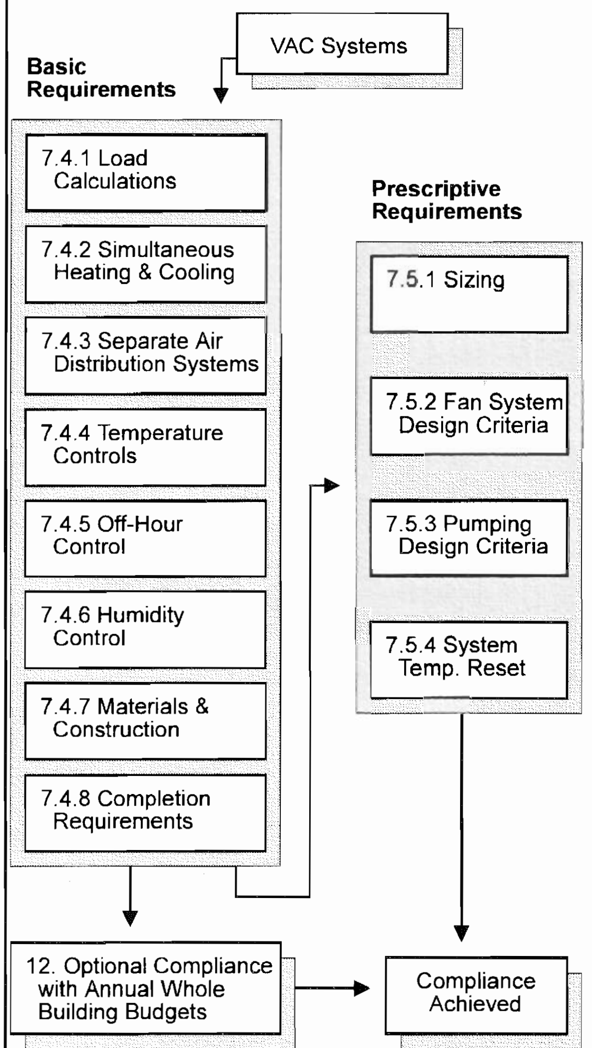


Figure H-2: Compliance With VAC Requirements of the EEBC

f) Specifies minimum criteria for pumps and water systems.

Per EEBC section 8, for VAC equipment the EEBC code:

g) Lists minimum equipment performance in relation to COP and EER in EEBC Table 8-1

h) requests that for Integrated Part-Load Values (IPLV) equipment, the efficiency shall comply with the requirements listed in the ARI standards.

For VAC systems, Figure H-2 shows schematically that compliance with the basic requirements is required in all cases (EEBC sections 7.4.1 to 7.4.8). In addition, one comply with either the prescriptive VAC system requirements of EEBC sections 7.5.1 to 7.5.5 or with the whole-building annual budget method of EEBC section 12. If the whole building approach of EEBC Section 12 is used, then the EEBC prescriptive VAC requirements are used to define a VAC base case. The base case defined for the entire building becomes a benchmark against which the building design is compared and tested.

Whole-building analysis and compliance requires the cooperation of Architect, Electrical and Mechanical Engineers and will likely result in a more innovative and energy efficient building, but must also be used in conjunction with basic and prescriptive requirements. In the future, compliance using the Whole-building Annual Budget Method of EEBC section 12 will be required for all buildings with gross floor area exceeding 4,000 m^2.

2 Ventilation & Air Conditioning Systems

2.1 Load Calculations

Load calculations may be used to accomplish one or more of the following objectives:

a) Provide information for equipment selection system sizing and system design.

b) Provide data for evaluating the optimum possibilities for load reduction.

c) Permit analysis of partial loads as required for system design, operation and control.

Before a cooling time can be properly estimated, a complete survey must be made of the physical data. Table 1.4 (ASHRAE GRP 158) gives a check list of both internal and external input information that should be included. The procedure for calculating space design cooling load is outlined in Table 1.2 (ASHRAE GRP 158) using the Cooling Load Temperature Difference (CLTD) method. The EEBC load criteria for applying the ASHRAE GRP 158 method are contained in EEBC sections 7.4.1.1 to 7.4.1.8. Figure H-3 explains the key criteria graphically. A Lotus 123 (TM) spreadsheet for using the ASHRAE GRP 158 method has been developed in Jamaica, and the JBS should be contacted for the availability and use of this software package.

Space cooling is the rate at which heat must be removed from the spaces to maintain air temperature at a constant value. Cooling load, on the other hand, is the rate at which energy is removed at the cooling coil that serves one or more conditioned spaces in any central air conditioning system.

It is equal to the instantaneous sum of the space cooling loads for all spaces served by the system plus any additional load imposed on the system external to the conditioned spaces. Items such as fan energy, fan location, duct heat gain, duct leakage, heat extraction lighting systems and type of return air systems all affect component sizing.

The manner in which load source enters a space is indicated as follows:

a) Solar radiation through transparent surfaces such as windows

b) Heat conduction through exterior walls and roofs

c) Heat conduction through interior partitions, ceilings and floors

d) Heat generated within the space by occupants, lights, appliances, equipment and processes

e) Loads as a result of ventilation and infiltration of outdoor air

f) Other miscellaneous heat gains.

Cooling: 24°C and 55% RH or equivalent →	7.4.1.1 Indoor Design Conditions
Zone A: Kingston 34°C db, 27°C wb Zone B: Montego Bay 32°C db, 26°C wb Zone C: Mandeville 31°C db, 24°C wb →	7.4.1.2 Outdoor Design Conditions
7 L/s non-smoking and 9 L/s smoking ASHRAE 62-1981 & later →	7.4.1.3 Outdoor Ventilation
Use actual, if known, or else use values in Table 7-2 →	7.4.1.4 Building Occupancy
Loads based on envelope characteristics consistent w/ Sect. 4 compliance →	7.4.1.5 Envelope
Use actual design or power budgets from Sections 5.5 or 5.6; other loads from design data or ref. sources →	7.4.1.6 Lighting and Other
May increase up to 10% at designer's option →	7.4.1.7 Safety Factor
May increase up to 10% above design loads to account for steady state loads →	7.4.1.8 Pickup Loads

Figure H-3: EEBC Criteria for Preparing Load Calculations

Diversity of cooling load results from not using part of the load on a design day. Therefore, diversity factors are factors of usage and are applied to the refrigeration capacity of large air conditioning systems. These factors vary with location, type and size of application.

Generally, diversity factors can be applied to loads from people, and lights as there is neither 100% occupancy nor total lighting at the time of such other peak loads as peak solar and transmission loads. The reduction in cooling loads from non-use are real and should be accounted for. Listed are some average typical diversity factors for large buildings during occupied periods.

Type of Application	**Diversity Factor** Lights	People
Office	0.70 to 0.85	0.75 to 0.90
Apartment, Hotel	0.30 to 0.50	0.40 to 0.60
Department Store	0.90 to 1.00	0.80 to 0.90
Industrial	0.80 to 0.90	0.85 to 0.95

In the case of Industrial, diversity should also be applied to the machinery load.

Peak loads vary with the time of day and month of year. Applications with low internal loads are more sensitive to building envelopes. For other types of applications where lights, people and other internal loads are more dominant, the hour of the peak load generally will depend on the relative magnitude and peak hours of the following loads:

a) Solar through—See GRP 158 Table 3.25 for glass peak hour for orientation of the major glass area
b) Lighting—See GRP 158 Table 4.4 for appropriate lighting schedule and profile
c) Ventilation—Typically peaks at 1500 hours (3:00 P.M.) solar time
d) Roof, if present—See GRP 158 Table 3.8 for appropriate type of roof and peak time

(Courtesy ASHRAE GRP 158 - Load Calculation Manual)

2.1.1 Indoor Design Conditions: Indoor design conditions may be 24°C DB 55% RH or any equivalent comfort conditions (19 °C WB).

2.1.2 Outdoor Design Conditions: Outdoor design conditions for Summer design loads may be as stated in Table 7-1, EEBC-94, but it is advisable to check local weather data.

2.1.3 Outdoor Air Ventilation: Outdoor air flows through a building in three different modes; forced ventilation, natural ventilation and infiltration. The air exchange rate at any given time generally includes all three modes. In large buildings, the effect of infiltration and ventilation and distribution and interzone airflow patterns, which include smoke circulation in the event of fire, should be determined (ref. 1987 HVAC vol. Chapter 58).

Forced ventilation is generally mandatory in larger buildings where a minimum amount of outdoor air is required for occupant health and comfort and where mechanical exhaust system is advisable or necessary. Tighter, more energy-conserving buildings require ventilation systems to assure adequate amount of outdoor air for maintaining acceptable indoor air quality. GRP 158 Table 5.3 outlines the ASHRAE ventilation requirements for occupants, but for further general applications, a basis of estimating the L/s per person is:

People not smoking	**People smoking**
7 recommended	19 recommended
2 minimum	12 minimum

In any event, to provide for physiological needs, the outdoor air quantity should never be less than 2 L/s per person.

2.1.4 Building Occupancy: The rates at which heat and moisture are given off by human beings depend on the type of activity, mode of dress and environmental conditions. Some practical values for these rates are given in Table 4.5 (ASHRAE GRP 158) for the approximate conditions, activity and dress appropriate to the applications listed and which are commonly encountered. The latent heat gain from people can be considered instantaneous cooling load, but the total sensible heat gain is not converted directly to cooling load. The radiant portion is first absorbed by the surroundings and then convected to the room at some later time depending upon the thermal characteristics of the room. The radiant portion of the sensible heat loss is near 70% and this was used to generate the cooling factors in GRP 158 Table 4.6. With regard to people density, column 1 of GRP 158 Table 5.3 namely "Estimated Persons/300 m^2 floor area" contains additional information for occupancy area by use.

2.1.5 Envelope: The EEBC Code requires that envelope cooling loads be based on envelope characteristics consistent with the values used to demonstrate compliance with EEBC Section 4. Building materials, external surface colours, orientation and external shading may be determined from the plans and specifications.

Possible high ground-reflected solar radiation from adjacent water, sand, parking lots or solar loads from adjacent reflective buildings should not be overlooked. The effect of solar radiation is more pronounced and immediate in its impact on exposed non-opaque surfaces. Chapter 27 of the 1989 HVAC Volume discusses the calculations of heat loads imposed by fenestration.

Heat gain through exterior opaque surfaces is derived from the same elements of solar radiation and thermal gradient as that for fenestration areas. It differs primarily as a function of the mass and nature of wall or roof construction, since those elements affect the rate of conductive transfer through the composite assembly to the interior surface.

2.1.6 Lighting: Since lighting is often the major space load component, an accurate estimate of the space heat gain it imposes is needed. Only part of the energy from lights is in the form of convective heat, which is picked up instantaneously by the air conditioning system. The remaining portion is in the form of radiation that affects the conditioned space once it has been absorbed and re-released by walls, floors, furniture, etc. This absorbed energy contributes to space cooling load only after a time lag, so part of this energy is radiating after the lights have been switched off. The time lag should always be considered when calculating cooling load.

2.1.7 Other Loads: The EEBC Codes list a number of sources from which data on other system loads may be compiled. Actual information based on the purpose for which the building is intended combined with the designer's experience should be close enough to satisfy the needs of the project.

In a cooling load estimate, heat gain from all appliances, electrical, gas or steam, should be taken into account. Electric typewriters, calculators, cheque writers, teletype units, copiers, posting machines, etc. can generate 10-15 W/m^2 for general offices or 20-25 W/m^2 for purchasing and accounting departments. In offices with computer display terminals at most desks, heat gains range up to 50 W/m^2.

Fans that circulate air through HVAC systems add energy to system by one or all of the following processes:

a) Temperature rise in the airstream from fan inefficiency
b) Temperature rise in the airstream as a consequence of air static and velocity pressure
c) Temperature rise from heat generated by motor and drive inefficiencies

Duct heat gain is normally about 1% of the space sensible cooling load. Outward duct leakage is a direct loss of cooling and must be offset by increased air flow unless it enters the conditioned space directly.

2.2 Simultaneous Heating and Cooling

2.2.1 Dual-duct, Multizone and Terminal Reheat Systems: These may be classified as all-air systems. These provide complete, sensible and latent cooling capacity in the cold air supplied by the system and no additional cooling is required at the zone.

Where reheat is obtained from refrigeration hot gas injection apparatus, much of the cost of prime fuel is eliminated, but refrigeration energy costs remain the same.

These systems can provide good control of space thermal conditions. However, they are also very energy intensive and the EEBC requirements limit their use to a few specific situations on an exception basis:

a) **Dual-Duct Systems.** Dual-duct systems condition all the air in a central apparatus and distributes it to the conditioned spaces through two parallel ducts extended through the building. One duct carries cold air and the other warm air, providing air sources for both heating and cooling at all times. In each zone, a valve responsive to a room thermostat mixes the warm and cold air in proper proportions to satisfy the prevailing heat load of the space.

b) **Multizone Systems.** The multizone system is similar to the dual-duct system except the zone requirements are met by mixing the cold and warm air through zone dampers at the central air handler in response to zone thermostats. The mixed, conditioned air is distributed throughout the building by a system of single zone ducts.

Multizone system applies to a relatively small number of zones served by a single central Air Handling Unit. Side-by-side hot and cold airstreams are provided. Each zone is provided with dampers to mix hot and cold air to satisfy the requirements of the zone.

c) **Terminal Reheat Systems.** Terminal reheat is a method of zone control. The system obtains conditioned air from the central unit at a fixed cold air temperature. The air quantity is selected to offset the maximum cooling load in the space. The control thermostat calls for reheat when the cooling load in the space drops below the design value and the reheat which is located close to the point of distribution, is applied. Reheat may be obtained from hot water, steam, electricity, condenser water or hot refrigerant gas.

2.2.3 Concurrent Operations In engineered control systems to minimize simultaneous heating and cooling either by sequencing the heating and cooling or by limiting the source of the heating energy input. Some exceptions will always exist as in the case of dehumidification with reheat.

2.2.4 Recovered Energy: The EEBC encourages the use of recovered energy. Recovered heat comes from internal heat sources such as lighting, computers, business machines, occupants, mechanical and electrical equipment. It is used for space heating, domestic or service water heating and air reheat in air conditioning systems. Proximity of the heat source to the heat use is the most significant constraint when using heat recovery equipment. The cost of transporting air over great distances can be prohibitive. A variety of heat exchangers are available for heat recovery but the heat wheel and reclamation of condenser heat are the most common.

The heat wheel is a rotary air-to-air heat exchanger. This revolving cylinder is filled with heat transfer media through which air passes. Supply air flows through half the wheel, exhaust air through the other half. In applications with 100% outside air, exhaust air passes through half the wheel, outside air through the other half.

The simplest method of using condenser heat is making return (hot) condensing water available directly to the reheat coils.

2.3 Separate Air Distribution Systems

2.3.1 Non-Simultaneously Operating Zones: The code requires that zones which are expected to operate nonsimultaneously for more than 750 hours per year be served by an independent air distribution system. The air conditioning system selection and design should, under these circumstances, provide central system components that will permit isolation of these areas.

An example of such a system is chilled water where a central chiller plant provides chilled water which is circulated through terminal units consisting of chilled water coils, blowers, air filters, drain pans for condensate, etc. Terminal units must be properly controlled by thermostats and be provided with positive means of shutdown. Variable Refrigerant Volume (VRV) systems using refrigerant in place of water should also be considered as the energy savings is considerable.

2.3.2 Zones with Special Requirements: The code requires that zones with specific temperature and humidity requirements be provided with separate air distribution systems or, alternatively, be equipped with additional equipment to enable the main plant to be controlled for comfort purposes only. Apart from the methods described in 7.4.3.1, radiant panel systems may be used to control the climatic conditions. Temperature is maintained by circulating water, air or electric resistance. Radiant panel systems may be combined with any central station air system.

2.4 Temperature Controls

An air conditioning system maintains desired environmental conditions within a space. In almost every application there are several ways in which this may be achieved. Temperature control operation should follow a natural sequence where one controlling thermostat monitors the requirement depending on the need.

2.4.1 System Control: The EEBC requires that each air conditioning system has at least one temperature control device. The function of the control system is to adjust the equipment to match the load. Controls should be automatic and simple for best operating and maintenance efficiency. Control devices may be grouped under the three classifications of sensors, controllers and controlled devices. Many control systems include other elements such as switches, relays and transducers for signal conditioning and amplification. Chapter 51 "Automatic Control", 1987 HVAC Systems and Applications ASHRAE Handbook may be used as reference.

2.4.2 Zone Control: The EEBC requires that each zone has thermostatic control that responds to the temperature of the zone. Loads vary over time in the various areas due to changes in weather, occupancy, activities and solar exposure. Each space with a different exposure requires a different control zone to maintain constant temperature. Some areas with special requirements may need individual control or individual systems independent of the rest of the building. A design should maintain conditions in no-load zones during peak and off-peak system loads.

2.4.3 Thermostats: The single most important symbol of an energy conservation programme is the room thermostat. This one device represents the entire HVAC system to the occupant who does not understand or even care where the cold air comes from. It is the easiest place to start conservation with comfort programme. EEBC section 7.4.1.1 requires indoor conditions to be maintained at conditions equivalent to 24 °C DB, 55% RH, but research has shown that comfort can and does exist at higher values of relative humidity. (ANSI/ASHRAE Standard 55 - 1981).

The savings will result from maintaining space temperatures at a level which is compatible with new standards and which cannot be easily defeated by occupants. All the benefit accruing can be undone by allowing free, unlimited access of the occupants to thermostat adjustments.

2.5 Off-Hour Controls

After the general needs of a building have been established and the building and system subdivision has been made based on similar needs, the mechanical system and its control approach can be considered. Designing systems that conserve energy requires knowledge of the building and its operating schedule.

The EEBC Code requires that automatic controls be used to reduce energy through equipment showdown in non-use areas. Run equipment only when needed. Under most conditions, equipment can be shut down some time before the end of occupancy. However, shut down time should not permit the space temperature to drift out of the selected comfort zone before end of occupancy. For residential and small commercial applications, the supply air fan may be allowed to cycle with the compressor. Fan systems serving areas where ventilation is critical, such as operating theatres, are not good candidates for this consideration.

Fixed minimum outdoor air control provides ventilation air, space pressurization and make up for air exhaust fans. The motorized outdoor air damper should be interlocked to open only when the supply fan operates and should do so quickly to prevent excessive negative duct pressurization. The rate of outdoor air flow is determined by damper opening and the pressure difference between the mixed air plenum and outdoor air conditions.

2.5.3 Isolation Areas: The EEBC Code requires the capability to isolate zones that have substantial non-simultaneous operation. Examples of such areas are meeting rooms, board rooms and lunch rooms. The designer must obtain as much information as possible regarding the anticipated hours of use and times of occupancy so that simultaneous loads may be considered to obtain optimum air conditioning loads and operating economy. It is desirable to design adequate flexibility into each HVAC System so that cooling and ventilation may be shut off when unoccupied. Ideally, each area should have equipment distribution and control that allows it to be cooled independently of any other area.

2.6 Humidity Control

The Code sets limits on the application of humidity controls. This is necessary to prevent corrosion, prevent condensation on work surfaces, reduce static electricity, prevent product contamination, provide personal comfort, compensate for hygroscopic materials and control microbial growth. Corrosion of surfaces such as bearings and electrical contact surfaces occurs with 50% RH. At relative humidities below 40%, static charges may form attracting dust particles that later may become airborne in objectionable concentrations. The process of dehumidification by refrigeration requires a cooling coil carefully selected to maintain space conditions. It is advisable to use a psychrometric chart for proper selection and to determine reheat requirements. Controlled dehumidification always requires the use of extra energy.

2.7 Materials And Construction

2.7.1 Piping Insulation: Thermal insulations are materials or combinations of materials, applied to retard the flow of heat energy by conductive, convective and/or radiative transfer modes. The main functions are to reduce heat gain or loss, prevent vapour condensation on surfaces with a temperature below the dewpoint of surrounding atmosphere and provide fire protection. For pipes, thermal insulation normally consists of inorganic fibrous materials such as glass and calcium silicate and organic cellular materials such as cork, foamed rubber, polystyrene and polyurethane. The physical form may be flexible, rigid or semirigid.

