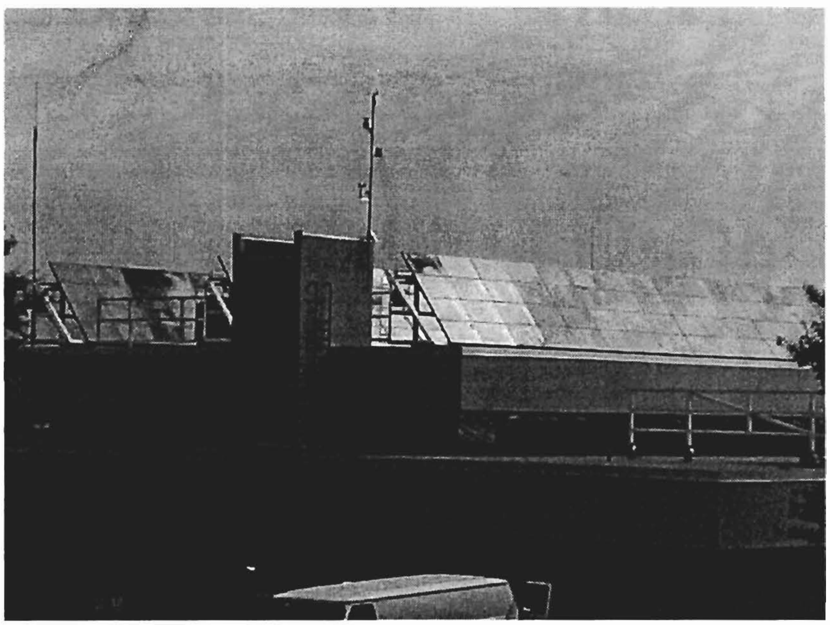
Montgomery College
Office of the Director of Facilities

ENERGY DESIGN GUIDELINES



Solar Electricity Generation Germantown Campus

Rev.	Date	Description	Sign
0	08/01/00	Issued for TP Design Team Review	JMW
1	6/26/03	Issued for GT Child Care Team Review	JMW

Executive Summary

This document discusses the design requirements for the expansion of the Germantown Campus of Montgomery College and includes information on Design Requirements for Energy(Architectural, Mechanical, Electrical & Plumbing), Equipment Preferences, Commissioning, Green Building Requirements and Operations & Maintenance. The requirements for the central plant are also discussed.

For further information pleas contact:

J. Michael Whitcomb, P.E.
Energy Manager
Montgomery College
Office of the Director of Facilities
Central Administration
Rm 315
900 Hungerford Dr.
Rockville, MD 20850
Phone: 301.251.7375
Fax: 301.251.7379
e-mail:mwhitcom@mc.cc.md.us

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SECTION 1

INTRODUCTION

Introduction

Introduction: This document has been prepared by the Montgomery College Energy Manager for the Owner, A/E and Construction Management team. It is a document, intended to be used as the outline for discussions on the development of the **Germantown Child Care Center** building and building systems and will be modified as required to include details of the Germantown Campus expansion project. In order to consolidate requirements, this document also contains specific lists of types of equipment, specific brands and standards desired by the Office of Facilities.

Energy, Building Code Authority: The Montgomery County Code, Chapter 8, Section 8-14A, Building Energy Design Standards, requires that all buildings built with Montgomery County Council funds meet minimum requirements for energy efficiency. The code places enforcement responsibility with the Montgomery Department of Environmental Protection and the Office of the Director of Facilities, Montgomery College. Submission of the required documents, i.e. reports, drawings and specifications and receipt of formal approval of those documents by the Montgomery College Office of Facilities will constitute compliance with the code.

Background: Montgomery College has been building energy efficient buildings since the mid 1980's. In the early 1990's the College completed Utility Master Plans for all three campuses, and provided the basis for installation of the central plants. The central plants provide both chilled and hot water using high efficiency equipment and demand management techniques such as ice thermal storage and co-generation. The loads on the central plant are based upon the buildings being as efficient as possible and include proper design of envelope, lighting, daylighting, HVAC, controls, commissioning, operations and maintenance. The resource conservation techniques implemented by the College have resulted in a reduction in the utility operating budget in light of continued increase in demand. The College is also a leader in the use of renewable resources, (solar electric and solar thermal) and strives to reduce the environmental impact of its operations.

Project Goals: The College goals are to provide facilities to meet the needs of the College's mission by providing a suitable environment for student success, while minimizing operating cost and the impact on the environment. The project will attempt to obtain a Silver LEED certification. The issues are many, i.e. occupant comfort, indoor air quality, maintenance, environmental impact, recycling and electricity reliability. To meet these goals the College asks its team members; College project representative, A/E team members and Construction Managers to combine their talents and creativity to optimize the design. An Energy Budget goal of **40,000 Btu/Gross Interior Square Foot/yr** is assigned to the Germantown Child Care building. The following provides guidance on some of these issues.

Implementation of these Energy Design Guidelines: ASHRAE Std. 90.1-2001, Energy Standard for Buildings Except Low-rise Residential Buildings, Ref. 1, is the basis for the design of the College's energy efficient buildings. Where necessary the Montgomery County Energy Design Guidelines, Ref. 2, have been included to provide design guidance. When the guidelines reference an ASHRAE standard the design team will use the latest revision of the standard. For example, ASHRAE Std. 90-1, 1989 is referenced extensively throughout the guidelines. The design team shall use ASHRAE Std. 90-1, 2001 instead.

Overview, Attachment 1-1, provides design team guidance and describes the functions of the design team. The design team will comply with this section and use the "roadmap" to assure compliance.

References: The following references will be used as back-up documentation for the project, the project team should obtain these documents:

1. ASHRAE Std. 90.1-2001 - Is the latest version of the Energy Standard for Buildings and will be used to develop the Energy Cost Budget Method (Energy Analysis) of compliance. Obtained from ASHRAE.

2. Montgomery County Energy Design Guidelines(EDG) - These guidelines as refined by the Office of Facilities provide guidance on the requirements for energy code compliance. EDGs have been incorporated in this document as required by Montgomery College.

3. 90.1, User's Manual - Is the user's manual for the ASHRAE Std. 90.1-2001 and contains explanations on the use of the standard and compliance forms. Obtained from ASHRAE.

4. Germatown Utilities Master Plan - This document was developed by Wiley & Wilson and describes the plan for the utilities expansion on the campus. Provided by Montgomery College.

5. Program Justification and Description.

6. ASHRAE Std. 62-(Latest Version), Ventilation for Acceptable Indoor Air Quality. This document describes the requirements for the design of acceptable indoor air quality. Obtained from ASHRAE.

7. ASHRAE Std. 15-(Latest Version) Safety Code for Mechanical Refrigeration, Design of Mechanical Rooms, latest edition. This standard describes the requirements for the design of refrigeration systems. Obtained from ASHRAE.

8. ASHRAE Std. 11-(Latest Version), Commissioning Guidelines, latest edition. This standard describes the requirements for system commissioning.

9. Installation of a 26 Kilowatt Solar Photovoltaic Thin Film Amorphous Silicon electrical Generation System, Science and Applied Studies Building, Germantown Campus. This document describes the design of a solar electricity generation plant on the roof of the SAS building on the Germantown Campus. Provided by Montgomery College.

10. ASHRAE Std 55-(Latest Edition), Thermal Environmental conditions for Human Occupancy. Obtained from ASHRAE.

11. Leadership in Energy and Environmental Design(LEED), Green Building Rating System.

12. ASHRAE Guideline 0P – The Commissioning Process.

Overview

The Energy Design Guidelines forms an integral part of the contract for design of an energy efficient building as entered into by the Architect/Engineer and the building Owner. The Guidelines provide very specific directions on energy design elements for each member of the design team. The Guidelines assume familiarity with contract requirements for energy analysis and performance requirements. Therefore, each member of the design team will want to thoroughly review and understand the following elements of the contract, prior to using this manual:

All Players in the Design Process should begin by reading this Overview Section....From here, different disciplines will be directed to specific sections.

"Articles of Agreement"

The contract main body forms agreements on the overall design approach, including energy analysis methods, life-cycle-cost approach, role of the energy analyst, and the maximum design energy use of the building, if required.

"Scope of Services"

The Scope of Services describes specific services and levels of detail by phase of design for energy, lighting, mechanical and electrical items.

"Energy Report Formats"

This exhibit provides detailed reporting requirements for Schematic Design and Design Development Energy Reports, including both form and contents of the required reports.

After reviewing the contract, all players in the design process should read this Overview Section. The design Architect, his electrical and mechanical engineers, the energy analyst, and the government engineer and project managers must all be familiar with the process and basic technologies presented here. The Overview has four key sections:

- **Role of the Energy Analyst**

The design team must designate a qualified Energy Analyst acceptable to the Owner. The Energy Analyst is responsible for coordination of energy design requirements on the design team. He will play a pivotal role in successful implementation of energy guidelines on this project.

- **Ground Rules**

Important "ground rules" for the design effort are described including the integrated design approach for cost control.

- **Management Road Map**

Management strategy for efficient design is summarized in a "management road map". The flow chart serves to keep the design on track to energy efficiency through a system of feedback and check points. The design process will proceed most smoothly and with minimum confusion when all members of the design team understand and follow the process described here.

The design process will proceed most smoothly when all team members follow the process described here.

- **Technology Application Matrix**

the Overview presents a technology summary for energy-efficient building design, indexed by building size. A "Technology Application Matrix" is presented to show the standards, technologies, and design approaches appropriate to each building. All members of the design team need to be informed of the technological choices and requirements already established for the building.

From here, different disciplines on the design team will be directed to specific sections of the Guidelines for detailed design guidance.

Role of the Energy Analyst

Overall, the Energy Analyst must ensure quality control for all energy design aspects of the project.

As part of contract requirements, the Architect must designate a qualified Energy Analyst to coordinate energy design requirements. The Energy Analyst on the design team needs to review and become familiar with all the material in these guidelines relevant to the project under design. It is the responsibility of the Energy Analyst to coordinate energy requirements within the design team, including the Architect, Mechanical designer and Electrical Designer. Specifically, the Energy Analyst is responsible for:

1) Understanding all energy guidelines and communicating them to the design team,

2) Making other team members aware of criteria which affects their design and redirecting design when necessary,

3) Attend all meetings where major Architectural decisions will be made, and advise the designer of impacts of such decisions on energy consumption, meeting prescriptive criteria and meeting the Energy Program of Requirements,

4) Performing the required energy analysis and preparing detailed reports,

5) Reviewing plans and specifications for correct and complete implementation of energy features prior to each submission for review by the Owner.

Overall, the Energy Analyst must ensure quality control for all energy design aspects of the project.

Ground Rules

Energy "Ground Rules"

- *Integrate Energy features into the design at the earliest phases.*
- *Make early decisions as an interdisciplinary team informed by energy analysis.*
- *Pursue cost trade-offs through an integrated design approach.*
- *When cost conflicts emerge, "use more thinking, not more money."*

Energy ground rules are the guiding principles for making decisions that affect energy use of the building. The Architect and the design team must all be aware of these rules in order for the design to proceed smoothly to the Owner's acceptance. Some ground rules will be specific to a building. The general rules that apply to almost all our projects are as follows:

1) Energy features must be integrated into the building from pre-design phases, not "added in" at late phases. For example, daylit buildings must include appropriate roof monitors and the building must be correctly oriented during Schematic Design. At a later phase it may be too late to achieve acceptable results.

2) Major decisions must be made as a team and based on energy analysis. Typically the Architect works alone during schematic design to configure the building shape and exterior elevation. This approach does not work well with advanced energy guidelines that limit glass area and promote climate-responsive design. The Architect needs to invite participation of the Energy Analyst in the early design to ensure prescriptive and program requirements are met and to help optimize design. Energy analysis must be used to make informed decisions since "intuition" is often mistaken concerning commercial building energy use.

3) The cost of the project must always be viewed as a whole. In new buildings, an energy improvement almost never exists in isolation and cost increases in one area will be balanced by cost decreases in another. For example, high-efficiency lighting fixtures with good optical control are "expensive" per fixture, but lower in total project cost because fewer fixtures are needed, electrical distribution costs are smaller, and total air-conditioning first costs are often reduced by 20%.