Small pipes are insulated with cylindrical half-sections of insulation with factory applied jackets that form a hinge and lap or with "slip-on" flexible closed-cell material. Fittings insulation should always be consistent with pipe insulation. Insulation on large piping requiring separate jacketing is wired or banded in place and the jacket wired, cemented or banded, depending on the type. Jacketing commonly consists of various combinations of laminates of paper, aluminium foil, plastic film and glass fibre reinforcing. This membrane should be impervious.

2.7.2 Airhandling System Insulation: The need for duct insulation is influenced by duct location, the effect of heat gain on equipment size and operating cost, the need to prevent condensation, the need to control temperature change in long duct lengths, the need to control noise with inferior duct lining.

All cooling ducts in any non-conditioned space should be insulated and have vapour retarders to prevent condensation. Duct liner insulations have sound-permeable coatings or other treatment on the side facing the airstream to withstand air velocities without deterioration. Duct insulations include semirigid boards and flexible blanket types.

Exterior duct insulation can be attached with adhesive with supplemental pre-attached clips and pins or with wiring and banding. Liners can be attached with adhesive, clips and pins.

2.7.3 Duct Construction: Duct construction standards do not deal with system design in terms of layout and sizing. This is provided by the Design Engineer. The VAC Contractor is responsible for the construction and installation of structurally sound ductwork that will meet specified performance, is satisfactorily air tight and will not vibrate and breathe when the air stream varies in pressure.

There are two distinct classifications of systems:

a) Low velocity for systems up to 50 mm wc and velocities up to 10 m/s.
b) High velocity for systems 50 mm through 250 mm wc and velocities over 10 m/s.

The EEBC outlines certain test procedures that must be observed and reports that shall be provided for duct work which is designed to operate at static pressures in excess of 75 mm wc.

Each classification has a separate duct construction standard contained in the SMACNA publications. The most extensively used construction material is galvanized steel sheets. This is due to its low cost, workability and structural strength. Others are aluminium for warm air ducts, ventilators and louvres to resist corrosion; black steel for boiler breechings, hoods, belt guards, fire dampers; copper and stainless steel for fume exhaust ducts, swimming pool exhaust and fume hoods; asbestos and fibrous glass for other special applications.

When copper is used in conjunction with other metals, the two must be isolated to prevent corrosion by electrolysis.

2.8 Completion Requirement

The Contractor should test all systems in the presence of the Engineer and owner's representative to prove performance, provide for the instruction of operating personnel on the attendance, operation and maintenance of the equipment, furnish "as installed" drawings, establish warranty dates and furnish warranty certificates.

Operating and maintenance manuals are the central reference of organized information and instructions. These manuals should be prepared by the Design Engineer who should ensure that the manufacturer furnishes at least one copy of the manual relating to his equipment to the original owner.

Balancing and adjusting of the air distribution system is essential to the performance of all ventilating and air conditioning systems and this exercise must be conducted before any attempt is made to balance hydronic or refrigerant systems. The minimum instruments necessary for air balance are manometer, tachometer, anemometer, ampere meter, thermometers and a few lengths of pitot tubes.

Chapter 57 of the 1987 HVAC Handbook outlines the procedure for air balance and discusses method of application. Additional information may be had from the Balancing and Adjustment Manual published by Sheet Metal and Air Conditioning Contractors National Association Inc. (SMACNA).

There are a number of methods employed to accomplish balancing of hydronic systems, but whichever approach is used, proper instrumentation and good pre-planning is needed. Water flow instruments and components must be installed during construction of the piping system.

Balancing by direct flow measurement is preferred. This approach is accurate because it eliminates compounding errors introduced by other methods. A full and detailed description of its application is contained in Chapter 57, 1987 HVAC Handbook.

Balancing by total heat transfer is based on the determination of water flow by an energy balance about the coil. From field measurements, water flow may be determined by the following equation:

$$L/s = \text{Load in W} / (500 \times \Delta t_w)$$

Test Data:

Entering WB Temperature = 20.3 °C (76,385 J/kg)

Leaving WB Temperature = 11.9 °C (51,916 J/kg)

Air Volume = 10,380 L/s

Leaving Water Temperature = 15 °C

Entering Water Temperature = 8.6 °C

$$L/s = [4.5 \times 10{,}383 \times (76{,}385 - 51{,}916)] / [15.67 \times 10^6 \times (15.0 - 8.6)]$$

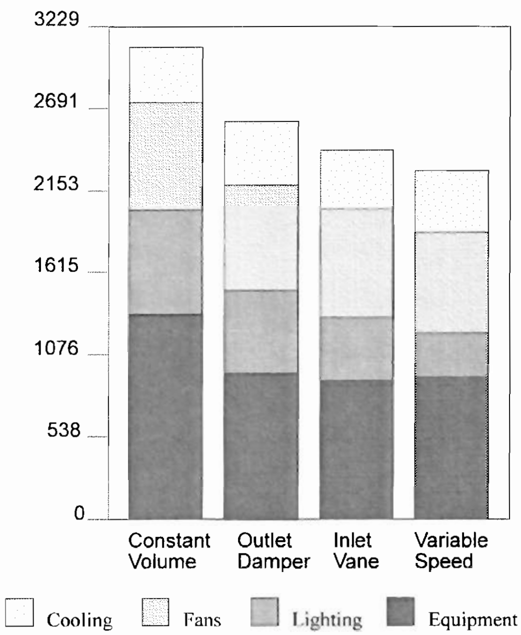
$$= 11.4$$

In order to test and adjust the HVAC control system, it will be necessary to become thoroughly acquainted with the design intent, obtain copies of control diagram and compare design to installed equipment and field installation, obtain manufacturers recommended operating and testing procedure. The proper location of controllers and transmitters should be checked, adverse conditions, if any, noted and alternative locations suggested.

3 Prescriptive Requirement

3.1 Sizing

The EEBC requires that the VAC system and equipment be sized at no more than the loads determined by the method described in EEBC section 7.4.1. Yet, the air conditioning equipment should be sufficiently sized to enable people or products to function within the buildings at optimum level. The system should at all times provide a desirable environment for employees to reduce fatigue and errors and make the location a desirable place to work.



Note: All options are water-cooled reciprocating chiller, COP=4.5

Figure H-4: Impact of Fan Control

The code specifies multiple cooling units whenever the design load is in excess of 500 kW. In such applications, other important factors, for example first cost, may prejudice the viability of the project when two or more chillers are selected to meet load requirements. In these circumstances, instead of using multiple units, one may opt for equipment equipped with multiple compressors and multiple fans with each circuit independently piped and wired.

In the event multiple units are selected, the code allows their combined capacity to exceed the design load. However, in such an application, the code requires that the units be sequenced and each controlled independently based on demand.

3.2 Fan System Design

The EEBC specifies that the fan systems under consideration for this section should be limited to supply, return and exhaust fans where the total of any single system is more than 7.5 kW input. Figure H-4 illustrates the impact of fan control on the electricity consumption for large office buildings and demonstrates by comparison the effectiveness of the various methods of control. These include constant volume, outlet damper, inlet vane and variable speed applications.

The code requires that for VAV fans with motors 25 kW or larger control devices shall be included to limit the motor demand to no more than 50% kW input at 50% design air volume, based on the manufacturers test data. A fan can be selected to meet this requirement as illustrated in Figure H-5. As can be seen, only air foil and backward inclined fans have part load ratios above 50% kW at 50% volume. This means that only these fan types will have a possibility of not meeting the VAV part load requirement of this section. Air foil and backward inclined fans using discharge dampers will almost never be able to meet this requirement, although this is not a very common design anyway. Air foil fans with inlet vanes (curve A in Figure H-5) are very common and may not meet the part load performance requirement. Actual fan selection part load performance, available from the fan manufacturer, should be used to test for compliance with this requirement.

3.2.1 Air Transport for All-Air Users: Air is the final transport medium for all-air systems. This is conveyed through filters, heat exchange equipment, ducts and various terminal devices to the space to be conditioned. The power to move the air is supplied by fans. EEBC requires that in any such cooling system the total sensible heat removed in W be no less than 5.5 times the total fan power input in W.

3.2.2 Other Systems: The Code prescribes that in selecting air conditioning systems other than all-air, the design must ensure that the total energy requirements including all fans and pumps is no more than that of an equivalent all-air system. The Code sites the following possibilities:

a) Air and water systems with central air conditioning equipment, duct and water distribution systems and a room terminal. The room terminal may be an induction unit, a fan-coil unit or a conventional supply air outlet combined with a radiant panel.

b) All water systems with central air conditioning

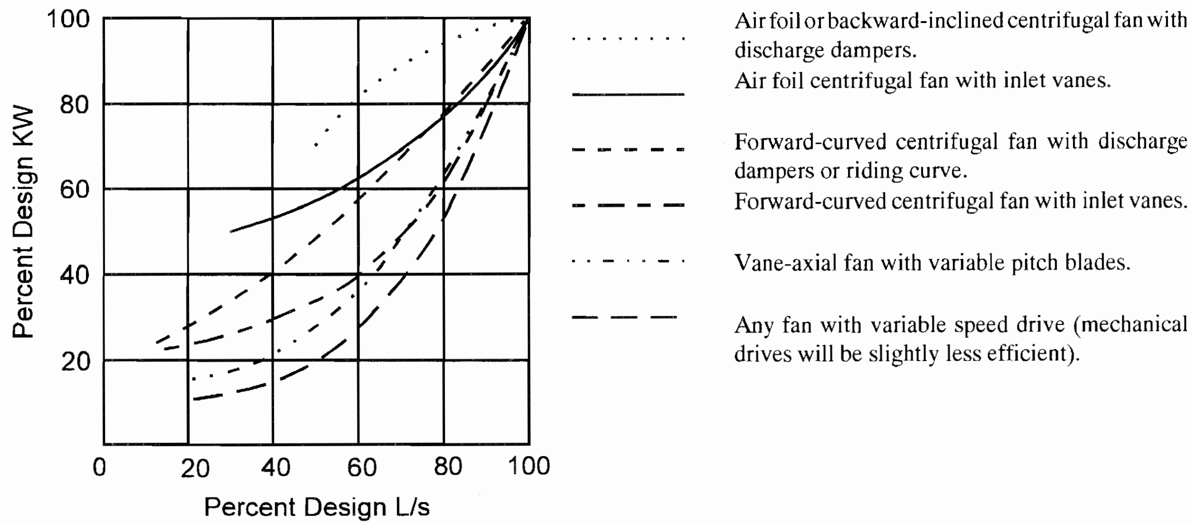


Figure H-5: Fan Energy at Part Load

plant, water distribution system, terminal units with chilled water coils, heating coils, blowers and filters. The fan recirculates air continuously from the space through the coil which contains either hot or chilled water.

c) Unitary systems with components factory assembled into an integrated package or self contained consisting of an indoor unit with either a water cooled condenser, integral air-cooled condenser or remote air cooled condenser.

The designer should prepare a summary of the design and selection criteria, a brief outline of the systems deemed inappropriate and a comparison of the systems selected for detailed study.

3.2.3 Power Consumption of Fans: The Code requires that system components, such as ducts and filters, be selected to provide the prescribed Fan Performance Index (FPI). The calculation used to determine FPI is stated and this relates to air flow quantity, total pressure of supply fan and gross floor area. Fans of different types and even fans of the same type but supplied by different manufacturers, do not necessarily react to a system in the same way. Therefore, judgement based on experience must be applied to any design. Chapter 32 of the 1989 ASHRAE Handbook - Fundamentals - gives information on calculating the system effect factors and lists loss coefficients for a variety of fittings.

3.2.4 Special Occupancies: For certain applications, the Code prescribes fixed values for Fan Performance Index. These relate to designs where the occupancy area by use is less than 4.75 m^2 per person. Table 7.2 of EEBC-94 may be used as reference.

3.2.5 Variable Volume Systems: A Variable Air Volume (VAV) system controls the dry bulb temperature within the space by varying the volume of supply air rather than the supply air temperature. The fan system is designed to handle the largest simultaneous block load, not the sum of the individual peaks.

As each zone peaks at a different time of day, it borrows extra air from off peak zones. Air is delivered to the space at fixed temperature and a space thermostat controls flow by varying the position of a volume regulating device in duct, pressure-reducing box or terminal diffuser or grille.

Fan controls must be used to save power and to operate at minimum system pressure for noise control. Check fan operating characteristics at maximum and minimum flow and provide the minimum outside air volume that complies with the Code.

Additional information may be sourced from Chapter 2, 1987 ASHRAE Handbook, Systems and Applications.

4 Ventilating & Air Conditioning Equipment

In order to apply equipment, the required environmental conditions, both for product and personal comfort, must be known. Mechanical cooling equipment should be selected in multiple units to match its response to load fluctuation and allow equipment maintenance during non-peak operation. EEBC-94 Table 8-1 lists the minimum performance requirements. With today's improved cooling equipment, machines are available with significantly higher efficiency values than older machines and even higher than minimum standards set by ASHRAE. Equipment is widely available to meet the basic requirements listed in EEBC-94 Section 8.4.4 which is mandatory under all compliance paths.

Tables H-1 through H-9 list more detailed rating conditions and basic requirements in relation to equipment performance.

4.1 Basic Requirements

4.1.1 Minimum Equipment Performance: The EEBC Code requires that equipment shall have a minimum performance criteria at standard conditions no more than the values shown in EEBC-94 Table 8-1. Rated cooling capacity of equipment and electrical consumption under normal operating conditions can be obtained from nameplate and manufacturers' technical literature. The Coefficient of Performance (COP) id defined as:

$$\text{COP} = \text{Useful Cooling Effect (kW)} \;/\; \text{Total Energy Input (kW)}$$

COP for electrically driven air conditioners include compressor, evaporator and condenser. COP for water chilling packages do not include chilled water or condenser water pumps or cooling tower fans.

4.1.2 Integrated Part Load Value: The Code requires that in complying with minimum efficiency requirements the equipment should also comply with part-load requirements. VAC systems are sized to satisfy a set of design conditions which are selected to generate near maximum load. Because these design conditions prevail during only a few hours each year, the equipment must operate most of the time at less than rated capacity.

Depending on equipment type, cooling system COP's will vary with changes in cooling load over a given period. In cases where COP drops significantly at part loads, improvement can be made by installing control systems to optimize operating conditions and performance by staging multiple machines or by increasing chilled water temperatures according to building cooling needs. Part Load improvement is applicable to equipment which does not cycle on and off to meet part load needs. The energy performance will depend on degree and duration of part load operation so that for buildings with constant cooling load near or equal to full load, the savings are negligible.

4.1.3 Field Assembled Equipment and Components: Field assembled (built-up) systems contain components such as supply fan, reheat coils, cooling coils, compressors, water pumps, cooling towers or air cooled condensers, etc. In all probability these components are not obtained from the same manufacturers in which case the entire system should comply with the requirements of the Code.

Heat operated cooling equipment such as absorption chillers must comply with the requirements of Table H-9 unless the source of heat is waste steam or special applications such as hospitals.

In evaluating the total energy input, the total sum of all energy consuming components and accessories must be used.

4.2 Maintenance

A ventilating and air conditioning system that is difficult to maintain will not be properly maintained, with a consequent increase in energy costs. The VAC designer should observe the following basic criteria:

a) Provide adequate space and accessibility for equipment. This includes ease of access, space for maintenance and repair, access for removal and replacement of large items of equipment

b) Request written maintenance and operating procedures. A collection of manufacturers' maintenance and operating procedures is helpful.

c) Provide basic training for equipment operators.

Chapter 35 of the 1991 ASHRAE Handbook - HVAC Applications - deals in detail with operation and maintenance management and addresses the issues that affect a maintenance programme.

4.3 Equipment Supplier Responsibility

The Code lists information that should be furnished by suppliers of ventilating and air conditioning equipment to enable determination of their compliance. As a rule, the manufacturers' engineering manual provides full mechanical and electrical specifications which are valuable guides to determine equipment performance.

Table H-1

Standard Rating Conditions and Minimum Performance Unitary Air Conditioners and Heat Pumps - Air Cooled Electrically - Operated <39,650 W Cooling Capacity - Except Packaged Terminal & Room Air Conditioners

Reference Standards	Category	Sub Category & Rating Condition (Outdoor Temperatures, deg. C)		Minimum Performance (1)
ARI 210-81 ARI 240-81 ARI 210/240-84	< 19,050 W Cooling Capacity Cooling Mode	1 Φ	Seasonal Rating	2.9 COP (seasonal)
		3 Φ	Standard Rating (35 db)	2.93 COP
		3 Φ	Low temp: Rating (28 db)	2.8 COP
	> 19,050 < 39,560 W Cooling Capacity Cooling Mode	All Φ	Standard Rating (35 db)	2.93 COP
			Low temp: Rating (28 db)	2.8 COP
	< 19,050 W Cooling Capacity Heating Mode	1 Φ	Seasonal Rating	2.9 COP (seasonal)
	> 19,050 < 39,560 W Cooling Capacity Heating Mode (Heat Pump)	All Φ	High Temp: Rating (8 db/ 6 wb)	3.3 COP
			Low temp: Rating (-8 db/ -9 wb)	2.3 COP

Note: 1) For multi-capacity equipment, the minimum performance shall apply to each capacity step provided and allowed by the controls.

Table H-2

Standard Rating Conditions and Minimum Performance Unitary Air Conditioners and Heat Pumps - Evaporatively Cooled Electrically - Operated <39,650 W Cooling Capacity - Except Packaged Terminal & Room Air Conditioners

Reference Standards	Category	Rating Conditions Indoor °C Outdoor	Minimum Performance
ARI 210-81 ARI 210/ 240-84	< 19,050 W	Standard Rating 27 db/ 19 wb 35 db/ 24 wb	2.9 COP
	> 19,050 W < 39,560 W	Standard Rating 27 db/ 19 wb 35 db/ 24 wb	2.9 COP
	< 19,050 W	Low Temperature Rating 27 db/ 19 wb 27 db/ 19 wb	2.93 COP
	> 19,050 W < 39,560 W	Low Temperature Rating 27 db/ 19 wb 27 db/ 19 wb	3.2 COP

Table H-3

Standard Rating Conditions and Minimum Performance Water-Cooled Air Conditioners and Heat Pumps - Cooling Mode <39,650 W Cooling Capacity - Electrically Operated

Reference Standards	Category	Rating Conditions Indoor Air °C Entering Water	Minimum Performance (1)
ARI 210-81	< 19,050 W	Standard Rating 27 db/ 19 wb 29 deg C	3.1 COP
ARI 210/ 240-84	> 19,050 W < 39,560 W	Standard Rating 27 db/ 19 wb 29 deg C	3.2 COP
ARI 320-85	< 19,050 W	Low Temperature Rating 27 db/ 19 wb 24 deg C	3.0 COP
ARI 325-85	< 39,560 W Ground water Cooled	Standard Rating Entering water 24 deg C Low Temperature Rating Entering water 10 deg C	3.5 COP 3.7 COP

Note: (1) For multi-capacity equipment, the minimum performance shall apply to each capacity step provided and allowed by the controls.

Table H-4

Standard Rating Conditions and Minimum Performance - Packaged Terminal Air Conditioners, Heat Pumps and Room Air Conditioners Air-Cooled, Electrically Operated

Reference Standards	Category	Sub Category & Rating Condition Outdoor Temperature (°C)	Minimum Performance (1)
ARI 310/85	PTAC's, PTAC H.P.'s (2) Cooling Mode	Standard Rating (35 db)	2.9 COP
		Low Temperature Rating (28 db)	3.6 COP
ARI 380-85	PTAC's H.P.'s Heating Mode	Standard Rating (8 db/6 wb)	3.3 COP
ANSI/ AHAM RAC-1-82	RAC's <2640W Cooling Mode	Standard Rating (35 db)	2.8 COP
	RAC's >2640W Cooling Mode	Standard Rating (35 db)	3.1 COP

Notes:
1) For Multi-Capacity Equipment, the minimum performance shall apply to each capacity step provided and allowed by the controls.
2) For Calculations: 2051W < Capacity < 4395W
3) Heat Pumps used to produce service hot Water

Table H-5

Standard Rating Conditions and Minimum Performance - Water-Source and Groundwater Source Heat Pumps Electrically Operated < 39,650 W Cooling Capacity

Reference Standards (3)	Rating Condition °C (1)	Minimum Performance
Water - Source Heat Pumps ARI 320-869 CTI 201-(86)	Standard Rating 21 deg. C Entering Water	3.8 COP
Groundwater-Source Heat Pumps	High Temperature Rating 21 deg. C Entering Water (2)	3.4 COP
ARI 325-85	Low Temperature Rating 10 deg. C Entering Water (2)	3.0 COP

Notes:
1) Air entering indoor section 21 deg. C db / 16 deg. C wb (max.)
2) Water Flow Rate Per Mfg. Spec.
3) For detailed references, see Section 14

Table H-6

Standard Rating Conditions and Minimum Performance - Large Unitary Air Conditioners & Heat Pumps - Electrically Operated > 39,650 W Cooling Capacity

Category/ Reference Standards	Efficiency Term	Minimum Performance COP
Air Conditioners Air Cooled ARI 360-85	COP IPLV	2.8 2.5
Air Conditioners Water/ Evap.Cooled ARI 360-85	COP IPLV	3.1 2.8
Condensing Units Air Cooled ARI 365-85	COP IPLV	3.1 3.4
Water/Evap. Cooled ARI 365-85	COP IPLV	3.8 3.8

Table H-7

Standard Rating Conditions and Minimum Performance - (Screw) Centrifugal and Rotary/type Water Chilling Packages - Electrically Operated

Category		Efficiency Term	Minimum Performance
ARI 360-85	Centrifugal Air Cooled	COP IPLV	3.5 3.5
	Water Cooled =< 880 kW	COP IPLV	5.0 5.1
	Water Cooled > 880 kW	COP IPLV	5.3 5.4
ARI 550-83	Air Cooled	COP IPLV	3.2 3.3
	Water Cooled	COP IPLV	5 5.2

Table H-8

Standard Rating Conditions and Minimum Performance - Reciprocating Water Chilling Packages - Electrically Operated

Category Reference Standards		Efficiency Term	Minimum Performance
ARI 590-81	Air Cooled with Condenser	COP IPLV	3.1 2.8
	Air Cooled without Condenser	COP IPLV	3.4 3.5
ARI 590-81	Water Cooled	COP IPLV	4.7 4.9

Table H-9

Standard Rating Conditions and Minimum Performance - Heat Operated Water Chilling Packages - Water Cooled Condensing

Category/ Reference Standards	Efficiency Term	Minimum Performance
Direct Fired ANSI Z21/40.1-1981 ANSI Z21.40.1a-1982	COP	0.5
Indirect Fired	COP	0.7

Note: COP is the net cooling output/ total heat input, with electrical auxiliary inputs excluded.

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Appendix I:

Service Water Heating - Systems and Equipment

Contents of this Appendix

1 General Design Considerations I-1
2 Compliance Procedures I-3
3 System Sizing I-4
4 Equipment Efficiencies I-6
5 Piping Insulation I-9
6 Solar Energy Alternative I-13
7 Operation and Management I-13

Commentary

Heating water for use in building services is utilized for comfort and for some level of sterilization, particularly in kitchens and laundries.

There are many different service water heating system designs available to the industry. All of the equipment types and/or systems utilize some form of energy which must be controlled.

The purpose of this appendix is to illustrate various methods for establishing standards which will assist the Bureau of Standards to implement an Energy Efficient Building Code (EEBC) for Jamaica.

1 General Design Considerations

In Jamaica, most of the hot water consumption occurs in the hotel industry, in hospitals and pharmaceutical manufacturing. However, the requirements are unlikely to apply to most pharmaceutical manufacturing spaces, since the requirements of the EEBC are for buildings and spaces intended primarily for human occupancy. Thus, the EEBC requirements will pertain mainly to hotels and hospitals.

An informal survey of a number of Jamaican facilities was conducted to estimate their energy consumption levels for service water heating. From this quick examination, very few of the facilities displayed energy consumption levels for service water heating as efficient as those produced by the EEBC code requirements. Also, there is currently in Jamaica little or no data collection as to hot water quantity, type, temperature, or flow consumption.

The energy usage in these buildings can be significantly reduced if the following conservation measures were adapted.

a) Metering of hot water usage
b) Metering of hot water temperature
c) Controlling hot water flow rate
d) Maintaining hot water generating and storing facilities
e) Insulate and maintain the insulation of all hot water storage, tanks and circulating pipelines.

Although the number of institutions and buildings impacted is small, the amount of energy used is considerable. Thus, savings through the adaptation of the EEBC service water heating requirements will be greatly beneficial to the national economy.

For example, from calculations using the service water heating system of a local typical hotel, to show a savings of J$246,429 per annum in fuel by the proper insulation of its hot water piping.

1.1 Hot Water Temperatures for Various Operations

There is no accepted definition for temperature of "hot" water. Each job or operation has its own suitable water temperature, whether set up by common practice or by the manager of a specific institution. Most sanitary codes or nationally adopted standards define the conditions of the hot water required for each application under consideration. Table I-1 lists recommended temperatures for a number of functions within buildings.

Table I-1 Recommended Service Water Temperatures

Use	Temperature °C
Human Needs	
Lavatory, hands & face	39-43
Shaving, shampooing	43-46
Warm bath	33-37
Hot bath	37-46
Housecleaning Needs	
Mopping, scrubbing	38
Wall and wood work cleaning	41-43
Cleaning glass	44
Window cleaning	49
Residential Dishwashing	
Machine	60
Handwash, towel dry	44
Residential Machine Laundry	60
Commercial/Industrial Laundry	82
Commercial Spray Dishwashing	
Rack type	> 66 wash 82-91 final rinse
Single tank conveyer type	> 71 wash 82-91 final rinse
Multiple tank conveyer type	> 60 wash > 71 pumped rinse 82-91 final rinse
Chemical sanitizing type	60 wash > 24 rinse

One may enter a public place and open a hot water faucet only to find the water that flows may be scalding hot, lukewarm, or even cold. A tavern cleanses its glasses or a sandwich shop washes its dishes in clear or treated water frequently below 49 °C and the resulting bacteria count may be above the minimum bacterial requirements established by public health codes.

Individual skin sensitivities vary. Many people cannot wash their hands in 49 °C water, while others can work in scalding hot water without harm. Temperatures generally desired for the most common operations of the home, commercial and manufacturing institutions are listed in the accompanying table. These can serve as one of the bases of most computations, as practical areas of operation rather than as specifications. Temperatures dictate most factors of hot water, controls, mixing arrangements, piping and insulation.

Most of the users of hot water in Jamaica are hotels, hospitals and to a lesser extent, food processing. To control bacterial growth in these industries, hot water temperatures within the 60 °C range are recommended. This high temperature, however, increases the potential for scalding, so care must be taken.

Supervised periodic flushing of fixture heads with 76 °C water is recommended in hospitals, hotels, and health centers. In some instances, water is only required at 49 °C. Here, it is more economical to supply water at the 60 °C level and blend the portion required at 49 °C. It is very important with this type of system to maintain good blending control and good quantity control metering.

It is almost axiomatic that hot weather, particularly with accompanying high humidities, increases the consumption of hot water for personal hygiene, laundries and beverage dispensaries. Probably the greatest use of hot water is for cleaning, whether for the human person or for apparel, home or shop cleaning.

With advancing labor costs as well as the scarcity of help for cleaning tasks, technology has entered the sanitary field more than ever before. Detergents and cleaning compounds have been highly developed, with special soaps for almost each type of job. At the same time, new and special types of floors and walls have come into use, such as polyvinyls, asphalt and rubber base tiles, terrazzo and plastics, each of which now demands some particular compound to produce optimum results.

Of equal importance in larger establishments is the wide use of machines for production cleaning where the type of hot water and cleaning compounds affect the efficacy and quality of cleaning. Most cleaning standards or sanitary codes specify end results in cleanliness, without mention of water quality or temperature requirements. Building supervision inspects the results without any consideration being given to the cleaners' problems of hot water supply.

1.2 Maintenance of Steam Traps

Steam traps are critical when used on steam heated hot water systems. Since these contain moving parts, they must be checked periodically for functionality.

When a trap fails to operate, it reduces system capacity and control. When these units are worn they must quickly be replaced. Note that the smallest leak from the orifice of a trap will result in hundreds of dollars in lost steam.

2 Compliance Procedures

To comply with the EEBC, it is mandatory for the relevant buildings to implement and comply with the service water heating system requirements contained in EEBC-94 section 9, including basic requirements for :

a) sizing of systems
b) equipment efficiency
c) piping insulation
d) controls
e) equipment and controls to conserve hot water

EEBC section 9 also contains additional prescriptive criteria that apply to special situations. These include:

f) the required economic cost-benefits analysis of an electric heat pump water heaters for low temperature service water heating (up to 63 °C).
g) the required use of a gas vent dampers when flue dampers and other safeguards are not present.
h) the required use of heat traps on storage water heaters.

Information about compliance with the various basic requirements is included below. Compliance with the various prescriptive measures is not included in this appendix.

2.1 Additional Recommendations

In addition to satisfying the EEBC requirements, it would also be highly desirable if additional steps were taken, as follows. First, the buildings, new or existing, must be surveyed to determine whether any area using hot water is operating efficiently. This survey must:

a) ascertain what is necessary to reduce hot water load to code requirement and
b) determine what is necessary to reduce hot water consumption.

Water consumption can be reduced by restricting flow rate and usage by installing flow restrictors in faucets, showers, etc. Timers can also be utilized in some instances.

Having determined the hot water consumption requirement for the building, with regards to supply temperature and minimum required supply temperature, the thermostat must be set at the lowest temperatures at which hot water will meet consumption needs. In cases of hot water fluctuations, mixing valves must be installed to control these fluctuations. Booster heaters should be installed to proved elevated temperatures rather than heating the total system to a higher temperature for this purpose.

2.2 Reducing Thermal losses

Thermal losses can be reduced by:

a) the heating medium
b) the distribution piping
c) the storage facility

These losses are proportional to the temperature differences between the hot water and the surroundings and to the resistance of pipe and storage tanks heat flows. These losses can be reduced as discussed above, or by adding insulation. Insulation is the most effective way of reducing losses in a hot water system.

All bare pipes and storage tanks must be insulated and damaged insulations repaired or replaced. Small pipes must be insulated with circular half-sections of insulation with flexible cell materials. Larger pipes should be insulated with flexible material.

3 System Sizing

Section 9.4.1 of EEBC-94 requires that service water heating design loads for the purpose of sizing and selecting systems by determined in accordance with procedures in Chapter 54 of ASHRAE Handbook, 1987 Systems and Applications Volume, or a similar procedure. Note that Chapter 44 of ASHRAE Handbook, 1991 Applications Volume is an update to Chapter 54 of the 1987 volume.

Table I-2 provides estimates of hot water usage by function and fixture type that might be used to determine system capacities. The material below is intended to provide guidance in determining design loads and system sizing requirements.

3.1 Storage Capacity & Hourly Heater Capacity

Systems for providing hot water for services and fixtures in buildings are of two kinds:

a) instantaneous, and
b) storage.

In the instantaneous system, the water is heated as used, there is no storage, and the capacity of the heater is equal to the peak demand.

In the storage system, hot water is heated continuously or intermittently as desired. When there is no demand the heated water is stored in a tank for installations of equal hot water capacity. The capacity of the heater in a storage system is less than that of an instantaneous heater.

3.1.1 Hourly heater capacity (H_{hc}): in a storage system this may range all the way from the minimum, where it is just equal to 1/24 of the average daily hot water consumption, up to an instantaneous heater, with a capacity equal to the actual peak demand. In the first case the storage tank would be of maximum capacity while in the second no storage would be needed. In between these two extremes, any number of combinations is possible.

Generally, however, for most building purposes it is more economical to install a small capacity heater and a large tank rather than a large heater and a small tank, because storage capacity costs less than heater capacity.

For the most economical installation, therefore, the general rule would be to use a small heater in combination with a large tank. This rule fixes the minimum hourly heater capacity (H_{hc}) at 1/24 the average daily hot water consumption. In practice, though, the capacity has to be slightly larger in order to provide for radiation losses.

The minimum heater with an hourly capacity of 5% of the average daily consumption may be used where this consumption may be accurately predicted and where it does not vary greatly from day to day. For average installations where the daily consumption and the peak demand may vary slightly from day to day, and where they can be predicted with reasonable accuracy, a heater having an hourly capacity of 7.5% of the average daily hot water consumption should be used. In buildings where the daily fluctuations may be great, where there is extraordinary uncertainty as to daily consumption, or where a considerable amount of hot water may be wasted, the heater should have an hourly capacity of 10% of the average daily consumption.

These figures are said to be not satisfactory for multicoil heaters. Where this type heater is used, a workable rule is to provide double the heater capacity indicated by the above percentages. Table I-3 summarizes the above data for determining the heater capacity.

3.1.2 Storage Tank Capacity (C_t): There are a number of methods of selecting the capacity of the storage tank. Perhaps the best is to plot a load curve based on actual metering of the hot water requirements. A horizontal line representing the heater capacity is drawn on the curve and the areas above this line studied to determine the correct capacity of a tank to supply the extra demand of the peak periods.

Table I-2
Hot Water Heater Estimate Data

Column 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Maximum Possible Hot Water Consumption, L per Hr													
Building Type	Bath Tub	Dish Washer	Foot Basin	Kitchen Sink	Laundry Stat.	Laundry Rev. Tub	Pantry Sink Tub	Private Wash	Public Wash Basin	Shower Bath Basin	Slop Sink	Max. Hourly Demand	Average Daily Con-sumption	Length of Peak Demand Hr.
Apartment	57	57	11	38	95	284	38	11	19	227	76	.20	10	4
Dormitory	114	-	11	-	132	379	-	11	38	757	57	.25	10	4
Gymnasium	114	-	45	-	-	-	-	11	38	757	-	.60	*	*
Hotel	76	114	11	76	132	568	76	11	38	284	114	.30	15	10
Indust . Plant	114	114	45	76	-	-	-	11	57	757	76	.70	*	*
Loft Bldg.	-	-	-	-	-	-	-	11	38	568	76	.20	7.5	3
Office Bldg.	-	-	-	-	-	-	-	11	30	-	57	.15	7.5	*
Residence	57	57	11	38	95	284	38	11	-	189	57	.30	10	4
YMCA	114	114	45	76	114	379	76	11	38	757	76	.30	*	*

All-Day					
Restaurant	Per $1.00 meal	8L per meal	6L per meal	15	10
2-Meal		Hand	Machine		
Restaurant	Per $2.00 meal	6L per meal	9L per meal	10	4
1-Meal		Dishwashing	Dishwashing		
Restaurant	Per $3.00 meal	4L per meal	17L per meal	5	3

Hospital	303 to 379 L per day per bed	* Must be figured individually
Garage	189 L of 32 °C water per car washed	

Table I-3
Hourly Heater Capacity
(From Average Daily Hot Water Consumption)

Type of Installation	Indirect Surface Heater Submerged, Steady Operation	Direct-Fired Multi-Coil Heater Intermittent Operation
Minimum	5.0%	10%
Average	7.5%	15%
Generous	10.0%	20%

Storage should be provided to take care of all reasonable peak loads. Additional capacity should be allowed in the cases where two or more peaks come close together and sufficient time does not elapse for the heater to warm up the tank water. In order to prevent the incoming water from lowering the temperature of the tank water too much, the capacity obtained by the above calculations should be increased by 1/3.

Where it is not possible to plot a demand curve the following rule may be used: tank capacity, in L, equals the length of peak demand, in hours, per Eq. I-1.

$$C_t = 1.33 \times L_{pd} \times (D_{mh} - H_{hc}) \qquad \text{Eq. I-1}$$

where,

C_t = Capacity of the storage tank, in L.
L_{pd} = Length of peak demand, in hr.
D_{mh} = Maximum hourly demand, in L.
H_{hc} = Hourly heater capacity, in L.

3.2 Example of Calculating Heater and Storage Tank Capacities

An apartment house contains 47 apartments. In each of these there is a bath, wash-basin, kitchen sink, and dishwasher. The following are calculations that use data from Tables I-1, I-2, and I-3 to determine the maximum hourly demand, average daily hot water consumption, capacity of an indirect heater, and capacity of the storage tank.

a) Maximum hourly demand (D_{mh}), Litres (Tbl. I-2)
Baths [47 apts x 57 (from Col. 2)] = 2679
Wash Basins [47 x 11 (from Col. 9)] = 517
Sinks [47 x38 (from Col. 5)] = 1786
Dishwashers [47 x 57 (from Col. 3)] = 2679
Maximum hourly consumption
= 2679 + 517 + 1786 + 2679
= 7661
Maximum hourly demand (D_{mh})
= 7661 x 0.20 (from Col. 13)
= 1532

b) Average daily consumption, Litres (Table I-3)
max. hourly demand x factor (from Col. 14)
= 1532 x 10
= 15320

c) Hourly capacity of heater (H_{hc}), Litres (Table I-2). Assume an average installation. Table I-2 indicates that 7.5% of average daily consumption is suitable. Thus:
= 15320 x 7.5% (or 0.075)
= 1149

d) Capacity of storage tank (C_t), Litres (Table 2). Since information to construct a demand curve has not been supplied for the example, use Eq. I-1. Obtain the length of the peak demand period (L_{pd}), in hours, from column 15 of Table I-2. The value obtained is 4 hours. The maximum hourly capacity of the heater (H_{hc}) has just been determined immediately above. Thus, from Eq. I-1:

$$C_t = 1.33 \times L_{pd} \times (D_{mh} - H_{hc})$$
$$= 1.33 \times 4 \times (1532 - 1149)$$
$$= 2043 \text{ L}$$

Dimensions for a suitable tank may be selected from Table I-4.

4 Equipment Efficiencies

4.1 Minimum Efficiencies

EEBC-94 Table 9-1 lists the minimum efficiencies required for various classifications of water heating equipment. There are two types of efficiency requirements: a minimum heater efficiency and a maximum standby loss.

Table I-4
Capacity of Storage Tanks

(Number of L per m of Length)

Diameter mm	Capacity L
450	50.0
500	61.7
600	89.0
750	138.9
900	198
1050	272.5
1200	355.8
1350	450.5
1500	556.1
1650	672.7

Data that can be used to support compliance includes data from recognized certification programs or from equipment manufacturers. The compliance with the minimum heater efficiencies is straightforward, from EEBC Table 9-1. The following efficiency factors should be considered, in complying with the specifications in the table:

a) **Recovery Efficiency** is the heat absorbed by water divided by heat input to the heating unit, during the period that water temperature is raised from inlet temperature to final temperature, using $(T_f-T_i)/T_f$ x 100.
b) **Thermal Efficiency** is the heat in the water delivered as the heater outlet divided by the heat input of the heater unit over a specific period.
c) **Energy Factor** is a measure of the overall efficiency of a storage water heater representing heat in the daily delivered water divided by the estimated daily energy consumption of the water heater (A USDOE test procedure may be used to determine this factor).
d) **Hot water Distribution Efficiency** is the heat contained in the hot water at point of use divided by the heat input to the heater at a given flow rate.
e) **Overall Efficiency** is the heat in the water delivered at point of use divided by the heat supplied to the heater for any selected closed time period. The critical design considerations are:

1) Hot water heaters of different sizes and insulation have different standby losses.
2) A properly designed, sized and insulated distribution system is necessary to deliver minimum water temperatures satisfactorily for the uses served.
3) Heat traps between recirculating mains and infrequently used branch lines will reduce convection losses to these lines.
4) Control of circulating pumps to operate only as needed to maintain proper temperature at the end of the main line, will reduce losses on return lines.
5) Provision for shutdown of circulators during building vacancy reduces circulation losses.
6) Provide and maintain adequate flow and temperature devices to all sizes and types of hot water service systems.