4) Both the energy budget and project cost budget must be met. Experience in our projects and around the nation shows that both energy and first-cost can be controlled together. Conflicts emerge primarily when one or more of the energy ground rules have been overlooked.

Management Road Map

The process of producing an energy efficient building extends all the way from drafting the Program of Requirements for the building through construction and the initial year of occupancy. We expect the Architect/Engineer to be involved through most of this process and to assume major responsibility for the outcome. The overall process flow charts or "road map" appear on the following pages.

In most cases, the design processes and standards currently used by Architects and Engineers will not suffice to meet our goals for energy efficiency. The Architect must resist the tendency to proceed with normal design approaches that assume energy standards can be "added on" later. The best way to avoid wasted effort and redesign is to carefully follow the requirements for early coordination, briefings, and reviews described in this section.

The process of producing an energy efficient building extends all the way from drafting the Program of Requirements for the building through construction and the initial year of occupancy.

The following section on Responsibilities describes the underlying role requirements for team members on the road map.

Responsibilities

Owner's Project Manager. The Project Manager ensures that events occur in the proper order as shown on the charts. Design should not be allowed to proceed without required meetings and energy report approvals at Schematic and Design Development.

Design Architect. The Architect ensures that the design team has appropriate expertise to carry out all requirements indicated. The Architect ensures that all disciplines follow the energy ground rules and work together to achieve energy efficiency and cost control in the design.

Energy Analyst. The Analyst provides analysis and review internal to the design team on compliance with energy requirements and optimization of design. He also compiles energy reports and provides the interface with Energy Engineer. The Analyst provides overall Quality Control of energy requirements in the design process.

Owner's Energy Engineer. The Energy Engineer provides the Owner's Quality Assurance of energy efficient design. The Energy Engineer reviews credentials of the proposed Energy Analyst and approves or disapproves the appointment. The Energy Engineer reviews required energy reports and checks implementation on the plans and specifications. When the designer's quality control is found to be inadequate, the Energy Engineer may require removal and replacement of the Energy Analyst.

Design Mechanical Engineer. The Mechanical Engineer provides implementation of all mechanical system energy efficiency requirements, indoor air quality and ventilation requirements, energy management requirements, and mechanical commissioning requirements. The Mechanical Engineer participates in all meetings involving functional zoning of the building, HVAC system types, and location and size for mechanical rooms.

Lighting Designer. The Lighting Designer uses the Owner's requirements for design approach to create a functional lighting system tailored to the individual spaces of the building and meeting all wattage budgets. The Lighting Designer uses furniture layouts provided by the Architect in the process. The lighting designer calculates the wattage budget and actual lighting wattage for use by the Energy Analyst and Mechanical and Electrical Engineers at Schematic Design and Design Development. The lighting designer provides complete specification of all lighting equipment and controls following the Owner's Guide Specifications at Design Development.

Design Electrical Engineer. The Electrical Engineer provides implementation of all electrical system energy efficiency requirements, and electrical commissioning requirements. The Electrical Engineer participates in all decisions involving distribution of electricity, and location and size of electrical rooms.

Owner's Maintenance Engineer. The Maintenance Engineer provides requirements on maintainability and accessibility of all mechanical and electrical systems at the Pre-Design briefing and all subsequent review meetings.

Owner's HVAC Engineer. The HVAC Engineer provides the Owner's Quality Assurance of mechanical systems, drawings and specifications in accordance the Owner's Design Guidelines. Where the designer consistently fails to follow the Owner's standards the HVAC Engineer may recommend issuance of a Contract Monitoring Report to restrict the designer from further work with the Owner until problems are resolved.

Process Flow

The "management road map" consists of several flow charts portraying the different phases of design. In front of each chart, an index provides detailed description of the steps involved at that phase and a listing of the players involved.

The process spans the following phases:

- **Selection**
- **Pre-Design**
- **Schematic Design**
- **Design Development**
- **Construction Documents**

Please review the entire process now, then refer back to this section as needed during the design process, especially at the start of each new phase.

1	**Energy Program of Requirements** *Energy Engineer reviews project and existing buildings and writes Energy P.O.R. for design of the facility.*	*Project Manager* *Energy Engineer*
2	**Request for Proposals** *Issue RFP for design services including:* *Energy P.O.R.* *Energy Rating Sheets (mandatory submission forms)*	*Project Manager* *Energy Engineer*
3	**Selection** *Select Architect based on proposal scores. Energy criteria should be weighted as 15 to 25% percent of total points.*	*Project Manager* *Selection Committee*
4	**Negotiations** *Architect and team members must become thoroughly familiar with the Contract, Scope of Services and Program of Requirements for design.* *Preview the Energy Guidelines.* *Propose an Energy Analyst and submit credentials for review.*	*Project Manager* *Owner's Energy Engineer* *Architect* *Energy Analyst*
5	**Notice to Proceed** *Successful conclusion of negotiations will result in Notice to Proceed on Schematic Design.*	*Project Manager*

6	**Transmit Guidelines** *With Notice to Proceed on Schematic Design. Architect read Overview and make copies for team members.*	*Project Manager* *Architect*
7	**Distribute Sections** *Each discipline must receive guidelines affecting their design.*	*Architect*
8	**Read Sections** *Each team member must become thoroughly familiar with the guidelines affecting their design, prior to the Pre-Design Briefing.*	*All Team Members*
9	**Set Up Pre-Design Meeting** *Notify the Architect that the complete design team attends this meeting. Notify all members of the Owner's project team.*	*Project Manager*
10	**Attend Pre-Design Energy Meeting** *Energy Engineer to present process overview and answer any technical questions from the design team.*	*Project Manager* *Owner's Project Team* *Design Team*

Design Team Provides	Owner's Team Provides

ARCHITECT
Continue from here

PROJECT MANAGER
Continue from here

[6] Transmit Guidelines to Architect

[Guidelines] →

Receive Guidelines

- Read OVERVIEW
- Make Copies

[7] Distribute Sections | **[8]** Read Sections

Complete Set to:	Energy Analyst
Envelope to:	Architect
HVAC/EMS and Ventilation to:	Mechanical Engineer
Lighting to:	Lighting/ Electrical Engineer
OVERVIEW to:	Everyone

[9] Set Up Pre-Design Meeting

[10] Attend Pre-Design Energy Meeting

Design Team:	Owner's Team:
Architect	Project Manager
Electrical Engineer	Engineer
Mechanical Engineer	Energy Engineer
Energy Analyst	Maintenance Engineer

Agenda:	"Process Overview"
Ground Rules:	■ Design Integration ■ Budgets
Responsibilities of the Energy Analyst:	■ Coordination ■ Design Checks ■ Reports
Energy Strategy: [Options to be Analyzed]	■ Thermal Envelope ■ HVAC systems ■ Lighting

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11	**Prepare Minutes of Pre-Design Meeting** *Close the loop on important initial directions with detailed minutes of the meeting.*	*Architect*
12	**Establish Boundaries of Design** *Determine all initial prescriptive requirements the design must meet as described in the Schematic Energy Report format and detailed in ASHRAE 90.1 and the Energy Guidelines.* *The Energy Analyst reviews this effort for completeness and accuracy.*	*Architect* *Energy Analyst* *Electrical Engineer* *Mechanical Engineer*
13	**Make the Major Design Decisions as a Team** *Organize meetings with the Energy Analyst, design team, and Owner to come to an initial design that solves the major requirements of the Program of Requirements.*	*Architect* *Owner's Project Team* *Design Team*

Attend Predesign Energy Briefing

ARCHITECT continue from here

[11] Prepare Minutes of Pre-Design Meeting

Document major decisions, options, directions
Transmit to Owner

[Review] ← Owner's Energy Engineer

[Minutes] → Owner's Energy Engineer

[12] Establish Boundaries of Design (Prescriptive Criteria)

Architect	Mechanical Engineer	Lighting / Electrical Engineer
R-values [roof,walls] Glazing Properties Window/Wall Ratio	Efficiencies Economizer Cycles Ventilation	Lighting Wattage Budgets: Interior Exterior

Energy Analyst Receives and Reviews Values

Project Manager Continue from Here

[13] Make the Major Design Decisions as a Team

Schematic Design Work Sessions and "Charrettes"

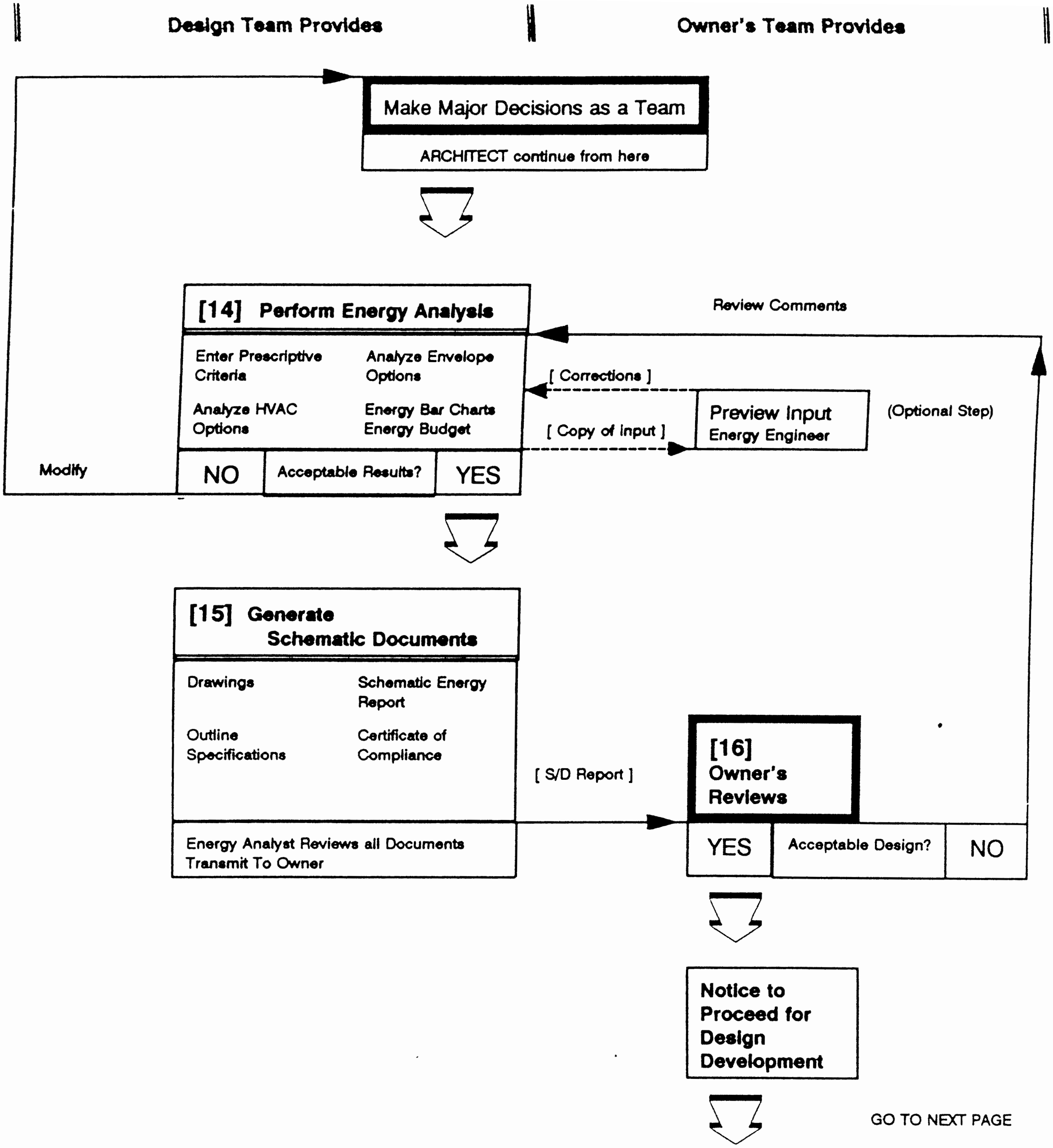
Architect	Design Engineers	Project Manager
Space Layouts Elevations	Equipment Space Solar Loads HVAC zoning	(HVAC Engineer) (Energy Engineer) (Maintenance)

Energy Analyst Advises All Decisions affecting Energy Use

Orientation Windows/Monitors Overhangs	(Heat Recovery) (Daylighting)	Operating Hours

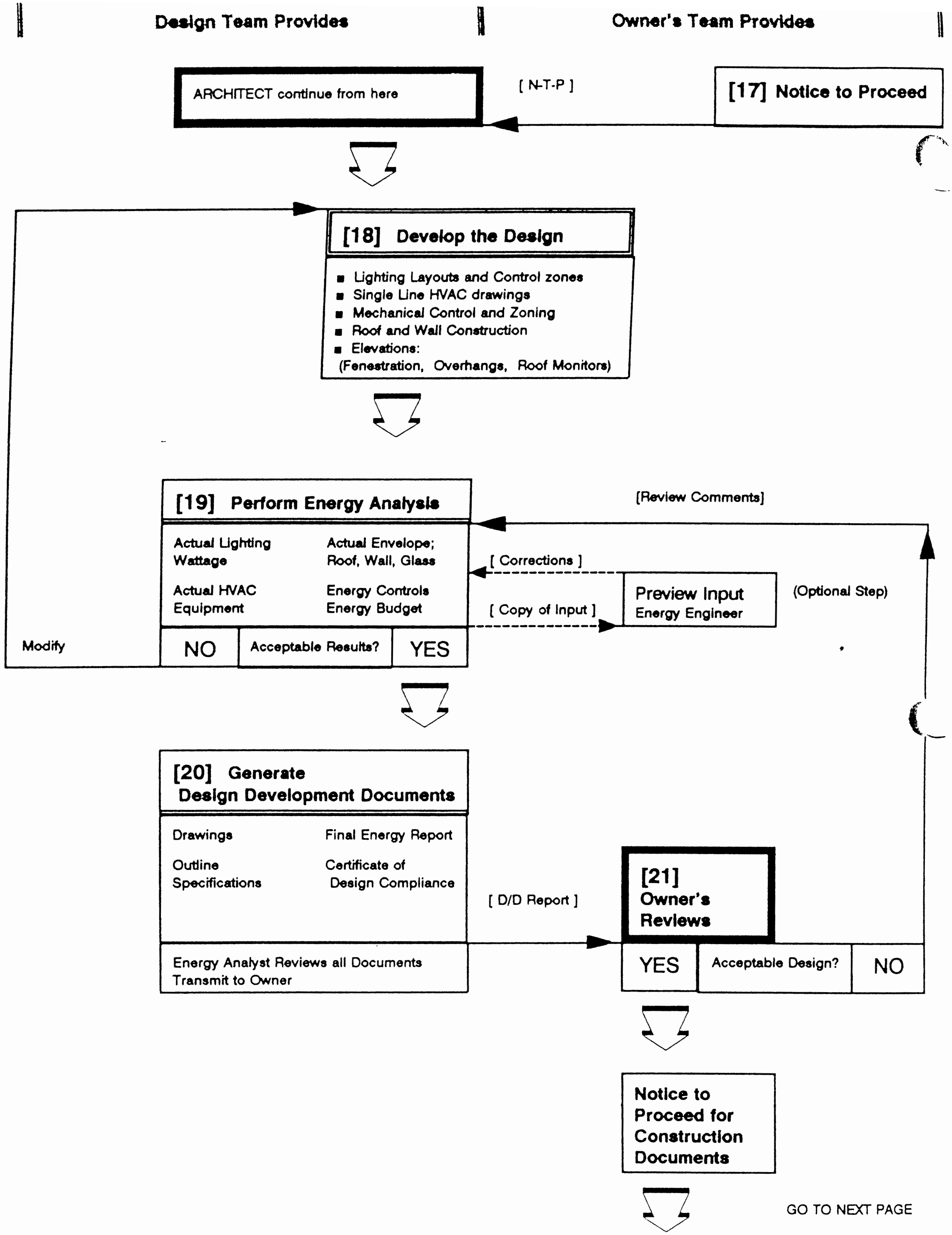
GO TO NEXT PAGE

14	**Perform Energy Analysis** *Analyze the proposed building as a whole for annual energy use. Compare life-cycle-cost of designated options in HVAC systems, thermal envelope.* *The Analyst may wish to have the Owner's Energy Engineer review the input for the computer analysis prior to initial runs.* *Designs that do not meet prescriptive or energy budget requirements must be reconsidered.*	*Energy Analyst* *Owner's Energy Engineer*
15	**Generate Schematic Documents** *Once acceptable energy design is achieved, prepare schematic documents and Schematic Energy Report. The Energy Analyst reviews the documents for completeness and accuracy of energy features.*	*Architect* *Energy Analyst* *Electrical Engineer* *Mechanical Engineer*
16	**Owner Reviews** *The Schematic Energy Report will be reviewed by the Energy Engineer against the Program of Requirements, Energy Guidelines and Report Formats. Unacceptable results will be returned for reanalysis or redesign before proceeding to Design Development.*	*Owner's Project Team*


Design Team Provides
Owner's Team Provides
Make Major Decisions as a Team
ARCHITECT continue from here
[14] Perform Energy Analysis
Enter Prescriptive Criteria
Analyze Envelope Options
Analyze HVAC Options
Energy Bar Charts
Energy Budget
Modify
NO
Acceptable Results?
YES
Review Comments
[Corrections]
[Copy of Input]
Preview Input
Energy Engineer
(Optional Step)
[15] Generate Schematic Documents
Drawings
Schematic Energy Report
Outline Specifications
Certificate of Compliance
Energy Analyst Reviews all Documents
Transmit To Owner
[S/D Report]
[16] Owner's Reviews
YES
Acceptable Design?
NO
Notice to Proceed for Design Development
GO TO NEXT PAGE

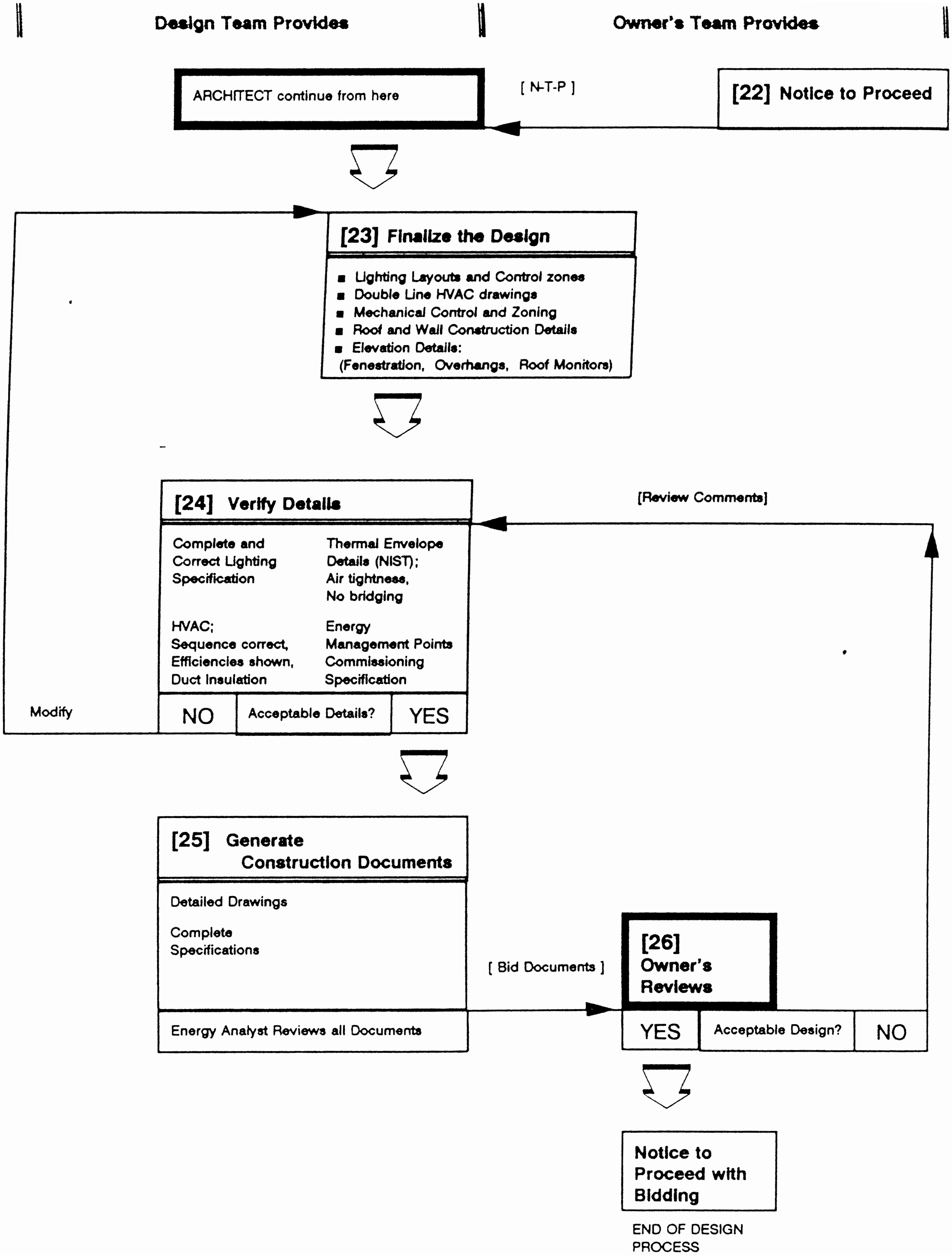
17	**Notice to Proceed on Design Development** *After approval of the Schematic Energy Report and acceptance of Schematic Design by the Owner, the Project Manager issues Notice to Proceed on the next phase of development.*	*Project Manager*
18	**Develop the Design** *Develop the design to the level of detail required by the Scope of Services and Design Development Energy Report.* *Clarify all design intentions in lighting, thermal envelope, energy management, and HVAC systems.*	*Architect* *Design Team*
19	**Perform Energy Analysis** *Analyze the proposed building as a whole for annual energy use. Perform optimization where required.* *Designs that do not meet prescriptive or energy budget requirements must be reconsidered.* *The Energy Analyst may wish to have the Owner's Energy Engineer review the input for the computer analysis prior to final runs.*	*Energy Analyst* *Owner's Energy Engineer*

20	**Generate Documents** *Once acceptable energy design is achieved, prepare design development documents and the Design Development Energy Report.* *The Energy Analyst reviews the documents for completeness and accuracy of each energy feature, prior to submitting to Owner.*	*Architect* *Energy Analyst* *Electrical Engineer* *Mechanical Engineer*
21	**Owner Reviews** *The Design Development Energy Report will be reviewed by the Energy Engineer against the Program of Requirements, Energy Guidelines and Report Formats. Unacceptable results will be returned for reanalysis or redesign before proceeding to Construction Documents.*	*Owner's Project Team*


Design Team Provides
Owner's Team Provides
ARCHITECT continue from here
[N-T-P]
[17] Notice to Proceed
[18] Develop the Design
■ Lighting Layouts and Control zones
■ Single Line HVAC drawings
■ Mechanical Control and Zoning
■ Roof and Wall Construction
■ Elevations:
(Fenestration, Overhangs, Roof Monitors)
[19] Perform Energy Analysis
Actual Lighting Wattage
Actual Envelope; Roof, Wall, Glass
Actual HVAC Equipment
Energy Controls Energy Budget
Modify
NO
Acceptable Results?
YES
[Review Comments]
[Corrections]
[Copy of Input]
Preview Input
Energy Engineer
(Optional Step)
[20] Generate Design Development Documents
Drawings
Final Energy Report
Outline Specifications
Certificate of Design Compliance
Energy Analyst Reviews all Documents
Transmit to Owner
[D/D Report]
[21] Owner's Reviews
YES
Acceptable Design?
NO
Notice to Proceed for Construction Documents
GO TO NEXT PAGE