It is recommended that the standard rating conditions and minimum performance of water heating equipment listed in the EEBC be further refined for application to Jamaican conditions.

Compliance with the standby loss requirements includes several exceptions, and is covered in the next section, below.

4.2 Calculating Heat Losses From Tanks

To comply with the EEBC-94 requirements for standby losses from storage tanks, one must determine that the loss is less than the requirement listed for the specific standby situation listed in EEBC Table 9-1.

An exception applies to large storage water heaters and unfired storage tanks because of difficulties in using standard test procedures to large storage systems. Therefore, the standby loss requirement does not apply to units without a standing pilot light that are over 530 litres capacity and have insulation of R-2.2 or more covering the tank surface.

It is possible to have standby losses much lower than those required by the EEBC. The following material assists the user to calculate tank heat losses, and to estimate tank insulation requirements for various levels of losses.

Steps 1 to 4 below enable the user to determine the base case heat losses per m^2 of tank surface and the annual energy consumption for a base case tank condition. Steps 5 to 8 below permit calculation of the tank insulation R-value needed to obtain a desired reduction in heat losses. After the process is described, an example calculation is performed for a 3 m diameter by 5 m tall tank.

Step 1: Calculate the area of the walls and top of the tank from equations I-2 and I-3:

$$A_w = \pi DH \qquad \text{Eq. I-2}$$

$$A_t = \pi D^2/4 \qquad \text{Eq. I-3}$$

where,

A_w = Area of walls of tank, m^2.

A_t = Area of top of tank, m^2.

D = Diameter of tank, in metres.

H = Height of tank, in metres.

Step 2: Calculate the heat loss from the tank walls and top from equations I-4 and I-5:

$$Q_w = h_{cw}A(T_T - T_A) \qquad \text{Eq. I-4}$$

$$Q_t = h_{ct}A(T_T - T_A) \qquad \text{Eq. I-5}$$

where,

Q_w,Q_t = Heat loss from walls and top of tank, respectively, in W.

h_{cw},h_{ct} = Heat loss coefficient for walls and top of tank, respectively, $W/m^2 \cdot K$.

T_T = Temperature within the tank, °C.

T_A = Temperature of the air outside the tank, °C.

Step 3: Calculate the total annual heat loss from equation I-6:

$$Q = (Q_w + Q_t) \times 8760 \text{ hr/yr} \qquad \text{Eq. I-6}$$

Step 4: Annual energy consumption can be estimated by dividing the total heat loss (Q) by the system efficiency (S_{eff}), per equation I-7:

$$E_b = Q / S_{eff} \qquad \text{Eq. I-7}$$

Step 5: Choose a desirable percentage loss reduction, and estimate the combined reduction through tank walls and top. This type of problem is easiest to calculate on a heat flux basis, i.e. heat loss per square metre per hour. On the average, the original base case heat flux is:

$$q_b = (Q_w + Q_t) / (A_w + A_t) \qquad \text{Eq. I-8}$$

where,

q_b = Base Case average heat flux, W/m^2.

and, the calculation of the desired average heat flux ($q_{desired}$) through the surface of the tank can be obtained from equation I-9:

$$q_{desired} = q_b \times (1 - \%\ \text{reduction}) \qquad \text{Eq. I-9}$$

Step 6: Determine insulation amount required to achieve this result by determining the new heat transfer coefficients (h_c) related to $q_{desired}$, from Table I-?, and then converting the h_c values to insulation R-values for tank walls and top respectively via equations I-10 and I-11:

$$R_{fw} = 1 / h_{cw} \qquad \text{Eq. I-10}$$

$$R_{ft} = 1 / h_{ct} \qquad \text{Eq. I-11}$$

The insulation to be added can be determined as the difference between the film resistances just determined above in Eq. I-12 and I-13 and the total thermal resistance of the tank.

Step 7: Determine the total thermal resistance of the tank from:

$$q_{desired} = (T_T + T_A) / R_{total} \qquad \text{Eq. I-12}$$

or

$$R_{total} = (T_T + T_A) / q_{desired} \qquad \text{Eq. I-13}$$

Step 8: The R-values of insulation to be added to the walls and top of the tank, respectively, will be the differences between the total resistance of the tank minus the film resistances for walls (R_{fw}) and top (R_{ft}):

$$R_{wins} = R_{total} - R_{fw} \qquad \text{Eq. I-14}$$

$$R_{tins} = R_{total} - R_{ft} \qquad \text{Eq. I-15}$$

Summary and further calculations: The above process results in determination of base case tank losses and energy use, plus estimated R-value of insulation needed to achieve a desired reduction in heat loss. Using the results above, one can also calculate the revised annual energy consumption, and the savings in annual energy cost from the added tank insulation. By comparing this with the cost of the insulation, the payback period for the added insulation can be determined.

4.3 Example - Storage Tank Heat Losses

An uninsulated hot water tank is kept at 66 °C (339 K) via steam coils inside the tank. If the tank is 3 m in diameter by 5 m tall, how much energy is lost from the walls and top of the tank each year? What R value of insulation would be required to eliminate 95% of this heat loss? Assume an average ambient temperature of 24 °C.

The solution uses ASHRAE Table 2, heat transfer section. Heat loss from the walls is found by using the figures for vertical surfaces near the bottom of the chart. Losses from the tank top are calculated using the figures for horizontal surfaces facing upward, directly below the vertical surfaces row.

The area of the walls and top of the tank are determined from equations (I-2) and (I-3) above:

$$A_w = \pi DH$$
$$= 3.14 \text{ x } 3 \text{ m x } 5 \text{ m}$$
$$= 47 \text{ m}^2$$
$$A_t = \pi D^2/4$$
$$= 3.14 \text{ x } 3^2 / 4$$
$$= 7 \text{ m}^2$$

The temperature difference between the tank walls and the air is 42 °C. The convective heat transfer coefficient is found by interpolating between the figure for 27.8 °C and 56.6 °C temperature difference (ΔT) from the table.

At ΔT = 27.8 °C, h_c = 10.45 W / m² • K.
At ΔT = 55.6 °C, h_c = 10.45 W / m² • K

Therefore, for our case,

$$h_c = 11.30 \text{ W / m}^2 \bullet \text{K}$$

Heat loss from the walls will be:

$$Q_w = h_c A (T_T - T_A)$$
$$= 11.30 \text{ W/m}^2 \bullet \text{K x } 47 \text{ m}^2 \text{ x } 42 \text{ K}$$
$$= 2.23 \text{ x } 10^4 \text{ W}$$

From the top of the tank, h_c can be found again by interpolation to be:

$$h_c = 12.50 \text{ W / m}^2 \bullet \text{K}$$

Heat loss from the tank top is:

$$Q_t = h_c A (T_T - T_A)$$
$$= 12.50 \text{ W/m}^2 \bullet \text{K x } 7 \text{ m}^2 \text{ x } 42 \text{ K}$$
$$= 3.68 \text{ x } 10^3 \text{ W}$$

Total heat loss per year, using Eq. I-6, is:

$$Q = (Q_w + Q_t) \text{ x } 8760 \text{ hr/yr}$$
$$= (2.23 \text{ x } 10^4 + 3.68 \text{ x } 10^3) \text{ W x } 8760 \text{ hr/yr}$$
$$= 8.19 \text{ x } 10^{11} \text{ J/yr}$$

Note that for a steam heated system with an 80% efficient boiler and distribution system, that Eq. I-7 can be used to determine annual fuel usage for the loss:

$$E_b = Q / S_{eff}$$
$$= 8.19 \text{ x } 10^{11} \text{ J/yr} / 0.80$$
$$= 1.0 \text{ x } 10^{12} \text{ J/yr in fuel usage.}$$

In order to reduce heat losses by 95%, the heat loss from the walls must be cut to 5% of its original value. This type of problem is easiest to calculate on a heat flux basis, i.e. heat loss per square metre per hour. On the average, the original heat flux is, from Eq. I-8:

$$q_b = (Q_w + Q_t) / (A_w + A_t)$$
$$= 2.23\text{x}10^4 + 3.67\text{x}10^3) / (47 + 7)$$
$$= 481 \text{ W/m}^2$$

The desired condition is to reduce this figure to 5% of that, or from Eq. I-9:

$$q_{desired} = q_b \text{ x } (1 - \% \text{ reduction})$$
$$= 481 \text{ W/m}^2 \text{ x } (1-0.05)$$
$$= 24.1 \text{ W/m}^2$$

Note from the table that as the temperature difference between the tank and the ambient air decreases, so does the heat transfer coefficient, h_c. If insulation is added, the surface temperature of the insulation will be nearly that of the ambient air. If a very precise answer were required, we could use an interactive process to determine the exact equilibrium conditions. Such precision is not warranted here. We will arrive at a conservative estimate for insulation thickness by simply using the h_c figures for $(T_T - T_A) = 10\,^{o}C$ from the table.

These coefficients translate into R values of:

$$R_{fw} = 1 / h_{cw} = 1/10.45 = 0.10\ m^2 \bullet K/W$$

$$R_{ft} = 1 / h_{ct} = 1/11.53 = 0.09\ m^2 \bullet K/W$$

The total thermal resistance required can be found by using Eq. I-13 so that for the tank in question:

$$R_{total} = (T_T + T_A) / q_{desired} = 42\ oK / 24.1\ W/m^2$$

The insulation that must be added is the difference between R_{total} and the film resistances found above, or from Eqs. I-14 and I-15:

$$R_{wins} = R_{total} - R_{fw} = 1.7 - 0.1 = 1.60\ m^2 \bullet K/W$$

$$R_{tins} = R_{total} - R_{ft} = 1.7 - 0.09 = 1.61\ m^2 \bullet K/W$$

The proper insulation level to achieve a 95% reduction in heat loss to the atmosphere is thus approximately $R = 1.6\ m^2 \bullet K/W$.

In making a recommendation to a building owner, the normal procedure would be to consider what standard thickness of an appropriate type of insulation met or exceeded this resistance value. Note that the level of 95% loss reduction was chosen arbitrarily for the example. Depending on the cost of fuel to service water heating system, and the cost of insulation, a lower level of insulation might provide a better return on investment. In calculating the optimum economic level of insulation, curves are generally drawn which balance the cost of insulation against the value of the fuel saved over the projected life of the insulation.

5 Piping Insulation

EEBC-94 section 9.4.3 specifies minimum piping insulation levels for both circulating and non-circulating systems. That section refers to EEBC Table 7-3 in the VAC section of the EEBC. That table lists minimum insulation thicknesses both for service water systems and for chilled water systems intended for space cooling. The portion of EEBC Table 7-3 that pertains to service water systems is reproduced here for reference.

Insulation thicknesses in EEBC Table 7-3 are based on insulation with thermal conductivities within the range listed for each fluid operating temperature range, rated in accordance with ASTM C 335-84 at the mean temperature listed in the table. For insulation that has a conductivity outside the range shown for the applicable fluid operating temperature range at the mean rating temperature shown, when rounded to the nearest 0.00144 $W/(m^2 \cdot K)$, the minimum thicknesses shall be determined by the following equation:

EEBC Table 7-3 (Partial)

Minimum Insulation Thickness[a,b], mm, for Various Pipe Sizes

Fluid Temp. Range °C	Run-outs to 51.0	Pipe Diameter, mm Less than 25.4	31.8 to 51.0	63.5 to 101.6	127.0 to 152.4	More than 203.2
Domestic and Service Hot Water Systems[c]						
40.6+	12.7	25.4	25.4	38.1	38.1	38.1

Notes:

1) For minimum thicknesses of alternative insulation types, see text below discussing EEBC Eq. 7-3.
2) Insulation thicknesses, mm, in the table are based on insulation having thermal resistance in the range of 0.028 to 0.032 m^2-°C/ W-mm on a flat surface at a mean temperature of 24 C. Minimum insulation thickness shall be increased for materials having R values less than 0.028 m^2-°C/ W-mm or may be reduced for materials having R values greater than 0.032 m^2-°C/W-mm.
3) Applies to recirculating sections of service or domestic hot water systems and to first 2.4 m from storage tank for non-recirculating systems.

$$T = PR[(1 + t/PR)^{K/k} - 1] \quad \text{EEBC Eq. (7-1)}$$

Where

T = minimum insulation thickness for material with conductivity K, mm.

PR = pipe actual outside radius, mm.

t = insulation thickness from the table, mm.

K = conductivity of alternate material at the mean rating temperature indicated in the table for the applicable fluid temperature range, $W/(m^2 \cdot K)$.

k = the lower value of the conductivity range listed in the table for the applicable fluid temperature range, $W/(m^2 \cdot K)$.

Table I-5 shows the heat conductivity of various pipe insulting materials, for possible application to EEBC Eq. 7-1.

5.1 Energy Savings from Piping Insulation, a Calculation Procedure

While the EEBC specifies minimum levels of insulation, increased insulation levels might be cost-effective, given hours of use and fuel costs. The following pages detail a procedure for calculating energy savings for increased insulation levels, and reference various insulating materials and conductivity (k) values. A calculation procedure for determining these factors is as follows:

Step 1: Verify that pipe is insulated (yes or no).

Step 2: Determine hot water temperature for the application, in °C.

Step 3: For the Base Case, estimate annual fuel consumption using the following equation:

$$E_b = (L \times X_b \times H) / (B_{eff} \times HV) \quad \text{Eq. I-16}$$

where,

E_b = Base Case annual fuel consumption, L/Yr.

L = length (L) of hot water piping from the drawings, in metres.

X_b = Base Case heat loss per metre of pipe, W. To derive, use the nomograph (Figures I-1a and I-1b at end of this Appendix on pages I-14 and I-15) to determine the heat loss per metre of pipe.

H = hours per year that pipe is hot, hr/yr.

B_{eff} = Estimated boiler efficiency.

HV = Heating Value of fuel, J/L. See Table I-?.

Step 4: For the base case, estimate the annual energy cost.

$$C_b = C_f \times E_b \quad \text{Eq. I-17}$$

where,

C_b = Base Case annual energy cost, J$.

C_f = Cost per unit of fuel, either in J$ or in US$.

Step 5: Estimate the amount of insulation (I) to add to piping, in mm. This becomes the Revised Case.

Step 6: Next, for the Revised Case calculate the annual fuel consumption and cost in a similar fashion to the Base Case, namely:

$$E_r = (L \times X_r \times H) / (B_{eff} \times HV) \quad \text{Eq. I-18}$$

where,

E_r = Revised Case annual fuel consumption, L/Yr.

X_r = Revised Case heat loss per metre of pipe, W. To derive, use the nomograph (Figures I-1a and I-1b) to determine the heat loss per metre of pipe.

Step 7: Likewise, for the Revised Case determine the annual energy cost, C_r in either J$ or US$ (consistent with step 4 above), using:

$$C_r = C_f \times E_r \quad \text{Eq. I-19}$$

Step 8: Energy Savings (E_S), in L/Yr, is then determined from:

$$E_S = E_b - E_r \quad \text{Eq. I-20}$$

where,

E_S = Savings in annual fuel consumption for the Revised Case compared with the Base Case, L/Yr.

Step 9: Finally, annual cost savings (C_S), in either J$ or US$ (consistent with steps 4 and 7 above), is determined from:

$$C_S = C_b - C_r \quad \text{Eq. I-21}$$

5.2 Piping Insulation Example

The following is an example of the process just described. A typical building operates a hot water circu-

Table I-5

Heat Conductivity Of Pipe Insulating Materials

(Values to be used in the absence of specific data for the exact material and brand name used)

Insulation Type	Appr. Use Range°C	Appr. Density Kg/m³	Mean Temperature, °C 38	93	149	204	260	316	371	427
			Conductivity, k W/m•K x 10⁻¹							
85% Magnesia	316	176	.50	.55	.61	.66	--	--	--	--
Laminated Asbestos	317	480	.58	.65	.72	.79	--	--	--	--
4-ply Corrugated Asbestos	149	192	.82	.89	--	--	--	--	--	--
Molded Asbestos	538	256	.48	.55	.62	.69	.76	.84	--	--
Mineral Fibre,* Wire-reinforced	538	160	.42	.50	.61	.71	.81	.91	--	--
Diatomaceous Silica	871	352	--	--	--	.92	.95	.98	1.01	1.04
Calcium Silicate	649	176	.46	.53	.61	.66	.74	.81	--	--
Mineral Fibre,* Molded	177	144	.37	.45	.56	--	--	--	--	--
Mineral Fibre,* Fine Fibre, molded	177	48	.33	.39	.45	--	--	--	--	--
Wool Felt	107	320	.48	.53	--	--	--	--	--	--

Values of k

The thermal conductivity k for specific insulations is available from manufacturers and it is suggested that calculations be based on data which apply to the material and brand name of the insulation to be used. In the absence of such data, Table I is included as a rough guide. Mean temperatures in Table I are arithmetic means between the inside surface and outside surface of insulation.

lating system which requires the pipe lines to be continuously maintained hot (H = 8760 hr/yr). There is a total of 1524 m of hot water piping in this building, of an average diameter size of 38 mm. The hot water supply temperature is 60 °C. The boiler used as the heating source is considered to have an efficiency (B_{eff}) of 80%, the fuel is #2 oil, and the cost per litre of #2 oil (C_f) is J$ 2.20 /L.

In step 3 or the procedure the values for equation I-16 are for this example:

L = 1524 m.

X_b = 3.17×10^5 J/m (the Base Case heat loss per metre of pipe, from nomograph I-1a)

H = 8760 hr/yr. (hours per year that pipe is hot).

B_{eff} = 0.80 (Estimated boiler efficiency).

HV = 4.94×10^7 J/L (the Heating Value of fuel).

and solving the equation yields the following base case annual fuel consumption:

$$E_b = (L \times X_b \times H) / (B_{eff} \times HV)$$

$$= (1524 \text{ m} \times 3.17 \times 10^5 \text{ J/m} \times 8760 \text{ hr}) / (0.80 \times 4.94 \times 10^7 \text{ J/L})$$

$$= (4.23 \times 10^{12} \text{ J/yr}) / (3.95 \times 10^7 \text{ J/L})$$

$$= 134{,}264 \text{ L/yr}$$

Step 4 of the procedure determines the annual energy cost for the Base Case example. Since the value for E_b has just been derived immediately above, and the cost per litre of #2 oil (C_f)is J$ 2.20 /L, then equation -- may be solved directly as:

$$C_b = C_f \times E_b$$
$$= J\$\ 2.20\ /L \times 134{,}264\ L/yr$$
$$= J\$\ 295{,}381\ /yr$$

Step 5 of the procedure involves determining the amount of insulation (I) to add to piping, in mm. This becomes the Revised Case. Various thicknesses of insulation were considered to reduce heat losses consistent with investment cost. For the example, a 25 mm thick fiberglass insulation was chosen for the 38 mm diameter pipe.

In Step 6 of the procedure, a revised heat loss for the pipe (X_r) is determined in order to calculate a revised annual fuel consumption (E_r). From the nomograph (Fig. I-1a), the revised heat losses (X_r) will be reduced to 5.27×10^4 J/hr per metre of pipe. Using this value in equation I-18 yields an annual fuel consumption of:

$$E_r = (L \times X_r \times H) / (B_{eff} \times HV)$$
$$= 1524\ m \times 5.27 \times 10^4\ J/m \times 8760\ hr)$$
$$/ (0.80 \times 4.94 \times 10^7\ J/L)$$
$$= 22{,}251\ L/yr$$

In Step 7, the annual energy cost for the Revised Case is:

$$C_r = C_f \times E_r$$
$$= J\$\ 2.20\ /L \times 22{,}251\ L/yr$$
$$= J\$\ 48{,}951\ /yr$$

In the final two steps of the procedure, the annual fuel consumption and annual fuel costs of the Revised Case are compared with those of the Base Case to derive the annual savings.