22	**Notice to Proceed on Construction Documents** *After approval of the Design Development Energy Report and acceptance of Design Development by the Owner, the Project Manager issues Notice to Proceed on the next phase of development.*	*Project Manager*
23	***Finalize the Design*** *Finalize the design to the level of detail required by the Scope of Services and Energy Design Guidelines.* *Specify and detail all design elements in:* *Lighting,* *Thermal Envelope,* *Energy Management, and* *HVAC Systems.*	*Architect* *Design Team*
24	**Verify Details** *Review the building design as a whole for compliance with:* *Thermal Envelope Integrity, HVAC System Efficiencies and Energy Management controls, duct and pipe insulation, Lighting fully specified and layout coordinated with final furniture and landscaping, and Commissioning Plan.* *Augment all details and specifications as necessary to fully cover energy design requirements.*	*Energy Analyst* *Owner's Energy Engineer*

25	**Generate Documents** *Once acceptable energy design is achieved, prepare Construction Documents.* *The Energy Analyst reviews the documents for completeness and accuracy of each energy feature, prior to submitting to Owner.*	*Architect* *Energy Analyst* *Electrical Engineer* *Mechanical Engineer*
26	**Owner Reviews** *The Construction Documents will be reviewed by the Energy Engineer for Quality Assurance of all energy requirements. Unacceptable results will be returned for increased Quality Control before proceeding to Bid.*	*Owner's Project Team*


Design Team Provides
Owner's Team Provides
ARCHITECT continue from here
[N-T-P]
[22] Notice to Proceed
[23] Finalize the Design
Lighting Layouts and Control zones
Double Line HVAC drawings
Mechanical Control and Zoning
Roof and Wall Construction Details
Elevation Details:
(Fenestration, Overhangs, Roof Monitors)
[24] Verify Details
Complete and Correct Lighting Specification
Thermal Envelope Details (NIST); Air tightness, No bridging
HVAC; Sequence correct, Efficiencies shown, Duct Insulation
Energy Management Points Commissioning Specification
Modify
NO
Acceptable Details?
YES
[Review Comments]
[25] Generate Construction Documents
Detailed Drawings
Complete Specifications
Energy Analyst Reviews all Documents
[Bid Documents]
[26] Owner's Reviews
YES
Acceptable Design?
NO
Notice to Proceed with Bidding
END OF DESIGN PROCESS

Guidelines Summary

This manual addresses the standard equipment, design methods and design criteria required for new construction and renovation projects of various sizes. A summary matrix appears below. One enters the matrix by selecting the size of building from the categories to the left, and then reading across to review specific technologies for Mechanical, Architectural and Electrical disciplines. To these technologies one must add the criteria shown across the top row for "ALL BUILDINGS".

Together, the matrix elements address the major energy problems in government and commercial buildings and form a firm basis for achieving desired energy performance levels.

The matrix represents decisions and selections made by the Owner in an organized and coordinated manner, based on life-cycle-cost analysis, advanced national standards, and research recommendations from a number of sources. Together, the matrix elements address the major energy problems in government and commercial buildings and form a firm basis for achieving desired energy performance levels. At the same time, the matrix provides for modern standards of good lighting, acceptable indoor air quality, and architectural creativity.

Review the matrix at this time familiarize yourself with the intended direction of energy conservation desired by the Owner. Technologies for individual buildings may be changed by the Energy Program of Requirements or at the Pre-Design meeting.

After completing this Overview, members of the design team should go on to study the detailed sections of the Energy Design Guidelines relevant to their work. Specifically:

Energy Analyst:	Read all Sections
Architect:	Read "Thermal Envelope"
Mechanical Engineer:	Read "HVAC Read " Energy Management" Read "Ventilation/IAQ"
Electrical Engineer:	Read "Lighting"

The Architect should provide copies of indicated sections to the indicated team members.

Guidelines Summary

	Mechanical	Architectural	Electrical
All Buildings	HVAC Equipment EfficienciesTable Baseline Air Systems Design Criteria ASHRAE 90.1 Sect. 9: HVAC Systems ASHRAE 62: Ventilation for Acceptable Indoor Air Quality Premium Efficiency Motors Condensing Boilers and Furnaces (where gas is available)	ASHRAE 90.1 Section 8.5: Envelope Component Packages NIST Envelope Guidelines: Thermal Integrity Details Comprehensive Air Barrier High-Performance Windows: NFRC U < 0.39 Btu/hr-ft2-F SC < 0.55 Daylighting Basics Light color Retractable Blinds Glare Control (Overhangs)	ASHRAE 90.1 Section 6.6: Wattage Budgets (x 65%) IES Light Levels with Localized or Task Lighting T8-Lamps/Electronic Ballasts CFL 13 for Task, Accent and Downlights HPS Exterior Cut-off Fixtures Convenient, Flexible Switching Occupancy Sensors (> 300 W) Switching zoned with Daylight
Complexes > 90,000 sf	DDC Plant and Distribution Controls DDC Terminal/Temperature Controls VFD's on System Pumps/Fans Draw-through Towers (Propeller) HVAC System Options: 1 Water-Cooled Centrifugal Chiller VAV Air-Handling/VFD 2 Water-Cooled Screw Chiller VAV Air-Handling/VFD 3 Hydronic Heat Pump	Core Daylighting Analysis Perimeter Daylighting/Controls Tinted / Reflective Windows Air-lock Vestibules	Automatic Daylight Controls: Photocell Control in Non-Task Areas Exterior Lighting Management through DDC system Interior Lighting Management through DDC [zone by floors]
Large Buildings 30,000 to 90,000 sf	DDC Plant and Distribution Controls DDC Terminal/Temperature Controls HVAC System Options: 1 Central Screw Chiller VAV Air-Handling/VFDs 2 Central Reciprocating Chiller VAV Air-Handling/VFDs 3 Hydronic Heat Pump	Core Daylighting Analysis Perimeter Daylighting/Controls Tinted / Reflective Windows Air-lock Vestibules	Automatic Daylight Controls: Photocell Control in Non-Task Areas Exterior Lighting Management through DDC system Interior Lighting Management through DDC [zone by floors]
Medium Buildings 10,000 to 30,000 sf	DDC Plant and Distribution Controls DDC Terminal/Temperature Controls HVAC System Options: 1 Central Chiller VAV Air-Handling/VFDs 2 Split System Heat Pump 3 Split System w/ Gas Furnace	Perimeter Daylight / Windows Air-Lock Vestibules	Exterior Lighting Management through DDC system Interior Lighting Management through DDC [2 or 3 zones]
Small Buildings 2,000 to 10,000 sf	DDC Package Control Interfaces DDC Unitary Controller HVAC System Options: 1 Packaged Terminal A/C 2 Packaged Heat Pump 3 Split System w/ Gas Furnace		Exterior Lighting Management through DDC Unitary Controller
Glossary	HVAC = Heating, Ventilating, and Air-conditioning CFL = Compact Fluorescent Lamp VAV = Variable Air Volume	VFD = Variable Frequency Drive DDC = Direct Digital Control A/C = Air Conditioning IES = Illuminating Engineers Society	NIST = National Institute of Standards and Technology ASHRAE = Am. Soc. of Heating, Refrigerating & Air-Conditioning Eng.

07/98

SECTION 2

ENERGY ANALYSIS & REPORTS

Section 2 - Energy Analysis & Reports

Introduction

The Energy Analysis & Life Cycle Cost shall comply with the ASHRAE Std. 90.1-1999, Energy Cost Budget Method and instructions in these sections. There are two reports required, one at the schematic design phase and one at the design development phase. Certification by a Registered Professional Engineer is required for code compliance.

Energy and Life Cycle Cost Analysis

The Energy Analysis shall comply with the ASHRAE Std. 90-1-1999, Energy Cost Budget Method, the NIST Building Life Cycle Cost Analysis Program(BLCC) and as prescribed in this section:

1. **The Energy Cost Budget Method** - requires that a baseline analysis(Energy Cost Budget) be developed and compared to the actual building(Design Energy Cost). To comply with the code, the actual building should more energy efficient than the baseline building. At a minimum there will be an analysis presented at the Schematic Design Submission and at the Design Development Submission as part of the Energy Reports. A 8760 hour simulation such as DOE-2 shall be used to simulate the building. The following will be include in the simulation:

   a. Occupancy Schedules – Occupancy schedules shall accurately reflect operation of the building. The College buildings are generally occupied during the Fall and Spring Semesters during the weekdays from 7:00 am to 11:00 pm, on Saturday from 7:00 am to 12:00 noon and limited occupancy on Sunday. Summer occupancy is reduced to about ¼ to ½ of that during the Fall and Summer.

   b. Specialty HVAC Items – Specialty HVAC items such as CO2 sensors, heat recovery or outdoor desiccant pre-treatment units do not need to be simulated if a canned routine is not available in the simulation package. Acurate assumptions on the energy and cost reduction may be applied at the end and inserted in the life cycle cost.

   c. Daylighting and Daylighting Controls – To the maximum extent possible, the analysis shall simulate the impact of daylighting and daylighting controls.

2. **Determination of HVAC Size** - Hourly simulation of the complete building allows accurate determination of the minimum size and cost of HVAC systems. Oversized equipment is not only more costly but creates environmental control problems. The HVAC equipment shall be sized with a diversity based upon the predicted "normal" building loads and not based upon the worst case conditions. Comparison of worst case

and simulated HVAC loads shall be presented and compared in tabular form at the Schematic Design and Design Development submission.

3. **Envelope Optimizations** - Placement of windows and overhangs may need to be optimized to achieve acceptable energy consumption. Energy simulation provides a true picture of annual total energy impacts to guide the optimization.

4. **Overall Energy Budget** – An energy goal of 40,000 Btu/Gross Interior Square Foot/yr has been assigned to this building.

5. **Life-Cycle Cost Analysis** – Life-cycle cost analysis can be accomplished within many of the energy analysis simulation programs, however, the College requests that the design team use the NIST Building Life Cycle Cost(BLCC) Analysis program. The program is available from the College or can be downloaded from the Web. The following economic factors shall be applied:

   a. Discount Rate: 7%
   b. Down Payment: 100%
   c. Inflation Rate: 4%
   d. Fuel Escalation Rate: Electric – 4%, Gas - 4%
   e. Analysis Term: 20 years
   f. First Costs: Current Means or documented Manufacturer's data
   g. Maintenance Costs: Reputable Reference Data
   h. Utility Rates: As Published by Utility Company, or in NIST Library file.
   i. Equipment Lifetime – The majority of equipment being prescribed for this project is of heavy duty industrial quality and is expected to have lifetimes in excess of 20 years.

Submission

At the schematic design phase and the design development phase a package consisting of one complete set of drawings, specifications and the report shall be delivered to the College's Energy Manager. The report shall contain a stamped certification by a Registered Professional Engineer. Approval of these submittals is required before proceeding onto the next design phase. Formal approval by the College constitutes code compliance. The following sections describe the report format.

Report Format

The reports shall be submitted in the following format.

1. General
   a. The document shall be prepared in standard technical report format in a 3-ring binder on 8.5 x 11 inch paper, using Times New Roman 12pt text, in MS Word Format. Provide a copy of the report on a diskette. The report shall contain a title page, executive summary, table of contents, introduction, discussion,

conclusions, appendices and a list of references. The discussion portion shall contain the same numbering sequence as the format. It is requested that the author use an “Avery Ready Index” indexing system. Examples of these documents are available from the College. Pages shall be consecutively numbered throughout the document and fully indexed in the Table of Contents.

b. All items described in the report format must be properly addressed in the written report. If an item is "not applicable" to the project the consultant must obtain the prior permission of the Owner's Energy Manager not to analyze the item and must describe in the corresponding section of the report why the item is "not applicable."

c. The following attachments list the format requirements for the schematic and design development reports.

Attachment 2-1, Format & Content, Schematic Design Energy Analysis Report

Schematic Design Energy Analysis Report - Contents

1. Cover Sheet
   - Montgomery College
   - Office of the Director of Facilities
   - Campus Name(Takoma Park Campus)
   - Schematic Design Energy Analysis Report
   - Building Name
   - Energy Analyst Name'
   - Firm
   - Date
2. Executive Summary
3. Table of Contents
4. Introduction
   a. Description - Briefly describe the scope of the building project and the eventual building functions. Describe the intended occupancy in the building and the total projected area(GSF). If possible include a simple diagram or a reduced sized drawing and include it in the Appendix as reference.

   b. Existing Conditions - Describe the existing conditions or site constraints which affect energy conservation. For renovations, thoroughly identify the HVAC distribution system(s), central plant types, assess age and condition and describe the general condition of the building thermal envelope.

   c. Strategy and Options - Describe the overall energy and cost-reduction strategies. State fuels availability and rate schedules. List the option packages developed for evaluation, including a number and short title for each package and a list of the elements involved. Elaborate where necessary to clearly define special equipment or specific operating strategies (e.g. thermal storage strategies, chiller and boiler staging, heat recovery.)

5. Discussion
   a. Energy Analysis Summary - Provide a descriptive narrative and grand summary table for the simulation results, ranking the packages by annual energy consumption in BTU per gross interior square foot per year. (The energy budget includes all metered energy to the site, not just HVAC energy use.) The information on annual energy use of the options must also be compared in a stacked bar-chart format.

b. Life-Cycle-Cost Summary - Provide a descriptive narrative and grand summary table for the Life-Cycle-Cost results, comparing the baseline building with the design building and ranking them by Net Present Value. Use the NIST BLCC program to document pollution reduction. Include a copy of the data file from NIST BLCC in the documentation diskette.

c. Energy Design Guidelines

Section 1 - Overview - Provide a brief description of the members of design team and how they interact to iterate to a final design solution. Refer to the listings of the design team members in the Overview Section under Responsibilities. Amplify by describing how the team has worked together to comply with Overview Section.

Section 2 - Energy Analysis & Reports - Describe the energy analysis. Provide a description of the simulations and use this section to describe how the simulation meets the energy design requirements. Provide any reference tables in an appendix. Provide a diskette with DOE-2 input detail including schedules (occupancy, lights, HVAC), loads, systems, and plant descriptions by verification tables LV-A,B,C,LV-G,SV-A, PV-A & PV-E and output detail tables BEPS,PS-B,LS-A,LS-C,SS-D,SS-H,PV-A,PS-C. Provide tables showing equipment sizing and any tables required by ASHRAE Std. 90.1-1999 to show compliance with the Energy Cost Budget Method. Discuss how the analysis will be amplified in the Design Development section.

Section 3 - Thermal Envelope Design - Describe in detail the energy components of the building envelope. Discuss the Architectural design elements such as orientation, massing, air-lock vestibules, vegetation for wind breaks and shading, location of buffer spaces, steps taken to minimize stack effects and location of restrooms to use secondary air for both ventilation and conditioning and any other passive design elements that will contribute to energy conservation. Discuss those components as listed in the Thermal Envelope Section, provide tabular values comparing the standards with the proposed design. Discuss all of the envelope design elements discussed in this section and how they are proposed to be incorporated. Provide manufacturer catalog cuts as example of materials to be specified. Provide hand sketches of the proposed envelope elements, i.e. roof, wall, windows,etc. Discuss daylighting and daylighting controls and evaluate daylit atrium applicability.

Elevator and other Conveyances - Discuss how the energy requirements will be applied to the specification of the elevator and conveyances. Discuss what steps will be taken to reduce stack effects.

Green Building Technologies - Discuss and make recommendations on how the requirements for the following Green Building features will be addressed:

a. Renewable Energy Resources - Discuss how the design team will propose incorporating building integrated renewable resources into the design.

b. Recycling - Make suggestion and establish attainable goals on the recycling of building materials at the end of their useful lives and for incorporating recycling of the daily waste stream into the building design.

c. Indoor Air Quality - Discuss how the design team will specify materials that will not introduce contaminants and contribute to poor indoor air quality.

Section 4 - HVAC Design Guidelines

a. Provide a discussion on how the design team proposes to meet the requirements of this section.

Section 5 - Building Automation Controls

a. Provide a discussion on how the design team proposes to meet the requirements of this section.

Section 6 - Ventilation/IAQ

a. Provide a discussion on how the design team proposes to meet the requirements of this section.

Section 7 - Lighting Design Guidelines

a. Provide a discussion on how the design team proposes to meet the requirements of this section. Include the following:

- Lighting Power Limits
- Table of Spaces, Lighting Levels
- Daylighting Measures
- Fixture Cuts & Catalog Cuts for Lights & Ballasts
- Narrative System Descripton

Section 8 - Commissioning

a. Provide a discussion on how the design team proposes to meet the requirements of this section.

Section 9 - Miscellaneous Design Issues

a. Provide a discussion on how the design team proposes to meet the requirements of this section.

d. Recommendations & Certifications - Provide recommendations on the Schematic Design and actions that will be taken in the Design Development Phase. Submit one of the following certification forms, signed and stamped by a Registered Professional Engineer.

- Certification of Schematic Energy Budget Compliance

- Request for Variance from Assigned Energy Budget - Variance from an assigned Energy Budget must be fully justified by the specific analysis in this report. Conjecture is not acceptable. If a Variance is requested, state request and supporting data in this section of the report.

Schematic Design Energy Budget Certification

Project Identification:

I hereby certify the schematic design with recommended options for the above project complies with the ASHRAE Std. 90.1-1999, Chapter 11, Energy Cost Budget Method and the Design Energy Cost is within 10 percent of the Energy Cost Budget.

Energy Cost Budget: ______________________ kBtu per Square Foot of Building Gross Interior Area Per Year.

Calculated Building Energy Use: ______________________ kBtu per Square Foot of Building Gross Interior Area Per Year.

SEAL

____

Signature

Registered Professional Engineer

Date: ___________________

Schematic Design Request for Variance of Building Energy Cost Budget

Project Identification:

I hereby certify that the Energy Cost Budget and Design Energy Cost has been calculated in accordance with ASHRAE Std. 90.1-1999, Chapter 11, Energy Cost Budget Method and the Design Energy Cost exceeds the Energy Cost Budget by more than 10 percent. I hereby request that a variance be issued in the Energy Cost Budget for this project. The Energy Cost Budget cannot be met, for reasons described in the attached narrative, and documented in the Schematic Design Energy Analysis Report.

Energy Cost Budget: ______________________ kBtu per Square Foot of Building Gross Interior Area Per Year.

Calculated Building Energy Use: ______________________ kBtu per Square Foot of Building Gross Interior Area Per Year.

SEAL

____

Signature

Registered Professional Engineer

Date: ___________________

Attachment 2-2, Format & Content, Design Development Energy Analysis Report

Note: This attachment will be delivered separately

Attachment 2-2, Format & Content, Design Development Energy Analysis Report

DESIGN DEVELOPMENT ENERGY ANALYSIS

Cover Sheet
(Study Title, Building Project Identification, Energy Analyst and Firm)

Table of Contents
(Page numbers of Sections and Major Subsections)

SECTION 1: OVERVIEW

1.1 Introduction

Briefly describe the scope of the building project and the eventual building functions. List the space programmed for each function in the building and the total project area.

1.2 Summary of Decisions from Previous Phase.

Describe the energy-related decisions made to date (based on the Schematic Energy Analysis), e.g., HVAC system selection, thermal envelope requirements, window types, etc.

1.3 Optimization Scope.

Describe the overall energy and cost-reduction strategies for the project. Describe the particular items optimized for energy conservation during Design Development. At a minimum, optimization must address Energy Management and Control strategies for HVAC and lighting.

SECTION 2: ENERGY ANALYSIS SUMMARY

2.1 Results of Energy Optimization.

Describe the results of energy optimization efforts during design development. Describe at a minimum the following: optimization of fenestration (area, transmittance, shading), thermal envelope (thermal mass, insulation position), HVAC zoning, and lighting management controls. Describe the type of HVAC control system (DDC/electric), the energy management strategies to be implemented and the EMCS hardware.

2.2 Comparison with Utility Rebate Baseline.

Describe the baseline systems used to run a comparison analysis for purposes of receiving a utility rebate for the energy analysis. State the kw reduced and percent energy reduction between the recommended and baseline packages, and any other analysis required by current rebate program guidelines.

2.3 Energy Certification.

For the recommended package, one of the following forms must be submitted (see attached):

a)Certification of Energy Budget Compliance or b) Request for Variance from an assigned Energy Budget. Variance from an assigned Energy Budget must be fully justified by the analysis in this report. Conjecture is not acceptable. If a variance is requested, state the request and supporting data in this section of the report.

SECTION 3: LIGHTING DESIGN

3.1 Lighting Power Limits.

Provide a narrative summary comparing the design lighting wattage for the building with lighting power budgets established at Schematic Design. Show separate limits for interior and exterior lighting. Include the worksheet used to arrive at the design lighting wattage for the building, showing the number of fixtures and the watts/fixture.

Note: the actual "watts/square foot" by fixture count as documented in this section must be used in all energy analysis for this phase.

3.2 Daylighting.

Describe daylighting measures to reduce daytime use of artificial interior lighting. Describe coordination of alignment and switching of lights with natural light where available. Provide data for sheets for proposed controls.

For new buildings, describe method and results of optimizing building daylighting for least annual energy consumption (combined heating, cooling and lighting).

3.3 Proposed Lighting Design.

Provide narrative describing task types and task surfaces encountered throughout the building. Update and submit the spreadsheet IES.WK3 listing footcandle levels to be maintained on task surfaces.
Provide fixture cuts and photometric reports for all proposed fixtures. Be certain to follow the "Lighting Design Guidelines" section in the Energy Design Guidelines in selecting each fixture.
Provide specifications for the ballasts and lamps used as the basis of design. Be certain to follow "Lighting Design Guidelines" on lamps and ballasts.
Submit Zonal Cavity Worksheets where applicable for selection of number of fixtures (IES light level Categories A, B, and C only).
Submit Point Calculations where applicable for lighting of task surfaces. (Light level Categories D and higher).
Submit reflected ceiling plans showing proposed fixture schedule, locations, switching and automatic controls.

SECTION 4: THERMAL ENVELOPE

4.1 For existing buildings describe any planned modification to thermal envelopes including, if applicable, changes to windows and insulation levels (roof and wall). Provide manufacturer's data sheets on any glazing, (state U-value, shading coefficient and visual transmittance).

4.2 For new buildings show compliance with the envelope constraints determined by ASHRAE Standard 90.1-1989 Section 8. Provide specific comparison between the ASHRAE 90.1 requirements and the proposed building U-values for walls, roof, floor slab and maximum percent fenestration allowed. Provide detail drawings to show required air barriers and avoidance of thermal bridging at susceptible areas as required by "Envelope Guidelines".

SECTION 5: ENERGY ANALYSIS DETAIL

5.1 Input Detail

Print out complete input data for the Energy Certification run, including schedules (occupancy, lights, HVAC), Loads, System, and Plant descriptions and building construction detail (Carrier "Simple (or Complex) Space Descriptions" or DOE2 DBL files.) For DOE2 also provide the following verification tables: (LV-A, LV-B, LV-C, LV-D, LV-H, LV-I); (SV-A); (PV-A, PV-E.)

Enclose a copy of the computer diskette with all imput files for the Certification run (5 - 1/4" DD DS floppy or 3 ½" floppy in IBM format.)

5.2 Output Detail

Show the following output tables as produced by the analysis program:

DOE2.1C Output Report Title	Carrier HAP Report Title
(BEPS) (Bldg. Energy Performance)	"Energy Budget"
(PS-B) (Monthly Energy Use)	"Electric Power Cost" and "Natural Gas Cost"
(LS-A, LS-C)	"Zone Cooling Load Summary"
(SS-D, SS-H)	"Zone Heating Load Summary"
(PV-A, PS-C)	"Maximum Block Load"

SECTION 6: HVAC DESIGN STANDARDS

6.1 System Standards

Design system in accord with ASHRAE Standard 90.1 Section 9 in full. Specifically state here how compliance will be achieved for each of the following items. Use the same subsections and titles shown below:

6.1.1 Load calculations and safety factors (ASHRAE Sec. 9.4.1)

Provide a table specifically comparing calculated loads with selected equipment size for chillers, boilers, air-handling and packaged or unitary HVAC equipment.