In Step 8, the annual savings in fuel consumption (E_S), in L/yr, is:

$$E_S = E_b - E_r$$
$$= 134{,}264\ L/yr - 22{,}251\ L/yr$$
$$= 112{,}013\ L/yr$$

Finally, in Step 9 the annual cost savings (C_S), in J$, is:

$$C_S = J\$\ 295{,}381\ /yr\ -\ J\$\ 48{,}951\ /yr$$
$$= J\$\ 246{,}429\ /yr$$

6 Solar Energy Alternative

During the past decade, considerable effort has gone into the development and use of solar energy for heating and cooling. The performance of solar heating and cooling systems, however, has not been totally satisfactory except in the area of water heating. Even in this area its use has been confined to low temperature heating. However, some new higher-temperature systems are being employed in the Caribbean area that are using several tanks in series, with each tank oriented vertically to produce high temperatures from the last tank in the series.

It is desirable to consider the use of solar energy for service water heating within this energy building code. However, the EEBC does not, at this point, contain requirements for the use of solar energy usage.

In order to assess the performance of a solar energy system, two performance measures must be used: 1) the percent solar and 2) the system's efficiency.

7 Operation and Management

Energy consumption management requires the implementation of the various guidelines as laid down by these codes for the various energy input to the buildings. All potential areas for heat loss must be constantly monitored. All heat transfer surfaces and systems must be maintained to the level indicated in these guidelines.

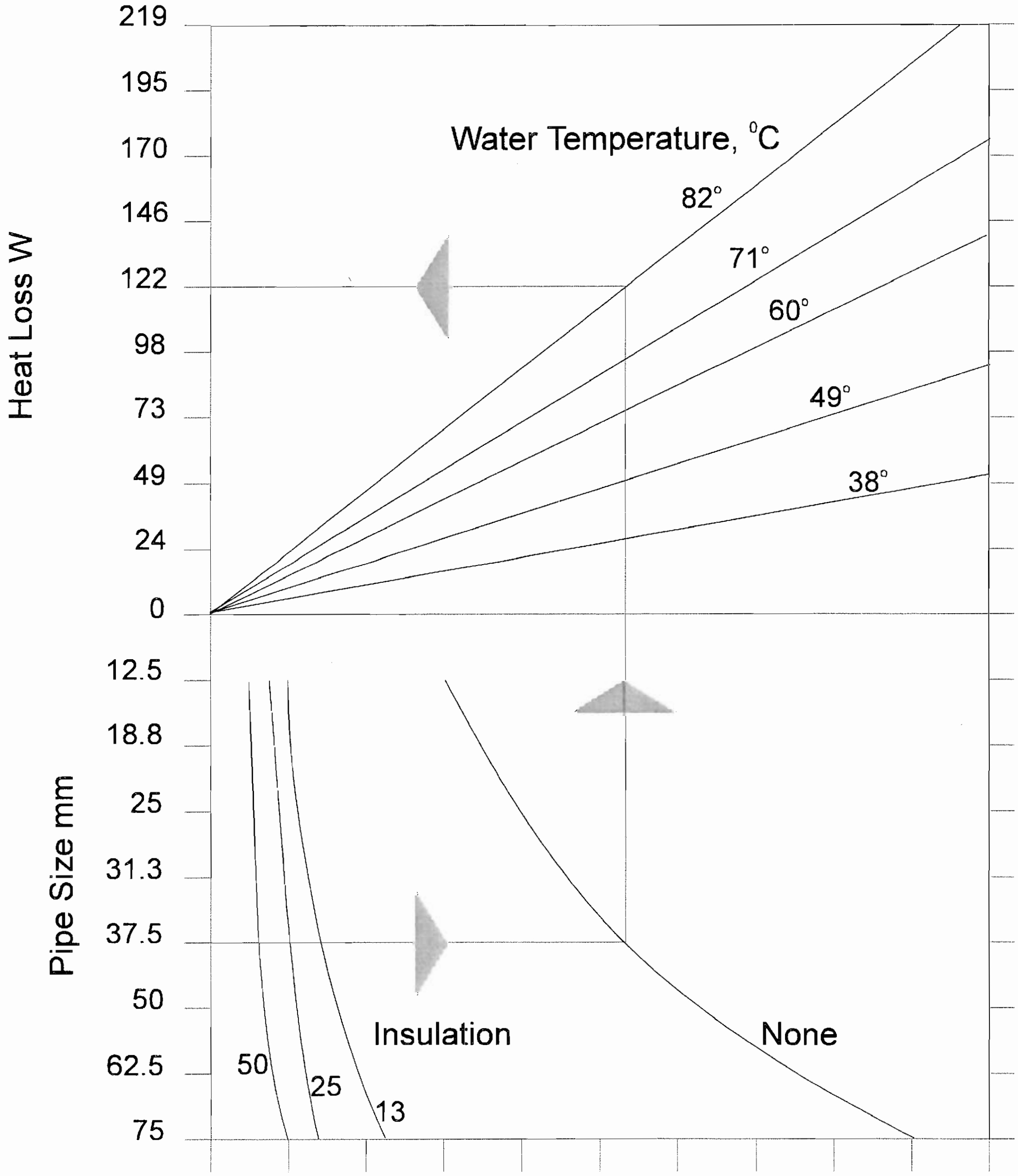

Figure I-1a: Heating - Heat Loss Nomograph for Various Pipe Sizes

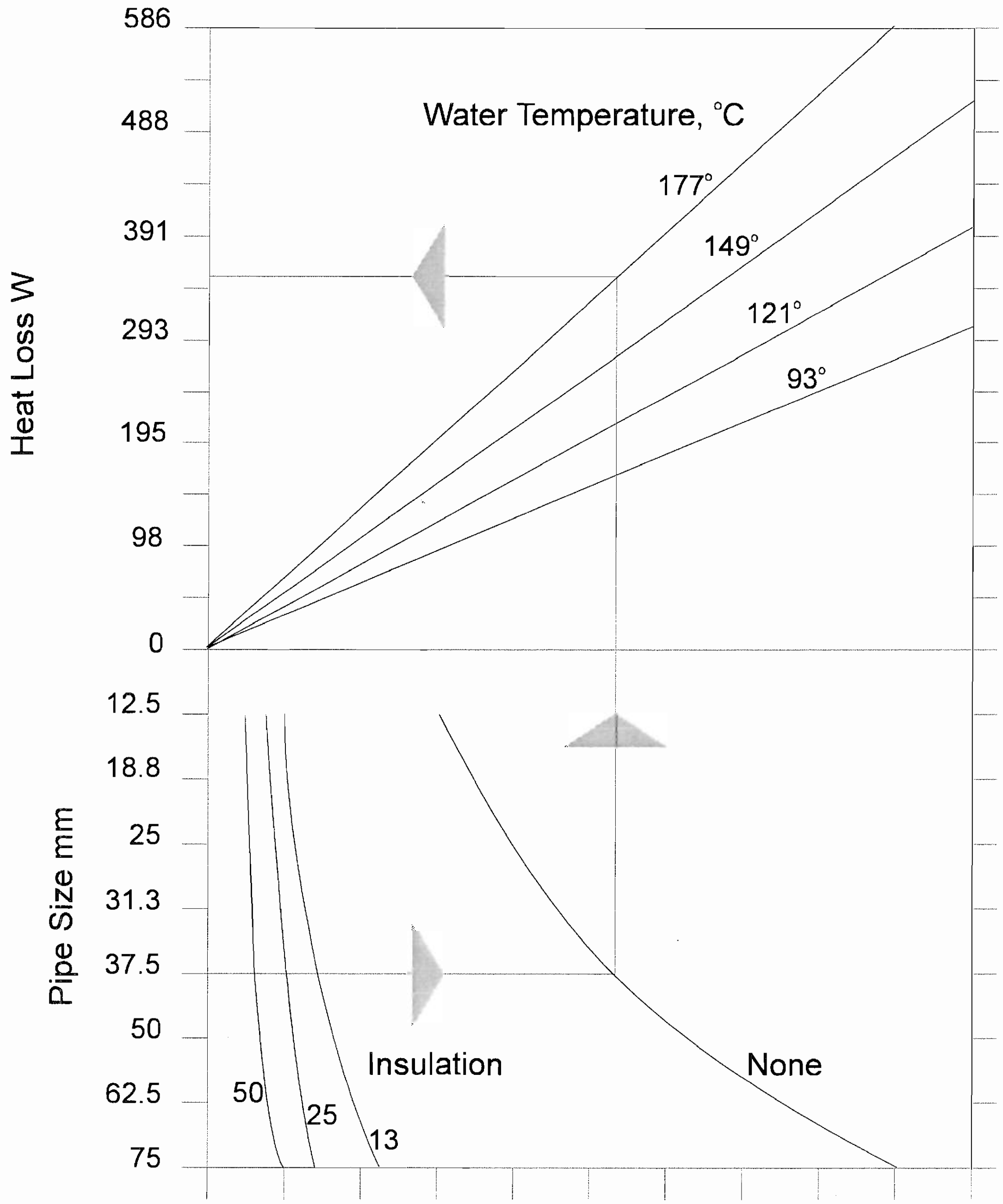

Figure I-1b: Heating - Heat Loss Nomograph for Various Pipe Sizes

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Appendix J:

Operations and Maintenance (O&M)

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4 O&M Support Services J-3

Commentary on this Appendix

The Energy Efficiency Building Code (EEBC) is intended to reduce the use of energy in commercial and institutional buildings. The EEBC focuses primarily on requirements for a building's design. A building's planning, design and construction can be accomplished to assure that the building, as turned over to the owner, has the potential to offer both the comfort level and the energy efficiency indicated by the EEBC.

The EEBC contains several design requirements to assist in proper building operation and maintenance (O&M). For example, ventilating and air-conditioning (VAC) vendors are required to provide information to owners about proper operation and performance of equipment and systems (see EEBC sections 8.4.7 and 8.4.8). Also, new buildings are required to contain adequate capabilities for being monitored relative to their energy consumption (See EEBC section 11).

However, the EEBC does not contain specific requirements for how the building should actually be operated and maintained. It is the intention of this appendix to offer some assistance to building owners and/or operators concerning the importance of proper operations and of good maintenance. These are two critical factors in the quest for effective energy management.

1 Introduction

For basic O&M objectives to be achieved for a building, a professional programme of energy management should be put into place. The key to the success is team work. It is strongly recommended that the O&M energy management team for a building include the following:

a) The energy coordinator, the operations and maintenance foreman and the utility clerk;
b) The representative of the principal fuel supplier (for most buildings, this will be the electric utility);
c) The principal building occupant and end user;
d) The use of the appropriate consultants and/or contractor must be involved at the earliest possible stage in the building's energy management programme.

For smaller buildings, one person may accomplish several of the functions just listed above. This professional approach should extend to all new buildings, as well as to all building retrofits and equipment replacements. Much benefit can be derived by having as much coordination between the design of the building and operation and maintenance of the building. This interaction will help give the building designers direct feedback as to how the next building might actually work.

The building's management and operating personnel should be fully cognizant of the provisions of the basic EEBC code. They should recognize that energy consumption is inextricably linked to proper operation and maintenance, and should understand that a holistic approach to energy management is necessary. The energy management programme should have several key components, including the establishment of proper data collection, metering and logging of building operation and performance, and establishing and maintaining a schedule of physical survey of the entire building.

Building conditions and energy use levels should be monitored routinely, including all fixtures and energy saving devices. Deviations from efficient conditions should be determined and corrected quickly. All metering devices should be kept in functional order and proper communication channels should be established between the various decision-makers.

Operational personnel and supervisors should be trained and an educational programme maintained to acquaint building occupants with energy-efficient operational procedures and goals.

Obviously, good housekeeping is of utmost importance, and it can save substantial energy. Cleaning of buildings, grounds, windows, shadings, walls and roofs would be included here. Operation, maintenance and repair of air conditioning, ventilation system and equipment is also crucial. Consideration must be given also to the operation, maintenance and repairs of lighting, power, and elevator systems. Maintenance and repairs of building structure, including interior and exterior walls, door, covering, painting and decoration all form part of the basic O&M practice.

Preventative maintenance should be emphasized in order to keep a building and its equipment in satisfactory operational condition by providing system inspection, detection and prevention of incipient failures, overhaul, lubrication, calibration, etc. This will reduce the need for corrective maintenance, which must be performed to restore an item to satisfactory condition after a malfunction has caused degradation below the specified performance.

For the O&M programme to be effective, the building management must be willing to commit the necessary financial support. In this context, both current and future plans for renovations and or expansion of the building should be determined and budgeted accordingly.

2 Maintenance Responsibility and Management Control

A major consideration with regards to building is whether the building is tenanted or owner-occupied. This has direct impacts on the allocation of maintenance funds. Usually the responsibility for O&M in Jamaica falls under one of the following headings:

a) The operator is the owner, who has direct responsibility for maintenance; or,

b) The operator is a tenant, who assumes no responsibility for maintenance.

In Jamaica, in either case, repair and maintenance is usually carried out by private contractors.

Also, a new trend is developing in Jamaica. The larger property owners are now using property management companies to perform all the necessary servicing and maintenance for the categories of buildings falling under this code. This is a positive development, but every effort must be made to assure that these companies incorporate energy-efficient methods as part of their servicing and maintenance practices.

The management team generated to oversee the operation and maintenance of each building will differ in terms of site and groupings. Proper supervision is the key to success or failure of the entire building management operation. The most effective methods, efficient equipment and thorough training will not produce satisfactory results unless they are accompanied by adequate and competent supervision.

Jamaica's rating in O&M management skills is fairly low, and for energy efficiency building O&M to become widespread, an attitudinal change must be achieved.

The main vehicle for this will be job training for building management and employees. Training courses should be developed, based on operating hand books, and circulated to all concerned so that uniform information is available nationally.

3 Need for Training in O&M Practices for Buildings

From an energy efficiency view point, it is necessary that the maintenance manager pay particular attention to interior and exterior deterioration. One approach to achieve this is to establish suitable preventative maintenance programs that emphasize cost-effective maintenance levels. Having identified the elements that will offer a better contribution to energy efficiency, the maintenance cycle must be tailored to suit.

Although there is considerable historical knowledge available indicating the benefits of proper O&M for buildings, such knowledge is not being properly utilized by the local Jamaican building industry. There are several causes for this situation. First, only a few Jamaican organizations now possess the technical skills needed to assess the costs and benefits of energy-efficient building operations and preventative maintenance programs. However, rising energy prices are helping to expand the local market for such skills. Second, building owners and operators lack understanding of capital investment strategies concerning energy-efficiency practices. The level of knowledge required to implement satisfactory O&M programmes is not readily available within the local building maintenance practice.

Because of the low level of O&M practice associated with the local building management program, technical assistance should be offered to raise skill levels. This technical training should address the proper use and maintenance of controls, metering instruments and the art of monitoring buildings for energy efficiency.

4 O&M Support Services

As part of establishing an O&M program, a building owner should determine what support services are available. Factors involved include: manpower utilization; spare parts; necessary tools and test equipment; contractor services; and, support facilities. Currently, very few local organizations would possess all the necessary resources to perform a comprehensive O&M programme. Generally, however, they should be able to perform adequate trouble shooting, plus some of the other services. In choosing an external (contractor) maintenance organization, it is very important that management ascertain the services mix and the reliability level of the organizations being considered.

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Appendix K: Definitions, Abbreviations, Acronyms and Symbols

Commentary

The purpose of this Appendix is to define terms, abbreviations, acronyms, and symbols which are used throughout both the Energy Efficiency Building Code (EEBC) and these Guidelines to the EEBC. The intent is to enable users of these documents to fully understand the context in which these terms, abbreviations, acronyms, and symbols are used.

Definitions

A

accessible (as applied to equipment): admitting close approach; not guarded by locked doors, elevation, or other effective means. (See also readily accessible.)

adjusted lighting power: lighting power, ascribed to a luminaire(s) that has been reduced by deducting a lighting power control credit based on use of an automatic control device(s).

annual fuel utilization efficiency (AFUE): the ratio of annual output energy to annual input energy which includes any non-heating season pilot input loss.

air conditioning, comfort: treating air to control its temperature, relative humidity, cleanliness, and distribution to meet the comfort requirements of the occupants of the conditioned space. Some air conditioners may not accomplish all of these controls.

area factor (AF): a multiplying factor which adjusts the unit power density (UPD) for spaces of various sizes to account for the impact of room configuration on lighting power utilization.

area of the space (A): the horizontal lighted area of a given space measured from the inside of the perimeter walls or partitions, at the height of the working surface.

automatic: self-acting, operating by its own mechanism when actuated by some impersonal influence, such as, a change in current strength, pressure, temperature or mechanical configuration. (See also manual.)

B

ballast: a device used to obtain the necessary circuit conditions (voltage, current, and wave form) for starting and operating an electric-discharge lamp.

ballast efficacy factor - fluorescent (BEF): the ratio of the relative light output expressed as a percent to the power input in watts, at specified test conditions.

ballast factor (BF): the ratio of a commercial ballast lamp lumens to a reference ballast lamp lumens, used to correct the lamp lumen output from rated to actual.

building: any new structure to be constructed that includes provision for any of the following or any combination of the following: a space heating system, a space cooling system, or a service water heating system.

building energy cost: the computed annual energy cost of all purchased energy for the building, calculated using the methods of Section 12 of this code.

building envelope: the elements of a building that enclose conditioned spaces through which thermal energy may be transferred to or from the exterior or to or from unconditioned spaces.

building type: the classification of a building by usage as follows:

a. **assembly:** a building or structure for the gathering together of persons, such as auditoriums, churches, dance halls, gymnasiums, theaters, museums, passenger depots, sports facilities, and public assembly halls

b. **health and institutional:** a building or structure for the purpose of providing medical treatment, confinement or care, and sleeping facilities such as hospitals, sanitariums, clinics, orphanages, nursing homes, mental institutions, reformatories, jails, and prisons

c. **hotel or motel:** a building or structure for transient occupancy, such as resorts, hotels, motels, barracks, or dormitories

d. **multifamily:** a building or structure containing three or more dwelling units (see dwelling units)

e. **office (business):** a building or structure for office, professional, or service type transactions; such as medical offices, banks, libraries, and governmental office buildings

f. **restaurant:** a building or a structure for the consumption of food or drink, including fast food, coffee shops, cafeterias, bars, and restaurants

g. **retail (mercantile):** a building or structure for the display and sale (wholesale or retail) of merchandise such as shopping malls, food markets, auto dealerships, department stores, and specialty shops (see also retail establishments)

h. **school (educational):** a building or structure for the purpose of instruction such as schools, colleges, universities, and academies

i. **warehouse (storage):** a building or structure for storage, such as aircraft hangers, garages, warehouses, storage buildings, and freight depots

C

check metering: measurement instrumentation for the supplementary monitoring of energy consumption (electric, gas, oil, etc.) to isolate the various categories of energy use to permit conservation and control, in addition to the revenue metering furnished by the utility.

coefficient of performance (COP) — cooling: the ratio of the rate of heat removal to the rate of energy input in consistent units, for a complete cooling system or factory assembled equipment, as tested under a nationally recognized standard or designated operating conditions.

coefficient of performance (COP), heat pump – heating: the ratio of the rate of heat delivered to the rate of energy input, in consistent units, for a complete heat pump system under designated operating conditions.

combined thermal transmittance values ($U_{0)}$: see thermal transmittance, overall.

conditioned floor area: the area of the conditioned space measured at floor level from the interior surfaces of the walls.

conditioned space: a cooled space, heated space, or indirectly conditioned space.

connected lighting power (CLP): the power required to energize luminaires and lamps connected to the building electrical service, in Watts.

control loop, local: a control system consisting of a sensor, a controller, and a controlled device.

control points: the quantity of equivalent ON or OFF switches ascribed to a device used for controlling the light output of a luminaire(s) or lamp(s).

cooled space: an enclosed space within a building that is cooled by a cooling system whose sensible heat capacity:

a. Exceeds 15.76 W/m^2 or

b. Is capable of maintaining space dry bulb temperature of 30 °C or less at design cooling conditions.