6.1.2 Off-hours Controls (ASHRAE Sec. 9.4.4) and isolation zoning and damper controls for meeting rooms, auditoriums, gymnasiums, etc. (See also 2.3 Energy Management System above).

6.1.3 Duct and pipe insulation levels (ASHRAE Sec. 9.4.8)

6.1.4 Zone Controls (ASHRAE Sec. 9.5.2) avoidance of reheating.

6.5.1 Economizer Controls (ASHRAE Sec. 9.5.3)

6.2 Equipment Efficiency Standards

Equipment efficiency shall comply with Energy Design Guidelines minimum efficiency requirements listed in the section "HVAC System". Find the minimum efficiency for each category of HVAC equipment to be used on this project and list these efficiencies in this report section. Also list the efficiency of the specified equipment to be shown on final drawings as the basis of design.

Provide a table specifically comparing the above minimum and actual design efficiencies of all equipment covered by efficiency standards in Energy Design Guidelines.

Provide data sheets to support efficiency statements.

6.3 Ventilation and Air Balance

Provide a ventilation analysis per Energy Design Guidelines and ASHRAE Standard 62 indicating outside air quantities to be introduced at each zone based on occupancy or appropriate criteria. Do not exceed the maximum design occupancy listed in Standard 62. Take reductions for intermittently occupied spaces.

CERTIFICATION OF BUILDING ENERGY BUDGET COMPLIANCE

Project Identification:

I hereby certify that the final design for the above project complies with the design energy budget.

Building Energy Use Budget: _______________ KBTU per Square foot of building gross Interior area per year.

Calculated Building Energy Use: _______________ KBTU per Per square foot of building gross Interior area per year.

SEAL

____

Signature

Registered Professional Engineer

Date: ___________________

REQUEST FOR VARIANCE OF BUILDING ENERGY BUDGET

Project Identification:

I hereby request that a variance be issued in the building energy budget for this project. The requested Building Energy Use Budget cannot be met, for reasons described in the attached narrative, and documented in the Schematic Energy Analysis report.

Building Energy Use Budget: ____________________KBTU per Square foot of building gross Interior area per year.

Calculated Building Energy Use: ____________________ KBTU per Per square foot of building gross Interior area per year.

SEAL

____

Signature

Registered Professional Engineer

Date: ___________________

SECTION 3

THERMAL ENVELOPE DESIGN

Section 3-Architectural Elements

Introduction

This section discusses the issues concerning the Architectural Elements of the design which the Thermal Envelope, Lighting System Design and Conveyances and Green Building Technologies: Renewable Energy Resources, Indoor Air Quality and Recycling.

Thermal Envelope Design

The building's thermal envelope shall be designed to minimize environmental loads and maximize occupant comfort. The designer shall consider in the thermal envelope design the Architectural design elements such as orientation, massing, air-lock vestibules, tightly fitting high performance entries, vegetation for wind breaks and shading, location of buffer spaces, location of spaces such as restrooms to use secondary air for both ventilation and conditioning and any other passive design elements that contribute to energy conservation. Daylighting and daylighting controls are a critical component of the design. The designer can also improve indoor air quality by designing an envelope that minimizes air and moisture infiltration. Passive envelope design techniques proved to be more cost effective when properly integrated into the building's design.

The ASHRAE Std 90.1-1999 and the attached EDG Section 3, Thermal Envelope Design provide guidance for complying with thermal design of the envelope. The designer shall disregard EDG references to ASHRAE Std 90.1-1989 and apply ASHRAE Std. 90.1-1999. The designer shall ensure that the building envelope has been optimized and discussed in both the Schematic and Design Development Energy Reports. Appropriate details must be developed and included on the design drawings. Building Construction Inspectors must insure that the details of the envelope design have been correctly installed. The College requests that the design team optimize the envelope by designing around a Brick & Block construction with an air gap between the exterior brick and the block. Continuous insulation and a continuous vapor barrier shall be installed on the interior face of the block and properly incorporated into the interior surfaces.

Windows play a critical role in the quality of the indoor environment and are a critical. The College requests that the designer optimize the window systems by designing a "Punch Window" with operable casement side panels. The operable casement shall have high performance seals, durable non-locking latches and clips to limit the swing. The design team is also requested to evaluate the use of the fiberglass framed windows as discussed in the EDG Section 3, at a minimum the design team must select a "true thermally broken" metal frame window, provide exact details and specifications and limit manufacturers to only those that can comply. Roof monitors and skylights are also a desirable Architectural element and a daylighting feature to be considered by the designer. If used the College requests that the designer use a fiberglass style opaque panel of the Kalwall type or equal.

Lighting System Design

The designer shall coordinate the use of both natural and artificial light and lighting controls to optimize illumination of the task while minimizing the consumption of electricity and loads placed upon the HVAC system. Section 9, Electrical Design discusses these issues. Lighting sources shall be selected for their efficacy.

Conveyances

Elevator and other conveyances - Elevators and other conveyance methods shall be specified to comply with the energy efficient requirements of other similar mechanical and electrical systems in the building. For example, common elements are premium efficiency motors, energy efficient/low maintenance cab lighting, electronic motor starters, occupancy controls, BAC controls compatibility, reliability and ease of maintenance. The elevator shaft shall be designed to minimize building losses through stack effects. The design team shall include the conveyances in the building's commissioning specification.

Green Building Technologies

Renewable Energy Resources such as Solar Electricity and Solar Thermal Energy Conversion are reliable and are being successfully integrated into many new buildings. The College is a participant in the Federal Governments Million Solar Roofs program and desires to integrate solar technologies into this building. The College will assist the designer in determining the appropriate level of integration of these technologies and assist in the design of these technologies. As part of the Pre-design meetings these opportunities shall be discussed. Ideally the building will be designed to incorporate the technologies into the construction of the building. However, at a minimum, the building will be designed to incorporate the infrastructure for these technologies to be integrated seamlessly at a later time. An example of this would be to design the roof structural members to accept additional loads and provide structural supports stubbed above the roof deck.

Adequate indoor air quality(IAQ) improves occupant comfort, contributes to student success, and is considered to be a Green Building Technology. The design team shall assist the College in identifying and specifying construction materials and methods which minimize contamination of the indoor environment. As part of the HVAC equipment the design team will also address IAQ in Section 6, Ventilation/IAQ.

Recycling as a Green Building Technology minimizes the environmental impacts for both the both the materials of building construction and the materials of building operations. The design team shall assist the College in identify building construction materials and set attainable goals for specifying those materials that can be recycled at the end of useful life of the building. Furthermore the design team shall work with the College to identify recycling needs for materials generated during the operation of the building and ensure that adequate space and infrastructure is included in the design. For example, recycling typically requires that material is segregated into several types and adds to the number of containers and storage space. Recycling may require that a loading dock be incorporated into the building's design. Additional ventilation and contaminant control may be required.

Attachment 3-1, EDG Chapter 3, Thermal Envelope Design

Thermal Envelope Design

New Buildings

In new buildings the designer shall follow ASHRAE 90.1 prescriptive requirements in full, for thermal envelope in the following areas:

- Air tightness of windows, doors and sealing of building joints and openings.
- Use of Overhangs and Maximum Percent Fenestration using the prescriptive route and "Alternative Component Packages" of Section 8.5, Table 8A.
- Maximum thermal transmittances of walls, roof and slab from table 8A, including the effects of all framing and thermal bridges. Use thermal network analysis for calculating average thermal transmittance, as shown in Section 8.4 of the standard.

ASHRAE 90.1 provides a simple table of "Alternate Component Packages" to select for the envelope criteria.

The most commonly needed sections are attached. Prescriptive envelope criteria must be determined and shown in the Schematic Energy Report. Compliance of the actual envelope assemblies must be demonstrated in the Design Development Energy Report.

Windows

In addition, the following **window specification** shall be used, which has been calculated to have the lowest life-cycle-cost for our buildings:

- **Low-emissivity Glazing** – Glazing assemblies shall be double pane with low-emissivity coating (the low-emissivity coating may be located on the glass or on a plastic sheet between glass layers).
- **Thermal Conductance less than 0.38** - The total window assembly shall have an NFRC conductance rating of less than 0.38 Btu/hr-ft2-deg F.

- **Shading Coefficient less than 0.55** - The maximum shading coefficient of the glass shall be 0.55. The designer shall analyze the use of lower SC in orientations with high solar gain, in order to reduce air-conditioning load and first cost.

- **Non-Metal Frames** - Metal frames are NOT permitted, even if "thermally broken". Frame material shall be wood, wood composite (e.g. Andersen "Fibrex") or fiberglass (e.g. Marvin "Ultrex"). Exterior cladding may be aluminum or fiberglass.

Product	Standard
Aluminum Windows & Doors	ANSI/AAMA 101-1988
PVC Window	ASTM D 4099-89
Wood Window	ANSI/NWMA I.S. 2-87
Sliding Wood Doors	ANSI/NWMA I.S. 3-83
Commercial Swinging and Revolving Doors	1.25 cfm/ft2 under ASTM E283-84
Residential Swinging Door	0.50 cfm/ft2 under ASTM E283-84

Major Renovations

Renovated buildings are generally not required to meet new insulation requirements in walls.

If the roof is being replaced as part of the renovation program then insulation shall be upgraded to ASHRAE 90.1 standards (R-17) or as close as is practical given existing constraints of the roofing system.

If windows are being replaced due to wear or deterioration then the same specification for new windows shall be applied. Air tightness requirements shall also be applied.

Existing buildings with window percentages higher than 50 % of gross wall area shall have window area reduced (covered and insulated) to meet ASHRAE 90.1 standards for maximum percent fenestration from Table 8A.

the intelligent approach

ALPEN, Inc.

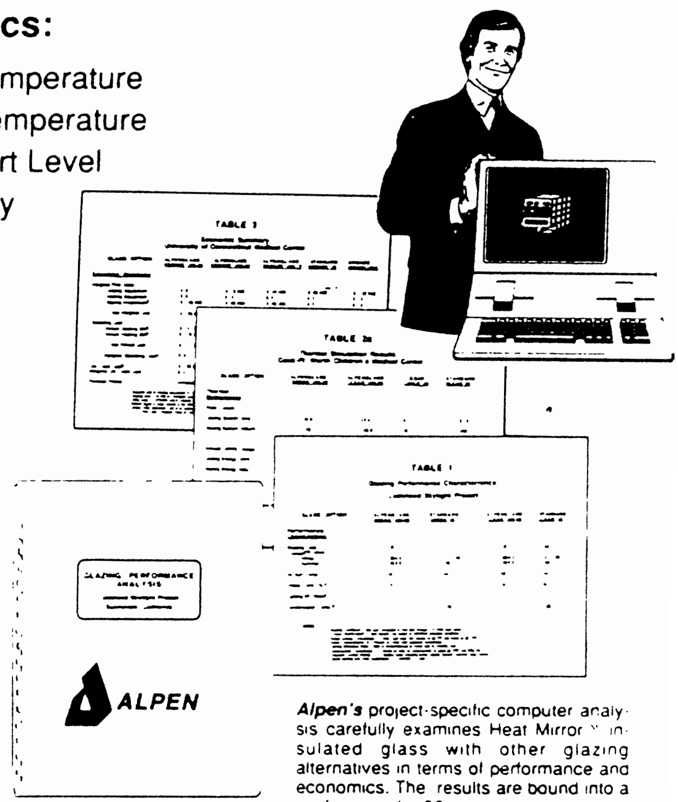
Takes the Guesswork Out of Glazing Specification

GLAZING PERFORMANCE ANALYSIS

A Free Service for the Project Design Team

I. COMPARE Performance Characteristics:

- Shading Coefficient
- R-Value / U-Value
- Ultraviolet Transmission
- Light Transmission
- Inner Surface Temperature
- Condensation Temperature
- Occupant Comfort Level
- Lighting Efficiency



II. CONTRAST Thermal Simulations:

- Peak Cooling and Heating Loads
- Annual Energy Consumption
- Hourly Temperature and Thermal Load Variations

III. ASSESS Project Economics:

- HVAC Equipment First Cost Comparison
- Glazing Investment Cost
- Annual Utility Heating and Cooling Cost
- Payback and Life Cycle Costing

Alpen's project-specific computer analysis carefully examines Heat Mirror™ insulated glass with other glazing alternatives in terms of performance and economics. The results are bound into a professional, 30-page, presentation-ready format.

For Additional Information and Application, Call SouthWall 1-800-365-8794

☐ **YES,** I am interested in ***ALPEN's*** free GLAZING PERFORMANCE ANALYSIS. Please contact me to answer my questions and/or arrange for this service.

Name ______________________ Title ______________

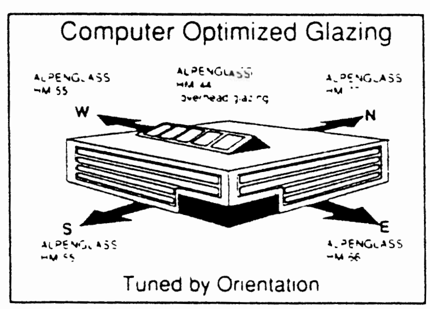
Company ______________________________________

Street Address _________________________________

City ________________ State ________ Zip __________

Phone # (____) ____-________ Approx. Ft² Glazing ________

Project _______________________________________



The best glazing type often differs for each side of a building. Five types of wavelength selective Alpenglass Heat Mirror allow customized performance without affecting visual appearance. ***Alpen's*** computer simulation produces an optimal mix of glazing types.

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Design Details

Thermal Bridging

The Architect shall design to explicitly avoid unintentional thermal bridging, for example, at the juncture of floor slabs with walls and any penetrations of the roof or wall insulation. The Architect shall provide details of all places where bridging may occur, to explicitly show how bridging will be avoided.

Good envelope joint details are critical to achieving thermal integrity and air-tightness.

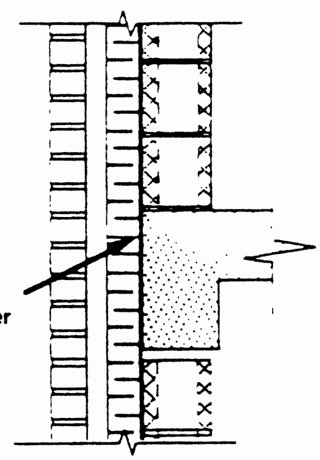
Air Tightness

To show compliance with envelope air-tightness criteria, the Architect shall prepare details showing a continuous air-barrier system. Particular attention shall be paid to joints, showing taping, sealing of air-barrier, caulking, gasketing, or weather stripping of each of the following areas:

- around frames of windows and doors
- between wall and foundation
- between wall and roof
- at roof parapets, overhangs, and edges
- between wall panels and at wall corners
- any penetration made in the envelope such as vents, hatches, and utility service entrances.

Detail Guidance

In developing the details for air-tightness and avoiding thermal bridges, the Architect shall consider the principles and details for good thermal envelope design contained in NIST report Thermal Envelope Design Guidelines for Federal Office Buildings. The implementation of these principles and any exceptions must be submitted for approval in the Design Development Energy Report.



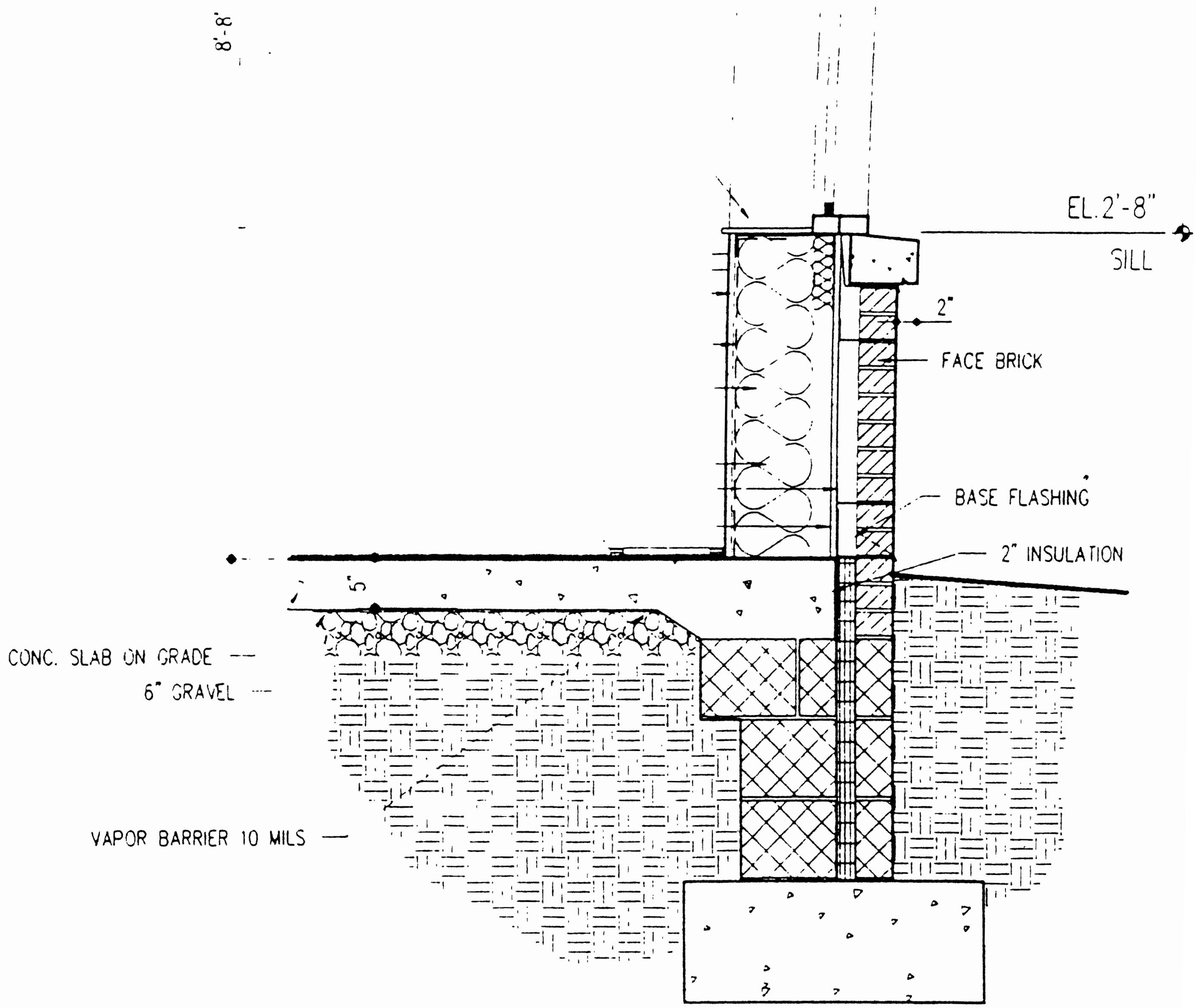
Masonry Wall Air Barrier

The most commonly needed chapters of the NIST report are provided at the end of this section. Other construction types will require other sections from the full NIST report.

Required Thermal Envelope details shall be included in design submittals beginning with Design Development Documents.

Perimeter Insulation Detail

For best thermal performance perimeter insulation should extend vertically from the top of the slab to the foot of the foundation. The outside of the foam insulation should be protected by a continuation of the face brick and then block as shown.



WALL SECTION @ OFFICE

3/4"=1'-0"

3

Thermal Envelope

Required Details

"Thermal envelope details must be complete"

Curtain Walls: In curtain walls the air barrier consists of the glass, metal pan and extrusions, insulation and sealants. Figure 31.6 (Perreault 1989) shows the basic approach to providing an air barrier in the system. The metal pan behind the spandrel insulation and the vision glass are the major elements of the air barrier; they must both be joined to the mullion using appropriate sealants to maintain the air barrier continuity.

ACCEPTABLE

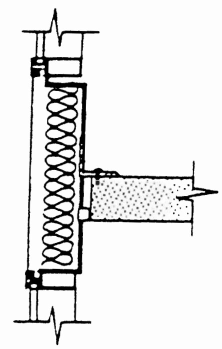


Figure 31.6 Curtain Wall Air Barrier (Perreault)

Metal Buildings: In metal building systems, the interior sheet steel liner serves as both an interior finish and a combined air/vapor barrier. Since the metal liner is airtight, the panel joints are the critical elements in the air barrier system. Care is also required in the design of wall/roof intersections and at the bottom of the walls in these systems.

Masonry Walls: Various approaches have been used for air sealing masonry walls. Factory-made elastomeric membranes provide a reliable air barrier, with the membrane being applied to the entire surface of the masonry backup wall as shown in Figure 31.7. These membranes may be thermofusible or peel-and-stick. Thermofusible membranes are adhered to the backup wall by heating the membrane backing with a propane torch. Insulation can be held in place with metal clips heat welded to the membrane. A sketch of an elastomeric membrane air barrier applied to a masonry wall is shown in the figure. The membrane runs continuously past the floor slab providing good continuity. Note the gap between the top of the backup wall and the bottom of the floor slab to accommodate deflection of the floor slab or other differential movement between the backup wall and the building structure.

ACCEPTABLE

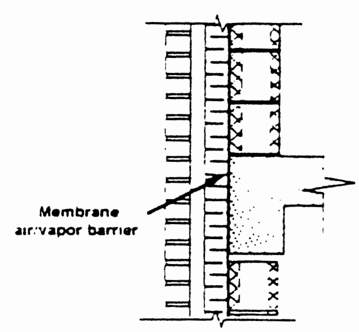


Figure 31.7 Masonry Wall Air Barrier (Perreault)

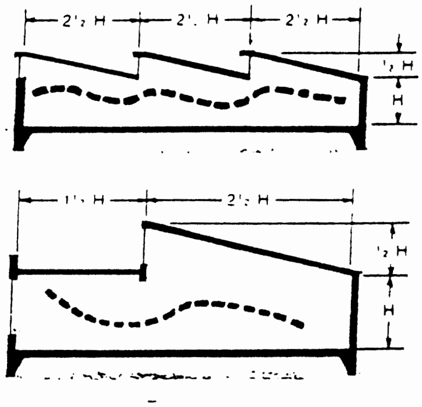
Find complete details in NIST "Envelope Design Guidelines"

Daylighting

Perimeter Daylighting

All buildings shall have perimeter fenestration with solar control appropriate to the use of natural daylight in the space. The upper limit on fenestration area is set by ASHRAE 90.1 Table 8A. The lower limit should generally be considered 10% of wall area. Additional design element should include:

- Use of light color, retractable blinds.
- Use of overhangs and light surfaces to reduce direct glare and reflect diffuse light high into the space.



INTERIOR LIGHT LEVELS

Core Daylighting

Natural lighting can produce a substantial reduction in energy use of commercial buildings.

In new large buildings the Energy Program of Requirements may direct core daylighting through use of roof monitors, atrium or courtyard. Analysis shall be provided by a qualified expert in daylighting analysis using DOE2.1D and physical models to optimize design and determine annual energy consumption.

Physical Models

A physical model is the best design tool for assessing the quantity and quality of light. Light performs in models exactly as it does in full-sized environments, provided the architectural surfaces and details are accurately replicated. These details include the scale and geometry of spatial elements, window openings, texture, reflectivity, transparency, and opacity of key finishes. Color is important if reflective properties are concerned. Transmission properties of glazing can be simulated or described by numerical factors if openings in the model are left uncovered.

The scale used for daylighting models can range from ¾ in. = 1 ft. (suitable for the study of single rooms) to ⅜ in. = 1 ft. (generally suitable for larger configurations). Smaller models are difficult to detail and are not recommended for room studies, although they may be appropriate for large spaces.