D

daylighted space: the space bounded by vertical planes rising from the boundaries of the daylighted area on the floor to the above floor or roof.

daylighted zone:

a. **under skylights:** the area under each skylight whose horizontal dimension in each direction is equal to the skylight dimension in that direction plus either the floor to ceiling height or the dimension to an opaque partition, or one-half the distance to an adjacent skylight or vertical glazing, whichever is least.

b. **at vertical glazing:** the area adjacent to vertical glazing which receives daylighting from the glazing. For purposes of this definition and unless more detailed daylighting analysis is provided, the daylighting zone depth is assumed to extend into the space a distance of 4.6 metres or to the nearest opaque partition, whichever is less. The daylighting zone width is assumed to be the width of the window plus either 0.61 metres on each side (the distance to an opaque partition) or one half the distance to an adjacent skylight or vertical glazing whichever is less.

daylight sensing control (DS): a device that automatically regulates the power input to electric lighting near the fenestration to maintain the desired workplace illumination, thus taking advantage of direct or indirect sunlight.

default assumption: the value of an input used in a calculation procedure when a value is not entered by the designer.

demand (electric): the rate at which electric energy is delivered to or by a system, part of a system, or a piece of equipment; expressed in kilowatts, kilovoltamperes, or other suitable units at a given instant or averaged over any designated period.

design conditions: the exterior and interior environmental parameters specified for air-conditioning and electrical design for a facility.

design energy consumption (DECON): the computed annual energy usage of a proposed building design.

design energy costs (DECOS): the computed annual energy expenditure of a proposed building design.

dwelling unit: a single housekeeping unit comprised of one or more rooms providing complete independent living facilities for one or more persons including permanent provisions for living, sleeping, eating, cooking, and sanitation.

E

economizer (air): a ducting arrangement and automatic control system that allows a cooling supply fan system to supply outside air to reduce or eliminate the need for mechanical refrigeration during mild or cold weather.

economizer (water): a system by which the supply air of a cooling system is cooled directly or indirectly or both by evaporation of water or by other appropriate fluid (in order to reduce or eliminate the need for mechanical refrigeration).

efficiency (VAC system): the ratio of the useful energy output (at the point of use) to the energy input in consistent units for a designated time period, expressed in percent.

emergency system (back up system): a system that exists for the purpose of operating in the event of failure of a primary system.

energy: the capability for doing work; having several forms that may be transformed from one to another, such as thermal (heat), mechanical (work), electrical, or chemical.

energy cost: the cost of energy by unit and type of energy as proposed to be supplied to the building at the site including variations such as "time of day", "seasonal" and "rate of usage".

energy cost budget (ECB): the maximum allowable computed annual energy expenditure for a proposed building.

energy management system: a control system designed to monitor the environment and the use of energy in a facility and to adjust the parameters of local control loops to conserve energy while maintaining a suitable environment.

energy recovered: see recovered energy.

enthalpy: a thermodynamic property of a substance defined as the sum of its internal energy plus the quantity Pv/J, where P is the pressure of the substance, v is its specific volume, and J is the mechanical equivalent of heat, formerly called total heat and heat content.

exterior envelope: see building envelope.

exterior lighting power allowance (ELPA): the calculated maximum lighting power allowance for an exterior area of a building or facility, in Watts.

F

fenestration: any light-transmitting section in a building wall or roof. The fenestration includes glazing material (which may be glass or plastic), framing (mullions, muntins, and dividers) external shading devices, internal shading devices, and integral (between-glass) shading devices.

fenestration area: the total area of fenestration measured using the rough opening and including the glass or plastic, sash, and frame.

G

gross exterior wall area: the gross area of exterior walls separating a conditioned space from the outdoors or from unconditioned spaces as measured on the exterior above grade. It consists of the opaque wall including between floor spandrels, peripheral edges of flooring, window areas including sash, and door areas (excluding vents and grills).

gross floor area: the sum of the floor areas of the conditioned spaces within the building including basements, mezzanine and intermediate-floored tiers, and penthouses of headroom height 2.3 m or greater. It is measured from the exterior faces of exterior walls or from the centerline of walls separating buildings (excluding covered walkways, open roofed-over areas, porches and similar spaces, pipe trenches, exterior terraces or steps, chimneys, roof overhangs, and similar features).

gross floor area over outside or unconditioned spaces: the gross area of a floor assembly separating a conditioned space from the outdoors or from unconditioned spaces as measured from the exterior faces of exterior walls or from the center line of walls separating buildings. The floor assembly shall be considered to include all floor components through which heat may flow between indoor and outdoor or unconditioned environments.

gross lighted area (GLA): the sum of the total lighted areas of a building measured from the inside of the perimeter walls for each floor of the building.

gross roof area: the gross area of a roof assembly separating a conditioned space from the outdoors or from unconditioned spaces, measured from the exterior faces of exterior walls or from the centerline of walls separating buildings. The roof assembly shall be considered to include all roof or ceiling components through which heat may flow between indoor and outdoor environments including skylights but excluding service openings.

H

heat: the form of energy that is transferred by virtue of a temperature difference or a change in state of a material.

heat capacity (hc): the amount of heat necessary to raise the temperature of a given mass one degree. Numerically, the mass multiplied by the specific heat.

humidistat: an automatic control device responsive to changes in humidity.

I

illuminance: the density of the luminous flux incident on a surface. It is the quotient of the luminous flux multiplied by the area of the surface when the latter is uniformly illuminated.

indirectly conditioned space: an enclosed space within the building that is not a cooled space, whose area weighted heat transfer coefficient to cooled spaces exceeds that to the outdoors or to unconditioned spaces; or through which air from cooled spaces is transferred at a rate exceeding three air changes per hour. (See also cooled space and unconditioned space.)

infiltration: the uncontrolled inward air leakage through cracks and crevices in any building element and around windows and doors of a building.

insolation: the rate of solar energy incident on a unit area with a given orientation.

integrated part-load value (IPLV): a single number figure of merit based on part-load COP expressing part-load efficiency for air-conditioning and heat pump equipment on the basis of weighted operation at various load capacities for the equipment.

interior lighting power allowance (ILPA): the calculated maximum lighting power allowed for an interior space of a building or facility, in Watts.

interior unit lighting power allowance - prescriptive: the allotted interior lighting power for each individual building type, in W/m2. (See EEBC Section 5.5 and EEBC Table 5-5.)

interior unit lighting power allowance - system performance: the allotted interior lighting power for each individual space, area or activity in a building, in W/m^2. (See EEBC Section 5.6 and EEBC Table 5-7.)

J

Joule (J): is the work done or the energy expended when a force of one newton moves the point of application a distance of one metre in the direction of that force.

K

Kelvin (K): the unit of thermodynamic temperature. It is 1/273.16 of the thermodynamic temperature of the triple point of water.

kilogram (kg): the unit of mass.

L

lighting power budget (LPB): the lighting power, in Watts, allowed for an interior or exterior area or activity.

lighting power control credit (LPCC): a credit applied to that part of the connected lighting power of a space which is turned off or dimmed by automatic control devices. It gives the specific value of lighting Watts to subtract from the connected interior lighting power when establishing compliance with the Interior Lighting Power Allowance (ILPA).

lumen (lm): unit of luminous flux. Radiometrically, it is determined from the radiant power. Photometrically, it is the luminous flux emitted within a unit solid angle (one steradian) by a point source having a uniform luminous intensity of one candela.

lumen maintenance control: a device that senses the illumination level and causes an increase or decrease of illuminance to maintain a preset illumination level.

luminaire: a complete lighting unit consisting of a lamp or lamps together with the parts designed to distribute the light, to position and protect the lamps, and to connect the lamps to the power supply.

M

manual (non-automatic): action requiring personal intervention for its control. As applied to an electric controller, nonautomatic control does not necessarily imply a manual controller but only that personal intervention is necessary (See automatic.)

marked rating: the design load operating conditions of a device as shown by the manufacturer on the nameplate or otherwise marked on the device.

motor efficiency, minimum: the minimum efficiency occurring in a population of motors of the same manufacturer and rating.

motor efficiency, nominal: the median efficiency occurring in a population of motors of the same manufacturer and rating.

N

Newton (N): is the unit of force which when applied to a body having a mass of one kilogram, causes an acceleration of one metre per second per second in the direction of the force.

O

opaque areas: all exposed areas of a building envelope which enclose conditioned space except fenestration areas and building service openings such as vents and grilles.

occupancy sensor: a device that detects the presence or absence of people within an area and causes any combination of lighting, equipment, or appliances to be adjusted accordingly.

offices, category 1: Enclosed offices, all open plan offices without partitions or with partitions lower than 1.48 m below the ceiling, where 90% of all work stations are individually enclosed with partitions of at least the height described.

offices, category 2: Open plan offices 85 m^2 or larger with partitions 1.15 to 1.48 m below the ceiling, where 90% of all work stations are individually enclosed with partitions of at least the height described. Offices less than 85 m^2 shall use category 1.

office category 3: large open plan offices 85 m^2 or larger with partitions higher than 1.15 m below the ceiling, where 90% of all work stations are individually enclosed with partitions of at least the height described. Offices less than 85 m^2 shall use category 1.

orientation: the directional placement of a building on a building site with reference to the building's longest horizontal axis, or if there is no longest horizontal axis then with reference to the designated main entrance.

outdoor (outside) air: air taken from the exterior of the building that has not been previously circulated through the building. (See also ventilation air.)

ozone depletion factor: a relative measure of the potency of chemicals in depleting stratospheric ozone. The ozone depletion factor potential depends upon the chlorine and the bromine content and atmospheric lifetime of the chemical. The depletion factor potential is normalized such that the factor for CFC-11 is set equal to unity and the factors for the other chemicals indicate their potential relative to CFC-11.

P

packaged terminal air-conditioner (PTAC): a factory-selected wall sleeve and separate unencased combination of heating and cooling components, assemblies or sections (intended for mounting through the wall to serve a single room or zone). It can include heating capability by hot water, steam, or electricity.

packaged terminal heat pump: a PTAC capable of using the refrigeration system in a reverse cycle or heat pump mode to provide heat.

piping: a system for conveying fluids including pipes, valves, strainers, and fittings.

plenum: an enclosure that is part of the air handling system and is distinguished by having a very low air velocity. A plenum often is formed in part or in total by portions of the building.

power: in connection with machines, it is the time rate of doing work; in connection with the transmission of energy of all types, it is the rate at which energy is transmitted, in Watts (W).

power adjustment factor (PAF): a modifying factor that adjusts the effective connected lighting power (CLP) of a space to account for the use of energy conserving lighting control devices.

power factor (PF): the ratio of total Watts to the root-mean-square (RMS) volt amperes.

prescribed assumption: a fixed value of an input to the standard calculation procedure.

private driveways, walkways, and parking lots: exterior transit areas that are associated with a commercial or residential building and intended for use solely by the employees or tenants and not by the general public.

process energy: energy consumed in support of a manufacturing, industrial, or commercial process other than the maintenance of comfort and amenities for the occupants of a building.

process load: the calculated or measured time-integrated load on a building resulting from the consumption or release of process energy.

proposed design: a prospective design for a building that is to be evaluated for compliance.

prototype building: a generic building design of the same size and occupancy type as the proposed design which complies with the prescriptive requirements of this code and has prescribed assumptions used to generate the energy budget concerning shape, orientation, HVAC, and other system designs.

public driveways, walkways, and parking lots: exterior transit areas that are intended for use by the general public.

public facility restroom: a restroom used by the transient public.

Q

qualified person: one familiar with the construction and operation of the equipment and the hazards involved.

R

radiant comfort heating: a system in which temperatures of room surfaces are adjusted to control the rate of heat loss by radiation from occupants.

readily accessible: capable of being reached quickly for operation, renewal, or inspections without requiring those to whom ready access is requisite to climb over or remove obstacles or to resort to portable ladders, chairs, etc. (See also "accessible").

recommend: suggest as appropriate, not required.

recovered energy: energy utilized from an energy utilization system which would otherwise be wasted (not contributing to a desired end use).

reference building: a specific building design that has the same form, orientation and basic systems as the proposed design and meets all the criteria of the prescriptive compliance method.

reflectance: the ratio of the light reflected by a surface to the light incident upon it.

reheating: raising the temperature of air that has been previously cooled either by a refrigeration or an economizer system.

residential building low-rise: single, two family, and multifamily dwelling units of three stories or fewer of habitable space above grade.

reset: adjustment of the controller set point to a higher or lower value automatically or manually.

retail establishments: classifications set for the purpose of determining lighting power allowance for buildings based upon the following primary design functions:

Type A Jewelry merchandising, where minute examination of displayed merchandise is critical.

Type B Fine Merchandising: fine apparel and accessories, china, crystal and silver, art galleries, etc., where the detailed display and examination of merchandise is important.

Type C Mass Merchandising: general apparel, variety, stationery, books, sporting goods, hobby, cameras, gifts, luggage, etc. displayed in a warehouse type of building, where focused display and detailed examination of merchandise is important.

Type D General Merchandising: general apparel, variety, stationery, books, sporting goods, hobby, cameras, gifts, luggage, etc. displayed in a department store type of building, where general display and examination of merchandise is adequate.

Type E Food & Miscellaneous: bakeries, hardware and housewares, grocery, appliances and furniture, etc., where appetizing appearance is important.

Type F Service Establishments: those establishments where functional performance is important.

roof: those portions of the building envelope including all opaque surfaces, fenestration, doors, and hatches which are above conditioned space and which are horizontal or tilted at less than 60° from the horizontal. (See also walls.)

room area (A_r): for lighting power determination purpose, the area of a room or space shall be determined from the inside face of the walls or partitions measured at work plane height.

room air conditioner: an encased assembly designed as a unit to be mounted in a window or through a wall, or as a console. It is designed primarily to provide free delivery of conditioned air to an enclosed space, room, or zone. It includes a prime source of refrigeration for cooling and dehumidification and means for circulating and cleaning air and may also include means for ventilating and heating

S

sash crack: the sum of all perimeters of all ventilators, sash, or doors based on overall dimensions of such parts expressed in metres (counting two adjacent lengths of perimeter as one).

sequence: a consecutive series of operations.

service systems: all energy-using or -distributing components in a building that are operated to support the occupant or process functions housed therein (including HVAC, service water heating illumination, transportation, cooking or food preparation, laundering, or similar functions).

service water heating: the supply of hot water for purposes other than comfort heating and process requirements.

service water heating demand: the maximum design rate of water withdrawal from a service water heating system in a designated period of time (usually an hour or a day).

shading coefficient (SC): the ratio of solar heat gain through fenestration, with or without integral shading devices, to that occurring through unshaded 3 mm thick clear double strength glass.

shall: where shall is used with a special provision, that provision is mandatory if compliance with the code is claimed.

shell building: a building for which the envelope is designed, constructed, or both prior to knowing the occupancy type. (See also speculative building.)

should: term used to indicate provisions which are not mandatory but which are desirable as good practice.

solar energy source: natural daylighting or thermal, chemical, or electrical energy derived from direct conversion of incident solar radiation at the building site.

speculative building: a building for which the envelope is designed, constructed, or both prior to the design of the lighting, VAC systems, or both. A speculative building differs from a shell building in that the intended occupancy is known for the speculative building. (See also shell building.)

standard calculation procedure: an energy simulation model and a set of input assumptions that account for the dynamic thermal performance of the building; it produces estimates of annual energy consumption for heating, cooling, ventilation, lighting, and other uses.

system: a combination of equipment and/or controls, accessories, interconnecting means, and terminal elements by which energy is transformed so as to perform a specific function, such as VAC, service water heating, or illumination.

T

tandem wiring: pairs of luminaires operating with one lamp in each luminaire powered from a single two-lamp ballast contained in the other luminaire.

task lighting: lighting that provides illumination for specific visual functions and is directed to a specific surface or area.

task location: an area of the space where significant visual functions are performed and where lighting is required above and beyond that required for general ambient use.

terminal element: a device by which the transformed energy from a system is finally delivered; i.e., registers, diffusers, lighting fixtures, faucets, etc.

thermal conductance (C): the constant time rate of heat flow through a unit area of a body that is induced by a unit temperature difference between the surfaces, in $W/(m^2 \cdot K)$. It is the reciprocal of the thermal resistance. (See thermal resistance.)

thermal mass: materials with mass heat capacity and surface area capable of affecting building loads by storing and releasing heat as the interior and/or exterior temperature and radiant conditions fluctuate. (See also wall heat capacity.)

thermal resistance (R): the reciprocal of thermal conductance; 1/C as well as 1/h, 1/U, $m^2 \cdot K/W$.

thermal transmittance (U): the overall coefficient of heat transfer from air to air. It is the time rate of heat flow per unit area under steady conditions from the fluid on the warm side of the barrier to the fluid on the cold side, per unit temperature difference between the two fluids, $W/(m^2 \cdot K)$.

thermal transmittance, overall (U_o): the gross overall (area weighted average) coefficient of heat transfer from air to air for a gross area of the building envelope, $W/(m^2 \cdot K)$. The U_o value applies to the combined effect of the time rate of heat flows through the various parallel paths such as windows, doors, and opaque construction areas comprising the gross area of one or more building envelope components such as walls, floors, and roof or ceiling.

thermostat: an automatic control device responsive to temperature.

total lighting power allowance: the calculated lighting power allowed for the interior and exterior space areas of a building or facility.

U

unconditioned space: space within a building that is not a conditioned space. (See conditioned space.)

unit lighting power allowance (ULPA): the allotted lighting power for each individual building type, W/m^2.

Unit Power Density (UPD): the lighting power density, in W/m^2, of an area or activity.

unitary cooling equipment: one or more factory-made assemblies which normally include an evaporator or cooling coil, a compressor, and condenser combination (may include a heating function as well).

unitary heat pump: one or more factory-made assemblies which normally include an indoor conditioning coil, compressor(s), and outdoor coil or refrigerant-to-water heat exchanger (including means to provide both heating and cooling functions.

unlisted space: the difference in area between the gross lighted area and the sum of all listed spaces.

V

VAC system: the equipment, distribution network, and terminals that provides either collectively or individually the processes of ventilating, or air conditioning to a building.

VAC system efficiency: see efficiency, VAC system.

variable air volume (VAV) VAC system: VAC systems that control the dry-bulb temperature within a space by varying the volume of supply air to the space.

ventilation: the process of supplying or removing air by natural or mechanical means to or from any space. Such air may or may not have been conditioned.

ventilation air: that portion of supply air which comes from outside (outdoors) plus any recirculated air that has been treated to maintain the desired quality of air within a designated space. (See also outdoor air.)

visual task: those details and objects that must be seen for the performance of a given activity and includes the immediate background of the details or objects.

W

walls: those portions of the building envelope enclosing conditioned space including all opaque surfaces, fenestration, and doors which are vertical or tilted at an angle of 60 °F from horizontal or greater. (See also roof.)

wall heat capacity: the sum of the products of the mass of each individual material in the wall per unit area of wall surface times its individual specific heat, J/K. (See thermal mass.)

Watt, (W): A unit of power. One watt is produced when one ampere, flows at an emf of one volt (unity power factor). (See also power.)

window to wall ratio (WWR): the ratio of the fenestration area to the gross exterior wall area.

Z

zone: a space or group of spaces within a building with any combination of heating, cooling, or lighting requirements sufficiently similar so that desired conditions can be maintained throughout by a single controlling device.

Abbreviations, Acronyms and Symbols

A	area of the space
A_o	total building floor area
A_r	room area
$A_{wall,roof,etc.}$	area of a specific building component
AF	area factor
AFUE	annual fuel utilization efficiency
AHAM	Association of Home Appliance Manufacturers
AIA	American Institute of Architects
ALP	adjusted lighting power
ANSI	American National Standards Institute
ARI	Air-Conditioning and Refrigeration Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
$BECON_{mi}$	budget energy consumption by month (m) and fuel type (i)
BEF	ballast efficacy factor - fluorescent
BF	ballast factor
°C	degree Celsius
C	thermal conductance
CEEU	cost equivalent energy units
CFM	cubic feet per minute
CH	ceiling height
CLP	connected lighting power
COP	coefficient of performance
$DECON_{mi}$	design energy consumption by month (m) and fuel type (i)
DECOS	annual design energy cost
DOE	U. S. Department of Energy
DS	daylight sensing control
ECB	annual energy cost budget
$ECOS_{mi}$	energy cost by month (m) and fuel type (i)
ELPA	exterior lighting power allowance
EPD	equipment power density
GLA	gross lighted building area

H	height from bottom of window to bottom of external shading projection
Hc	heat capacity
hp	horsepower
HSPF	heating seasonal performance factor
IEPA	interior equipment power allowance
IES	Illuminating Engineering Society of North America
ILPA	interior lighting power allowance
IPLV	integrated part load value
IRF	internal reflecting film
LPB	lighting power budget
LPD	lighting power density
LPCC	lighting power control credit
NFPA	National Fire Protection Association
PAF	power adjustment factor
PTAC	packaged terminal air-conditioner
r	thermal resistivity
R	thermal resistance
SC	shading coefficient
SWH	service water heating
TEFC	totally enclosed, fan cooled
U_o	overall thermal transmittance
U_{or}	overall thermal transmittance of roof assembly
U_{ow}	overall thermal transmittance of opaque wall
ULPA	unit lighting power allowance
UPD	Unit Power Density
VAC	ventilating and air conditioning
VAV	variable air volume
VLT	transmittance of glazing material over visible portion of solar spectrum
W	watts
WC	water column
WWR	window to wall ratio

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Appendix L:
Conversion Tables

Multiply	By	To Obtain
acre	.405	ha
bar	100	kPa
barrel (42 US gal petroleum)	159	L
	0.159	m^3
Btu, IT	1.055	kJ
Btu/ft^3	37.3	J/m^3; J/L
Btu/gal	0.279	kJ/L
Btu • fl/h • ft^2 • °F	1.731	W/(m • K)
Btu • in/(h • ft2 • °F)		
(thermal conductivity, k)	0.144	W/(m • K)
		W/(m • °C)
Btu/h	0.293	W
Btu/ft^2	11.4	kJ/m^2
Btu/(y • ft^2) [not SI]	0.000293	kWh/(y • m^2)
Btu/(y • ft^2)	0.0000114	GJ/(y • m^2)
Btu/(h • ft^2)	3.15	W/m^2
Btu/(h • ft^2 • °F)		
(overall heat trans coeff U)	5.68	W/(m^2 • K)
(thermal conductance, C)		W/(m^2 • °C)
Btu/lb	2.33	kJ/kg
Btu/(lb-°F) (specific heat, c)	4.19	kJ/(kg • K)
		kJ/(k8 • °C)
bushel	0.0352	m
calorie, gram	4.19	J
calorie, kilogram; kilocalorie	4.19	kJ
centipoise, viscosily, u		
(absolute, dynamic)	*1.00	mPa • s
centistokes, kinematic		
viscosity, v	*1.00	mm2/s
cost, J$ per square foot	10.8	J$/$m^2$
cost, J$ per pound	2.20	J$/kg
cost, J$ per ton (refrigeration)	0.284	J$/kW

Multiply	By	To Obtain
dyne/cm^2	*0.100	Pa
EDR hot water (150 Btu/h)	44.0	W
EDR steam (240 Btu/h)	70.3	W
EER	0.293	COP
fuel cost comparison		
@ 100% efficiency		
J$ per gallon	0.264	J$/L
J$ per gallon (#2 fuel oil)	6.77	J$/GJ
J$ per gallon (#6 fuel oil)	6.32	J$/GJ
J$ per gallon (propane)	11.3	J$/GJ
J$ per kWh	278	J$/GJ
J$ per therm	9.48	J$/GJ
ft	*0.3048	m
ft	*304.8	mm
ft/min, fpm	0.00508	m/s
ft/s fps	*0.3048	m/s
ft of water	2.99	kPa
ft of water per 100 ft pipe	0.0981	kPa/m
ft^2	0.0929	m^2
ft^2 • h • °F/Btu		
(thermal resistance, R)	0.176	m^2 • K/W
		m^2 • °C/W
ft^2/s, kinematic viscosity, v	92900	mm^2/s
ft^3	28.3	L
ft^3	0.0283	m^3
ft^3/h, cfh	7.87	mL/s
ft^3/min, cfm	0.472	L/s
ft^3/s, cfs	28.3	L/s
ft • lb_f (torque or moment)	1.36	N m
ft • lb_f (work)	1.36	J
ft • lb_f/lb (specific energy)	2.99	J/kg
ft • lb_f/min (power)	0.0226	W

Multiply	By	To Obtain
gallon, US	3.79	L
gallon, US	0.00379	m^3
gallon, Imperial	4.55	L
gallon, Imperial	0.00455	m^3
gph	1.05	mL/s
gpm	0.0631	L/s
gpm/ton refrigeration	0.0179	mL/J
grain (1/7000 lb)	0.0648	g
gr/gal	17.	mg/L
gr/lb	0.143	g/kg
horsepower (boiler)	9.81	kW
horsepower (550 ft-lb_f/s)	0.746	kW
inch	*25.4	mm
in of mercury (60°F)	3.38	kPa
in of water (60°F)	249	Pa
in/100 ft, thermal expansion	0.833	mm/m
in/lb_f(torque or moment)	113	mN/m
in^2	645	mm^2
in^3 (volume)	16.4	mL
in^3/min (SCIM)	0.273	mL/s
in^3 (section modulus)	16 400	mm^3
in^4 (section moment)	416 000	mm^4
km/h	0.278	m/s
kWh	*3.60	MJ
kWh/(y • ft^2)	0.0388	GJ/(y • m^2)
kWh/1000 cfm	2.12	J/L
kilopond (kg force)	9.81	N
kip (1000 lb_f)	4.45	kN
kip/in^2 (ksi)	6.89	MPa
litre	*0.001	m^3
micron of mercury (60°F)	133	MPa
mile	1.61	km
mile, nautical	1.85	km
mph	1.61	km/h
mph	0.44	m/s
millibar	*0.100	kPa
mm of mercury (60°F)	0.133	kPa
mm or water (60°F)	9.80	Pa
metre of water	9.80	kPa
ounce (mass, avoirdupois)	28.3	g
ounce (force or thrust)	0.278	N
ounce (liquid, US)	29.6	mL

Multiply	By	To Obtain
ounce inch (torque, moment)	7.06	mN • m
ounce (avoirdupois) per gallon	7.49	g/L
perm (permeance)	57.4	ng/(s•m^2•Pa)
perm inch (permeability)	1.46	ng/(s•m•Pa)
pint (liquid US)	473	mL
pound		
lb (mass)	0.454	kg
lb (mass)	454	g
lb_f(force or thrust)	4.45	N
lb/ft (uniform load)	1.49	kg/m
lb_m/(ft • h) viscosity (absolute, dynamic, u)	0.413	mPa • s
lb_f/(ft • s) viscosity (absolute, dynamic, u)	1 490	mPa • s
lb/h	0.126	g/s
lb/min	0.00756	kg/s
lb of steam per hour @ 212°F (100°C)	0.284	kW
lb_f/ft^2	47.9	Pa
lb_f • s/ft^2 viscosity (absolute, dynamic u)	47 900	mPa • s
lb/ft^2	4.88	kg/m^2
lb/ft^3 (density, Q)	16.0	kg/m^3
lb/gallon	120	kg/m^3
ppm (by mass)	*1.00	mg/kg
psi	6.89	kPa
quad	1.055	EJ
quart (liquid U.S.)	0.946	L
square (100 sq ft)	9.29	m^2
tablespoon (approximately)	15	mL
teaspoon (approximately)	5	mL
therm (US)	105.5	MJ
ton, long (2,240 lb)	1.016	t (tonne); Mg
ton, short (2,000 lb)	0.907	t (tonne); Mg
ton, refrigeration (12,000 Btu/h)	3.52	kW
torr (1 mm Hg @ 0°C)	133	Pa
watt per square foot	10.8	W/m^2
yd	*0.9144	m
yd^2	0.836	m^2
yd^3	0.765	m^3

*Conversion factor is exact.
Units are US values unless otherwise noted.

Table of Equivalents

Mass

	lb	kg
	1	= 0.45359
	2.20462	1

Volume

	in^3	ft^3	gal	litre	metre^3
	1	= 5.787 x 10^{-4}	= 4.329 x 10^{-3}	= 0.0163871	= 1.63871 x 10^{-5}
	1728*	1	7.48055	28.317	0.028317
	231.0	0.13368	1	3.7854	0.0037854
	61.02374	0.035315	0.264173	1	0.001*
	61,023.74	35.315	264.173	1000	1

Energy

	Btu	ft• lb	calorie	Joule	watt-sec
	1	= 777.65	= 251.9957	= 1054,35	= 1054.35
	1.2859 x 10^{-3}	1	0.32405	1.3558	1.3558
	3.9683 x 10^{-3}	3.08596	1	4.184'	4.184'
	9.4845 x 10^{-4}	0.73756	0.2390	1	1

Density

	lb/ft^3	lb/gal	g/cm^3	kg/m^3 (g/L)
	1	= 0.133680	= 0.016018	= 16.018463
	7.48055	1	0.119827	119.827
	62.4280	8.34538	1	1,000
	0.0624280	0.008345	0.001	1

Pressure

psi	in. Hg	atm	mm Hg	bar	kg/cm^2	dyne/cm^2	pascal
1	2.0360	0.068046	51.715	0.068948	0.07030696	68,948	6894.8
0.491154	1	0.033421	25.400	0.033864	0.034532	33,864	3386.4
14.6960	29.921	1	760.0	1.01325*	1.03323	1,013,250	101,325*
0.0193368	0.03937	0.00131579	1	0.0013332	0.0013595	1333.2	133.32
14.5038	29.530	0.98692	750.062	1	1.01972	10^{6}*	10^{6}*
14.223	28.959	0.96784	735.559	0.98066	1	9480,665*	98,066
1.45038 x 10^{-5}	2.953 x 10^{-5}	9.8692 x 10^{-7}	0.000750	10^{-6}	1.01972 x 10^{-6}	1	0.100*
1.45038 x 10^{-4}	2.953 x 10^{-4}	9.8692 x 100^{-6}	0.0750	10^{-5}	1.0192 x 10^{-5}	10*	1

Specific Volume

	ft^3/lb	gal/lb	cm^3/g	m^3/kg(L/g)
	1	= 7.48055	= 62.4280	= 0.0624280
	0.133680	1	8.34538	.008345
	0.016018	0.119827	1	0.001
	16.018463	119.827	1000	1

Table of Equivalents

Specific Heat or Entropy	Btu/lb • °F	cal/(g • K)	J/(g • K)
	1	= 1	= 4.184*
	1.0	1	4.184*
	0.2390	0.2390	1

Enthalpy	Btu/lb	cal/g	J/g
	1	=0.55556	= 2.3244
	1.8*	1	4.184*
	0.43021	0.2390	1

Thermal Conductivity

Btu/h • ft • °F	cal/(s cm • °C)	J/(s • cm • °C)	W/(cm • °C)	W/(m • K)
1	= $4.1338 \cdot 10^{-3}$	= 0.17296	= 0.017296	= 1.7296
241.91	1	4.184*	4.184*	418.4*
57.816	0.2390	1	1	418.4*

Viscosity (1 poise = dync-sec/cm2 = 0.1 newton-sec/m2)

poise g/(cm • s)	lb_f • s/ft²	lbr • hr/ft²	kg/(m • s)	N • s/m²	lb_m/(ft • s)
1	=2.0885 x 10-3	=5.8014×10^{-7}	= 0.1	= 0.1	=6.71955×10^{-2}
478.8026	1	2.7778×10^{-4}	47.88026	47.88026	32.17405
1,723,689	3600	1	172 ,369	172.369	115,827
10	0.020885	5.8014×10^{-6}	1	1	0.0671955
14.8819	3.1081×10^{-2}	8.6336×10^{-6}	1.4882	1.4882	1

Coefficient of Heat Transfer

Btu/h • ft² • °F	cal/(s • cm² • °C)	W/(cm² • °C)	kcal/(h • m² • °C)	W/(m² • K)
1	= $1.3562 \cdot 10^{-4}$	= $5.6783 \cdot 10^{-4}$	= 4.8823	= 5.6783
7373.5	1	4.1869	36000	41869
1761.1	0.2388	1	8598	10000
0.2048	$2.778 \cdot 10^{-5}$	$1.1630 \cdot 10^{-4}$	1	1.630
0.1761	$2.388 \cdot 10^{-5}$	$1 \cdot 10^{-4}$	0.8598	1

Appendix M:
Compliance Forms

Contents of this Appendix

1 Forms for Prescriptive and System Performance Compliance for Small Buildings, Less than 1,000 m^2 .... M-2
2 Forms for Prescriptive and System Performance Compliance for Medium and Large Buildings, Larger that 1,000 m^2 .... M-7
3 Forms for Whole-Building Energy Cost Budget Compliance Option M-18

Commentary

This Appendix contains the compliance forms intended for use in complying with the requirements of the EEBC-94. Three sets of forms are included.

Forms for Prescriptive and System Performance Compliance for Small Buildings

A set of 5 forms are provided for small buildings, less than 1,000 m^2 in gross floor area. These forms, which are contained on pages M-2 through M-6, include:

1. *General Compliance Small Building Form SB/G-1*
2. *Envelope Compliance Small Building Form SB/E-1*
3. *Lighting Compliance Small Building Form SB/LTG-1*
4. *Lighting & Electric Compliance Small Building Form SB/E-2*
5. *VAC Compliance Small Building Form SB/VAC-1*

Proper completion of these 5 forms will permit compliance to be achieved for small buildings.

Forms for Prescriptive and System Performance Compliance for Medium and Large Buildings

For medium-sized buildings, from 1,000 m^2 to 4,000 m^2 in gross floor area, a more detailed set of 11 compliance forms is provided. These forms, which are contained on pages M-7 through M-17, include:

1. *General Compliance Form G-1*
2. *Envelope Compliance Form ENV-1*
3. *Envelope Compliance Form ENV-2*
4. *Lighting Compliance Form LTG-1*
5. *Lighting Compliance Form LTG-2*
6. *Electric Compliance Form ELEC-1*
7. *Electric Compliance Form ELEC-2*
8. *VAC Compliance Form VAC-1*
9. *VAC Compliance Form VAC-2*
10. *VAC Compliance Form VAC-3*
11. *Service Water Heating Compliance Form SWH-1*

Proper completion of these 11 forms will permit prescriptive and/or system performance compliance to be achieved for medium and large buildings.

Form for Whole-Building Energy Cost Budget Compliance Option, Form WBEB-1

This form, which is on page M-18, is for use with the optional whole-building compliance path that is available for all buildings, but is especially intended for large buildings (those over 4,000 m^2).

To use this form, one must also complete either the set of 5 forms for small buildings, or the set of 11 forms for medium and large buildings, in order to determine the energy consumption of a Base Case building.

JAMAICA ENERGY EFFICIENCY BUILDING CODE (EEBC-94)

Prescriptive and System Performance Compliance Approach For Buildings Less Than 1,000 sq. metres in Gross Floor Area

VAC Compliance Small Building Form SB/VAC-1

A. CERTIFICATION

(For Form SB/VAC-1, by registered architect or engineer)

Name (printed or typed)	Signature and Seal	Registration Number
________________	______________________________	

B. VAC SYSTEMS - BASIC REQUIREMENTS

Item	Requirement	Application	Complies? Yes	N/A	EEBC Section
1 Load Calculations	Perform detailed calculation procedure	All buildings	☐	☐	7.4.1
2 Temperature controls					
a. System control	Each AC system shall have at least one temp. control		☐	☐	7.4.4.1
b. Zone Control	Cooling energy controlled by individual thermostats responding to temp. in zone	Some exceptions apply	☐	☐	7.4.4.2
c Thermostats	Capable of being set up to 29.5 deg C		☐	☐	7.4.4.3

C. VAC SYSTEMS - PRESCRIPTIVE REQUIREMENTS

Item	Requirement	Application	Yes	N/A	EEBC Section
1 Sizing - VAC System & Equipment					
a. Sizing, general	System & equipment shall be sized no more than space loads.	The loads calculated in EEBC-94 7.4.1	☐	☐	7.5.1
2 Fan System Design Criteria					
a. VAV fan control	Fan motor shall demand less than 50% of design wattage at 50% of design air volume	Fan > 25 kW	☐	☐	7.5.3.2
b. Fan power consumption	Fan Power Index (FPI) less than 645 L/s-mm per sq.m of floor area of conditioned space.	Some exceptions apply	☐	☐	7.5.3.5 7.5.3.6 7.5.3.7

D. VAC EQUIPMENT - BASIC REQUIREMENTS

Item	Requirement	Application	Yes	N/A	EEBC Section
1 Minimum Equipment Performance	Equipment shall have minimum COP listed in Table 8-1, at rated conditions.	List information requested below	☐	☐	8.4.1

Equipment type	Size	Number	Required Value	Design Value
____________	______________	____	______	____
____________	______________	____	______	____
____________	______________	____	______	____

Item	Requirement	Yes	N/A	EEBC Section
2 Equipment Controls	Equipment has controls required by EEBC-94 8.4.5	☐	☐	8.4.5
3 Maintenance Information	Information provided to building owner on maintenance procedures is sufficient maintain efficient operation	☐	☐	8.4.6

JAMAICA ENERGY EFFICIENCY BUILDING CODE (EEBC-94)

Envelope Compliance
Small Building Form SB/E-1

Prescriptive and System Performance Compliance Approach For Buildings Less Than 1,000 sq. metres in Gross Floor Area

A. CERTIFICATION

(For Form SB/E-1, by registered architect or engineer)

Name (printed or typed)	Signature and Seal	Registration Number

B. OVERALL THERMAL TRANSMITTANCE VALUE (OTTV)

Item	Requirement	Application	Complies? Yes	N/A	EEBC Section
1 **External Walls**	OTTV <= 61.7 W/sq.m	Offices smaller than 4,000 sq.metres	☐	☐	4.5.1 or 4.6.1
	OTTV <= 55.1 W/sq.m	All other buildings	☐	☐	
2 **Roof/Ceiling**	OTTV <= 20.0 W/sq.m	All buildings	☐	☐	4.5.2 or 4.6.2

Note 1: *For external walls, if prescriptive compliance is used, then attach a copy of EEBC Table 4-2 or 4-2. For roof/ ceilings, attach a copy EEBC-94, Table 4-3. On each table submitted, circle the option that complies.*

Note 2: *If the system performance approach is used for compliance for either walls or roof/ceilings, then attach a copy of the computer spreadsheet printout showing compliance, or attach complete calculations showing compliance*

C. AIR LEAKAGE

Item	Requirement	Application	Complies? Yes	N/A	EEBC Section
1 **Windows & Doors**					
a. Windows	EEBC-94, 4.4.2	Attach certification from supplier that requirement has been met.	☐	☐	4.4.2
b. Sliding doors	EEBC-94, 4.4.3.1		☐	☐	4.4.3.1
c. Swinging or revolving doors	EEBC-94, 4.4.3.2		☐	☐	4.4.3.2
2 **Caulking, Weatherstripping & Sealants**					
a. Around window and door frames			☐	☐	4.4.1
b. Between wall and foundation, wall and roof, and wall and floor			☐	☐	4.4.1
c. Through wall panels and wall top and bottom plates			☐	☐	4.4.1
d. At penetrations of service openings (including utility services)			☐	☐	4.4.1
e. Between wall panels, especially at changes in wall direction			☐	☐	4.4.1

JAMAICA ENERGY EFFICIENCY BUILDING CODE (EEBC-94)

Prescriptive and System Performance Compliance Approach For
Buildings Less Than 1,000 sq. metres in Gross Floor Area

Lighting Compliance
Small Building Form SB/LTG-1

A. CERTIFICATION (For Forms SB/LTG-1 and SB/LTG-2, by registered architect or engineer)

Name (printed or typed)	Signature and Seal	Registration Number
______________	______________	______________

B. BASIC LIGHTING REQUIREMENTS

1 LIGHTING CONTROLS

Item	Requirement	Application	Complies? Yes	N/A	EEBC Section
a. Minimum number of Lighting Controls	1 control for each 1550 W of connected lighting power	(exceptions apply)	☐	☐	5.4.2.1 & 5.4.2.2
b. Lighting control accessibility	Controls readily accessible to occupants		☐	☐	5.4.2.5

2 FLUORESCENT LAMP BALLASTS

Item	Requirement	Application	Yes	N/A	EEBC Section
a. Fluorescent ballast Efficacy Factor	BEF>=1.80, for 1 - 1200 mm 40 W rapid start lamp		☐	☐	5.4.4.1
	BEF>=1.05, for 2 - 1200 mm 40 W rapid start lamps		☐	☐	No req.
	BEF>=1.30, for 2 - 1200 mm 32 W tri-phosphor lamps		☐	☐	for other
	BEF>=0.57, for 2 - 1800 mm 70 W slimline lamps		☐	☐	lamp
	BEF>=0.39, for 2 - 2400 mm 110 W high output rapid start lamps		☐	☐	types.
b. Fluorescent ballast Power Factor	PF >= 90%		☐	☐	5.4.4.2
c. Tandem wiring	Required for 1- and 3- lamp fixtures.	Distance limits apply	☐	☐	5.4.4.3
	Two-lamp ballasts required for 2- and 4-lamp fixtures. If 1-lamp ballasts used, losses shall not be greater than 1/2 of those for a complying 2-lamp ballast.		☐	☐	5.4.4.3

C. PRESCRIPTIVE REQUIREMENTS - INTERIOR LIGHTING POWER ALLOWANCE (ILPA)

Building type/ space use (EEBC-94, Table 5-5)	Illuminance (fc) Recommended (Tbl 5-5)	Design	Unit Lighting Power Allowance (ULPA), W/sq.m. (Tbl. 5-5)		Gross Lighted Area (GLA), sq.m.		ILPA for space or bldg (W)
______________	☐	☐	☐	X	☐	=	☐
______________	☐	☐	☐	X	☐	=	☐
______________	☐	☐	☐	X	☐	=	☐

REQUIREMENT -----> **Total Internal Lighting Power Allowance (ILPA) for Building** = ☐

JAMAICA ENERGY EFFICIENCY BUILDING CODE (EEBC-94) — **Lighting & Electric Compliance**

Prescriptive and System Performance Compliance Approach For Buildings Less Than 1,000 sq. metres in Gross Floor Area

Small Building Form SB/LTG-2

D. PRESCRIPTIVE COMPLIANCE - INTERIOR LIGHTING POWER ALLOWANCE (ILPA)

a. When Separate Lamp and Ballast Information is Available

1 Type of lamp and fixture	Watts per Lamp		Lamps per fixture		No. of fixtures		Total Watts
______	☐	X	☐	X	☐	=	☐
______	☐	X	☐	X	☐	=	☐
______	☐	X	☐	X	☐	=	☐

2 Type of ballast used	Watts per Ballast		Number of Ballasts		
______	☐	X	☐	=	☐
______	☐	X	☐	=	☐

b. When Combined Lamp and Ballast Information is Available

1 Type of lamp and fixture	Total input watts for lamp(s) & ballast combined		Lamp/ ballast combinations per fixture		Number of fixtures		Total Watts
______	☐	X	☐	X	☐	=	☐
______	☐	X	☐	X	☐	=	☐
______	☐	X	☐	X	☐	=	☐

Sum of lines a.1, a2, and b.1 ---> **TOTAL CONNECTED LIGHTING POWER (CLP) FOR BUILDING** = ☐

Compliance is achieved if CLP (from previous line) is less than or equal to ILPA (from part C, Form SB/LTG-1)

Note: The system performance compliance option may be used, if desired. It is more complicated, but it is sensitive to specific lighting tasks and provides a more flexible, accurate, and detailed compliance procedure. To use this option, complete the calculations and submit those in place of Parts C. and D. on this page.

D. ELECTRIC POWER & DISTRIBUTION - BASIC REQUIREMENTS

Item	Requirement	Complies? Yes	N/A	EEBC Section
1 **Electric Motor Efficiency**	Minimum efficiency not less than the values in EEBC-94 Table 6-1 For nominal 1000, 1500, or 3000 RPM for 50 Hz.	☐	☐	7.4.5.1

JAMAICA ENERGY EFFICIENCY BUILDING CODE (EEBC-94)

Envelope Compliance Form ENV-1

Prescriptive and System Performance Compliance Approach For Buildings Equal to or Greater than 1,000 sq. metres in Gross Floor Area.

A. CERTIFICATION

(For Forms ENV-1 and ENV-2, by registered architect or engineer)

Name (printed or typed)	Signature and Seal	Registration Number
______________________	______________________	______________

B. OVERALL THERMAL TRANSMITTANCE VALUE (OTTV)

Item	Requirement	Application	Complies? Yes	N/A	EEBC Section
1 **External Walls**	OTTV <= 67.7 W/sq.m	Offices equal to or larger than 4,000 sq.metres	☐	☐	4.5.1 or 4.6.1
	OTTV <= 61.7 W/sq.m	Offices smaller than 4,000 sq.metres	☐	☐	
	OTTV <= 55.1 W/sq.m	All other buildings	☐	☐	
2 **Roof/Ceiling**	OTTV <= 20.0 W/sq.m	All buildings	☐	☐	4.5.2 or 4.6.2

Note 1: *For external walls, if prescriptive compliance is used for buildings less than 4,000 sq.m, then attach a copy of EEBC Table 4-2 or 4-2. For roof/ ceilings, attach a copy of EEBC-94 Table 4-3. On each table submitted, circle the option that complies.*

Note 2: *If the system performance approach is used for compliance for either walls or roof/ceilings, then attach a copy of the computer spreadsheet printout showing compliance, or attach complete calculations showing compliance*

C. AIR LEAKAGE

Item	Requirement	Application	Complies? Yes	N/A	EEBC Section
1 **Windows & Doors**					
a. Windows	EEBC-94, 4.4.2	Attach certification from supplier that requirement has been met.	☐	☐	4.4.2
b. Sliding doors	EEBC-94, 4.4.3.1		☐	☐	4.4.3.1
c. Swinging or revolving doors	EEBC-94, 4.4.3.2		☐	☐	4.4.3.2
2 **Caulking, Weatherstripping & Sealants**					
a. Around window and door frames			☐	☐	4.4.1
b. Between wall and foundation, wall and roof, and wall and floor			☐	☐	4.4.1
c. Through wall panels and wall top and bottom plates			☐	☐	4.4.1
d. At penetrations of service openings (including utility services)			☐	☐	4.4.1
e. Between wall panels, especially at changes in wall direction			☐	☐	4.4.1

JAMAICA ENERGY EFFICIENCY BUILDING CODE (EEBC-94)

Envelope Compliance Form ENV-2

Prescriptive and System Performance Compliance Approach For Buildings Equal to or Greater than 1,000 sq. metres in Gross Floor Area.

Check those boxes that apply to the building design.

1 Window Glazing:

- Double ☐
- Clear ☐
- Tinted ☐
- ☐
- Reflective ☐
- Low-e ☐
- Other (specify) ☐
- ☐

2 Window Type:

- Fixed sash ☐
- Double hung ☐
- Casement ☐
- Other (specify) ☐

3 Exterior Glass Shading Devices:

- Aluminum slatted screens ☐
- Wood slatted screens ☐
- Nylon mesh solar screens ☐
- Awnings ☐
- Bldg struct. overhangs ☐
- Bldg struct. vert. fins ☐
- None ☐

4 Interior Glass Shading Devices:

- Shades ☐
- Blinds ☐
- Tinted film ☐
- Reflect. film ☐
- Drapes, open mesh ☐
- Drapes, opaque ☐
- None ☐

5 Glass Interior & Exterior Shading locations	**Interior Shades**	**Exterior Shades**	**6 Outside Reflection on Wall From: Bldg**	**Concrete**	**Grass**	**Water**	**Soil**
North Orientation	☐	☐	☐	☐	☐	☐	☐
Northeast Orientation	☐	☐	☐	☐	☐	☐	☐
East Orientation	☐	☐	☐	☐	☐	☐	☐
Southeast Orientation	☐	☐	☐	☐	☐	☐	☐
South Orientation	☐	☐	☐	☐	☐	☐	☐
Southwest Orientation	☐	☐	☐	☐	☐	☐	☐
West Orientation	☐	☐	☐	☐	☐	☐	☐
Northwest Orientation	☐	☐	☐	☐	☐	☐	☐

7 Exterior Opaque Wall Construction

- Frame ☐
- Curtain Wall ☐
- Solid Masonry ☐
- Brick and masonry ☐
- Masonry cavity ☐
- Other (specify) ☐

10 Roof Construction and Type

- Masonry ☐
- Wood ☐
- Metal ☐
- Flat ☐
- Sloped ☐
- Pitched ☐

8 Exterior Opaque Wall Insulation

Material ____________

R-Value ____________

Thickness ____________

	Outside	Inside
Insulation Location	☐	☐

9 Exterior Opaque Wall Colour ____________

11 Roof Insulation

Material ____________

R-Value ____________

Thickness ____________

	Outside	Inside
Insulation Location	☐	☐

12 Roof Colour ____________

	Yes	No
Fungus & mold resistant paint is used	☐	☐

JAMAICA ENERGY EFFICIENCY BUILDING CODE (EEBC-94)

Prescriptive and System Performance Compliance Approach For Buildings Equal to or Greater than 1,000 sq. metres in Gross Floor Area.

VAC Compliance Form VAC-1

A. CERTIFICATION

(For Forms VAC-1, VAC-2 and VAC-3, by registered architect or engineer)

Name (printed or typed)	Signature and Seal	Registration Number

B. VAC - BASIC REQUIREMENTS

Item	Requirement	Application	Complies? Yes	Complies? N/A	EEBC Section
1 Load Calculations	Perform detailed calculation procedure	All buildings	☐	☐	7.4.1
2 Dual duct, multizone & terminal reheat	Prohibited except under special circumstances		☐	☐	7.4.2.1 - 7.4.2.4
3 Reheat	Capacity <= 15% of system cooling design capacity.	Control req.apply, see 7.4.2.5	☐	☐	7.4.2.5
4 Zoning Considerations					
a. Zones with different operating schedules	If more than 750 hr/yr (more than 3 hr-day) of non-simultaneous operation,				
	1) provide separate systems or off-hour controls		☐	☐	7.4.3.1
	2) provide isolation devices to cut off supply of cooling to each zone separately		☐	☐	7.4.5.3
b. Zones with special process temp. or humidity requirements	Provide separate systems from those for comfort cooling, or limit primary systems to comfort cooling only		☐	☐	7.4.3.2
6 Temperature controls					
a. System control	Each AC system shall have at least one temp. control		☐	☐	7.4.4.1
b. Zone Control	Cooling energy controlled by individual thermostats responding to temp. in zone	Some exceptions apply	☐	☐	7.4.4.2
c Thermostats	Capable of being set up to 29.5 deg C		☐	☐	7.4.4.3
7 Off-Hour Control					
a. Automatic controls	Shut-down or reduce energy use.		☐	☐	7.4.5.1
b. Dampers	Motorized or gravity dampers		☐	☐	7.4.5.2
8 Piping Insulation					
a. Domestic and Service Hot water Systems	Use minimum insulation thicknesses from Table 7-3 in EEBC-94	Some exceptions apply	☐	☐	7.4.7.1
b. Cooling Systems	Use minimum insulation thicknesses from Table 7-3 in EEBC-94	Some exceptions apply	☐	☐	
9 Air handling duct & plenum insulation	Use minimum insulation thermal resistances from Table 7-4 in EEBC-94 based on temperature differences between design duct air and air surrounding ducts.		☐	☐	7.4.7.2
10 Duct construction	Specifications in EEBC-94, 7.4.7.4		☐	☐	7.4.7.4

JAMAICA ENERGY EFFICIENCY BUILDING CODE (EEBC-94)	VAC
Prescriptive and System Performance Compliance Approach For	Compliance
Buildings Equal to or Greater than 1,000 sq. metres in Gross Floor Area.	Form VAC-2

The Prescriptive Requirements on this page apply for VAC systems of all buildings except when the Whole building Analysis Methods are used for compliance, from EEBC-94 Section 12

C. VAC - PRESCRIPTIVE REQUIREMENTS

Item	Requirement	Application	Complies? Yes	N/A	EEBC Section
1 Sizing - VAC System & Equipment					
a. Sizing, general	System & equipment shall be sized no more than space loads.	The loads calculated in EEBC-94 7.4.1	☐	☐	7.5.1
b. Sizing for multiple units	Minimum of two chillers or a multiple compressor unit.	Design load is greater than 500 kW	☐	☐	7.5.2
c. Multiple units, concurrent operation	Units shall have controls to optimally control each unit based on load.	Multiple units exceeding load	☐	☐	7.5.3
2 Fan System Design Criteria					
a. VAV fan control	Fan motor shall demand less than 50% of design wattage at 50% of design air volume	Fan > 25 kW	☐	☐	7.5.3.2
b. Air Transport Factor	ATF >= 5.5	All-air systems	☐	☐	7.5.3.3
c. other systems	Energy less than equivalent all-air system with ATF >= 5.5	See EEBC-94 7.5.3.3	☐	☐	7.5.3.4
d. Fan power consumption	Fan Power Index (FPI) less than 645 L/s-mm per sq.metres of floor area of conditioned space	Some exceptions apply	☐	☐	7.5.3.5 7.5.3.6 7.5.3.7
3 Pumping System Design					
a. Friction Rate	Friction pressure loss rate <= 1.2 m of water per 30 equiv. m. of pipe.		☐	☐	7.5.4.2
b. Variable flow	If system designed to modulate or step open and closed as function of load, it shall use variable flow, with variable speed pumps, staged multiple pumps, or pumps riding their characteristic perf. curves.		☐	☐	7.5.4.3
4 System Temperature Reset	(For resetting cold deck temps., or fan discharge temps.)				
a. Representative zone	May represent no more than 10 similar zones		☐	☐	7.5.5
b. Temperature	Cold deck temp. shall be automatically reset to median temp. required to satisfy average cooling req. of zone requiring most cooling.		☐	☐	7.5.5

JAMAICA ENERGY EFFICIENCY BUILDING CODE (EEBC-94)	VAC
Prescriptive and System Performance Compliance Approach For	Compliance
Buildings Equal to or Greater than 1,000 sq. metres in Gross FLoor Area.	Form VAC-3

D. VAC EQUIPMENT - BASIC REQUIREMENTS

Item	Requirement	Application	Complies? Yes	N/A	EEBC Section
1 **Minimum Equipment Performance**	Equipment shall have minimum COP not less than the values listed in Table 8-1, at rated conditions.	List information requested below	☐	☐	8.4.1

Equipment type	Size	Number	Required Value	Design Value

Note: If more detail is desired on the performance of various types of equipment, then Tables H.8-1 through H.8-10 in Appendix H of the Compliance Guidelines may be used.

Item	Requirement	Application	Complies? Yes	N/A	EEBC Section
2 **Integrated Part-Load Value (IPLV)**	Equipment complies with part-load requirements referenced in ARI documents and discussed in Appendix H of the Compliance Guidelines		☐	☐	8.4.5
3 **Equipment Controls**	Equipment has controls required by EEBC-94 8.4.5		☐	☐	8.4.5
4 **Responsibility of Equipment Suppliers**	Suppliers shall furnish as requested the full and partial capacity and standby input(s) and output(s) of all equipment and necessary components to determine compliance with this code.		☐	☐	8.4.7
5 **Maintenance Information**	Information provided to building owner on maintenance procedures is sufficient maintain efficient operation		☐	☐	8.4.8

JAMAICA ENERGY EFFICIENCY BUILDING CODE (EEBC-94)

Service Water Heating
Compliance Form SWH-1

Prescriptive and System Performance Compliance Approach For
Buildings Equal to or Greater than 1,000 sq. metres in Gross Floor Area.

A. CERTIFICATION

(For Form SWH-1, by registered architect or engineer)

Name (printed or typed)	Signature and Seal	Registration Number
______________	______________	______________

B. BASIC REQUIREMENTS - SERVICE WATER HEATING

Item	Requirement	Application	Complies? Yes	Complies? N/A	EEBC Section
1 **Sizing**	Use procedures in Chapter 54, ASHRAE Handbook, 1987 HVAC Systems & Application Volume (or later edition)		☐	☐	9.4.1
2 **Equipment Efficiency**	Water heaters and storage tanks shall meet criteria of EEBC-94 Table 9-1.	Exceptions apply	☐	☐	9.4.2
3 **Piping Insulation**	Meet requirements of EEBC-94 9.4.3		☐	☐	9.4.3
4 **Controls**					
a. Adjustable	Capable of adjusting from 32 deg C up to temperature compatable with intended use.		☐	☐	9.4.4.1
b. High temperatures	Install remote heaters or booster heaters for particular use.	Where temperatures greater than 49 deg C are required for uses.	☐	☐	9.4.4.1.1
b. Circulating systems	Provide automatic time switches or other controls to turn off system when not in use.		☐	☐	9.4.4.1.2
5 **Conserve Hot Water Use**					
a. Shower flow	Flow restrictors limit maximum flow to 0.2 L/s	Exceptions apply	☐	☐	9.4.5.1
b. Public restrooms	Shall comply with specified flow rates, total flow, and temperature requirements		☐	☐	9.4.5.2

C. PRESCRIPTIVE REQUIREMENTS - SERVICE WATER HEATING

Item	Requirement	Application	Complies? Yes	Complies? N/A	EEBC Section
1 **Gas-Fired Water Heaters**	Install with vent damper.	When in conditioned space & flue damper is not used.	☐	☐	9.5.2.2
2 **Heat Traps**	Install insulated heat traps on both inlets and outlets.	For storage water heaters without integral heat traps and with vert. risers	☐	☐	9.5.2.3

JAMAICA ENERGY EFFICIENCY BUILDING CODE (EEBC-92) Whole-Building Energy Budget Compliance Approach. An Alternate Compliance Path for All Buildings, Especially Those Buildings Larger than 4,000 sq. metres.	**General Compliance Form WBEB-1**

A. CERTIFICATION

(For this Form WBEB-1, by registered architect or engineer)

Name (printed or typed)	Signature and Seal	Registration Number
______________________	______________________________	_______________

B. GENERAL INFORMATION

1 Building Name ________________________________

2 Building Address ________________________________

____

____

3 Gross Floor Area ____________________

4 Conditioned Floor Area ____________________

5 Number of Floors

6 Registered Architect or Engineer for Building, Address, & Tele. Number ________________________________

____

____

7 Building Owner Name, Address, and Telephone Number ________________________________

____

____

C. PRELIMINARY CONDITIONS

	Applicable	Not Applicable
1 This building satisfies the criteria that the EEBC-92 code is:	☐	☐

D. COMPLIANCE

1 A Building Design which satisfies this compliance procedure is deemed to comply with the Energy Efficiency Building Code (EEBC-94).

2 This compliance procedure is intended for all buildings greater than 4,000 sq. metres in gross floor area. Smaller buildings may also use this compliance procedure as an alternate to the prescriptive and/or system performance compliance procedures.

	Yes	No
3 This building design complies with all the applicable basic performance requirements of EEBC-92 as outlined in the forms ENV-1 & ENV-2; LTG-1 & LTG-2; ELEC-1; VAC-1, VAC-2 & VAC-3; and SHW-1, or the Whole-Building Energy Budget method defined in Section 12 of EEBC-92, and with the detailed analysis instructions contained in Appendix C of the Compliance Guidelines to the EEBC-92. Documentation is attached.	☐	☐

Appendix N:

Compliance & Resource Diskette

See diskette attached to inside back cover.

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