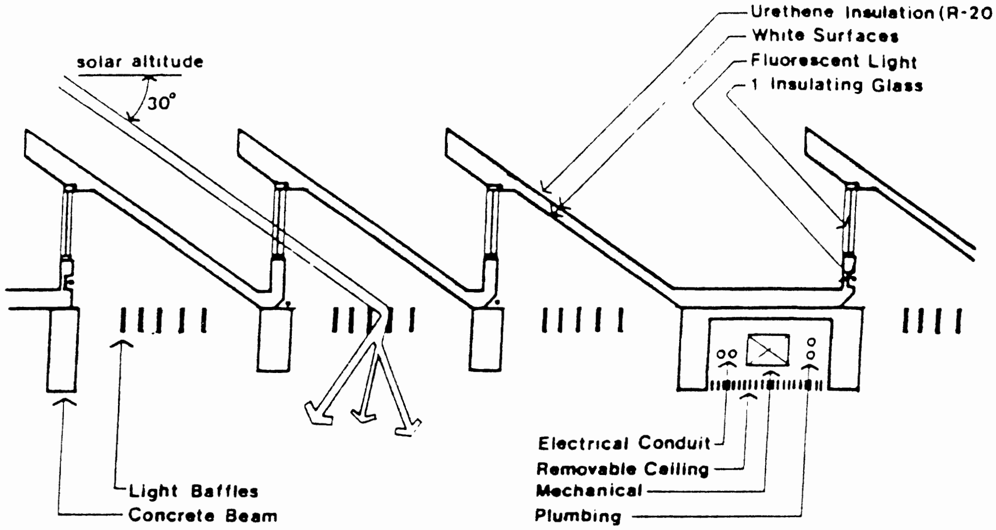


Figure 4-3. Section through roof apertures, Mt. Airy Public Library

Successful daylighting designs shared a number of characteristics. The most important aspect of the successful use of daylighting was distribution. If daylight was well distributed, a visually comfortable and largely glare-free environment was attained. The most successful design solutions had the following characteristics.

- Glare and contrast were controlled.
- Beam daylighting was not allowed to enter an occupied space directly. Baffles, diffusing reflecting surfaces, and/or diffusing glazing were used to break up beam lighting
- Occupants were not able to see the light source directly from the spaces they usually occupied.
- Light was admitted high on the wall plane or at the ceiling plane.
- The view was retained.
- A number of smaller roof apertures (clerestories and roof monitors) were used rather than a few large openings.
- Roof monitors and clerestories were designed with south-facing glazing.

Satisfaction with the lighting environment was quite high. In most buildings, daylight provided ambient or background illumination, with artificial lighting used to provide task-specific lighting. However, in three buildings — Mt. Airy Library, Security State Bank, and St. Mary's School Gymnasium — daylight provided the majority of the required task lighting. Daylight is a principal contributor to the increased amenity of passive buildings. Fewer than 5% of the occupants complained about "too dim" or "too bright" conditions, across all buildings and types of daylighting design. The many spontaneous comments about the delightful qualities of the daylighting attest to user satisfaction

NISTIR 4821

Envelope Design Guidelines for Federal Office Buildings: Thermal Integrity and Airtightness

Andrew K. Persily

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U. S. Department of Commerce
Ronald H. Brown, *Secretary*
National Institute of Standards and Technology
Raymond G. Kammer, *Acting Director*
Building and Fire Research Laboratory
Gaithersburg, MD 20899

Prepared for:
General Services Administration
Dennis J. Fischer, *Acting Administrator*
Public Buildings Service
P. Gerald Thacker, *Acting Commissioner*
Office of Real Property Development
Washington, DC 20405

PREFACE

The exterior envelopes of office buildings perform a variety of roles including keeping the weather outdoors, facilitating the maintenance of comfortable interior conditions by limiting the transfer of heat, moisture and air, providing a visual and daylight connection to the outdoors, limiting noise transmission, supporting structural loads, and providing an aesthetically pleasing appearance. Although building envelopes are generally successful in meeting these requirements, there are cases in which they do not perform adequately. Shortcomings in thermal performance are manifested by excessive transfer of heat, air or moisture that can lead to increased energy consumption, poor thermal comfort within the occupied space, and deterioration of envelope materials. While some cases of poor performance occur due to the specification of insufficient levels of thermal insulation or inappropriate glazing systems, other cases occur because of discontinuities in the envelope insulation and air barrier systems, such as thermal bridges, compressed insulation and air leakage sites. These discontinuities result from designs that do not adequately account for heat, air and moisture transmission, are difficult to construct, do not have sufficient durability to perform over time, or can not withstand wind pressures or differential movements of adjoining elements. Other thermal envelope defects occur due to poor technique during the construction phase.

Despite the existence of these thermal envelope performance problems, information is available to design and construct envelopes with good thermal envelope performance. In order to bridge the gap between available knowledge and current practice, the Public Buildings Service of the General Services Administration has entered into an interagency agreement with the Building and Fire Research Laboratory of the National Institute of Standards and Technology to develop thermal envelope design guidelines for federal buildings.

The goal of this project is to take the knowledge from the building research, design and construction communities on how to avoid thermal envelope defects and organize it into a form for use by building design professionals. These guidelines are not intended to direct designers to choose a particular thermal envelope design or a specific subsystem, but rather to provide information on achieving good thermal performance for the design that they have already chosen. Given that the designer has made decisions on the envelope system, materials, insulation levels and glazing areas, the guidelines will provide specific information to make the building envelope perform as intended through an emphasis on design details that avoid thermal defects. Much of the material in these guidelines is in the form of design details for specific building envelope systems, both details that result in thermal defects as well as improved alternatives.

TABLE OF CONTENTS

B GLOSSARY

The following glossary contains terms relevant to discussions of the thermal performance of building envelopes. Many of the definitions are based on the glossaries of the documents referenced at the end of this section.

Adhesion - the clinging or sticking together of two surfaces. The state in which two surfaces are held together by forces at the interface.

Adhesive - a substance capable of holding materials together by surface attachment.

Adhesive Failure - type of failure characterized by pulling the adhesive or sealant loose from the substrate surface.

Aging - the progressive change in the chemical and physical properties of a sealant or adhesive.

Air Barrier (sometimes referred to as Air Retarder) - an assembly or building element that provides resistance to through-flow of air from inside to outside or vice-versa.

Air Infiltration - air leakage into a building. Conversely, air exfiltration is air leakage out of a building.

Air Leakage - the passage of uncontrolled air through cracks or openings in the building envelope or its components because of air pressure differences.

Alligatoring - cracking of a surface into segments so that it resembles the hide of an alligator.

Ambient Temperature - temperature of the air surrounding the object under construction.

As-built - pertaining to the as-constructed state of a finished product relating to size, shape, materials, and finish regardless of drawings or specifications.

Asphalt - naturally occurring mineral pitch or bitumen.

Back-up - a compressible material used at the base of a joint opening to provide the proper shape factor in a sealant. This material can also act as a bond-breaker.

Bead - a sealant or compound after application in a joint irrespective of the method of application, such as caulking bead, glazing bead, and so on.

Bedding Compounds - any material into which another material such as a plate of glass or a panel, may be embedded for close fit.

Bond-Breaker - thin layer of material such as tape used to prevent the sealant from bonding to the bottom of the joint.

Bond Durability. a test cycle in ASTM C-920 for measuring the bond strength after repeated weather and extension cycling.

Building Envelope - the outer elements of a building, both above and below ground, that divide the external from the internal environments.

Built-Up Roofing - a roof covering made up of alternating layers of tar and asphaltic materials.

Butt Joint - a joint having the edge or end of one member matching the edge, end, or face of another member without overlap.

Butyl Rubber - a copolymer of essentially isobutene with small amounts of isoprene. As a sealant it has low recovery and slow cure.

Capillary Migration - movement of water induced by the force of molecular attraction (surface tension) between the water and the material it contacts.

Caulk (noun) - a material with a relatively low movement capability, usually less than + 10%. Generally refers to oil-based caulks, and sometimes to butyl and acrylic latex caulks.

Caulk (verb) - to install or apply a sealant across or into a joint, crack, or crevice in order to prevent the passage of air or water.

Closed-cell Foam - A foam that will not absorb water because all the cells have complete walls.

Closed Cell - a cell totally enclosed by its walls and hence not interconnecting with other cells.

Cohesion - the molecular attraction that holds the body of a sealant or adhesive together. The internal strength of an adhesive or sealant.

Cohesive Failure - failure characterized by rupture within the sealant, adhesive, or coating.

Compatibility - the capability of two or more materials to be placed in contact or close proximity with one another and each material maintaining its usual physical or chemical properties, or both.

Compression gasket - a gasket designed to be used under compression.

Compression Seal - a preformed seal that is installed by being compressed and inserted into the joint.

Compression Set - the amount of permanent set that remains in a specimen after removal of a compression load.

Condensation - the change of state of a vapor into a liquid by extracting heat from the vapor.

Construction Joint - in the construction of members intended to be continuous, a predetermined, intentionally created discontinuity between or within constructions and having the ends of the discontinuous members fastened to each other to provide structural continuity.

Control Joint - a formed, sawed, tooled or assembled joint acting to regulate the location and degree of cracking and separation resulting from the dimensional change of different elements of a structure.

Crack - a flaw consisting of complete or incomplete separation within a single element or between contiguous elements of constructions.

Crazing - a series of fine cracks that may extend through the body of a layer of sealant or adhesive.

Creep - the deformation of a body with time under constant load.

Cure - to set up or harden by means of a chemical reaction.

Dew-Point Temperature - the temperature at which condensation of water vapor begins for a given humidity and pressure as the vapor temperature is reduced. The temperature corresponding to saturation (100 percent relative humidity) for a given absolute humidity at constant pressure.

EIFS (exterior insulation and finish system) - non-load-bearing outdoor wall finish system consisting of a thermal insulation board, an attachment system, a reinforced base coat, exterior joint sealant, and a compatible finish.

Elasticity - the ability of a material to return to its original shape after removal of a load.

Elastomer - a macromolecular material that returns rapidly to approximately the initial dimensions and shape after substantial deformation by a weak stress and release of the stress.

Elastomeric - having the characteristics of an elastomer.

Epoxy - a resin formed by combining epichlorohydrin and bisphenols. Requires a curing agent for conversion to a plastic-like solid. Has outstanding adhesion and excellent chemical resistance.

Expansion Joint - a discontinuity between two constructed elements or components, allowing for differential movement (such as expansion) between them without damage.

Extrusion Failure - failure that occurs when a sealant is forced too far out of the joint. The sealant may be abraded by dirt or folded over by traffic.

Flashing - strips, usually of sheet metal or rubber, used to waterproof the junctions of building surfaces, such as roof peaks and valleys, and the junction of a roof and chimney.

Gasket - any preformed, deformable device designed to be placed between two adjoining parts to provide a seal.

Glazing - the installation of glass or other materials in prepared openings.

Gunability - the ability of a sealant to extrude out of a cartridge in a caulking gun.

Heat Transfer - flow of heat energy induced by a temperature difference.

Conduction - heat transfer whereby heat moves through a material; the flow of heat due to temperature variations within a material.

Convection - heat transfer by movement of a fluid or gas.

Radiation - heat transfer through space by electromagnetic waves emitted due to temperature.

Humidity, Absolute - the weight of water vapor per unit volume.

Humidity, Relative - the ratio of water vapor present in air to the water vapor present in saturated air at the same temperature and pressure.

Hypalon - a chlorosulfonated polyethylene synthetic that has been used as a base for making solvent-based sealants.

Insulation - a material used in building construction to retard the flow of heat through the enclosure. It is made from a variety of organic and inorganic fibers and foams, e.g., expanded/extruded polystyrene, glass fiber, cellular glass, phenolic foam, perlite, polyurethane foam, polyisocyanurate foam. It can be loose-filled, or used in batt, board, or block form..

Isolation Joint - a formed or assembled joint specifically intended to separate and prevent the bonding of one element of a structure to another and having little or no transference of movement or vibration across the joint.

Jamb - the side of a window, door opening, or frame.

Joint - the space or opening between two or more adjoining surfaces.

Lap Joint - a joint in which the component parts overlap so that the sealant or adhesive is placed into shear action.

Latex - a colloidal dispersion of a rubber resin (synthetic or natural) in water, which coagulates on exposure to air.

Latex Caulks - a caulking material made using latex as the raw material. The most common latex caulks are polyvinyl acetate or vinyl acrylic.

Latex Sealant - a compound that cures primarily through water evaporation.

Lock-strip Gasket - a gasket in which sealing pressure is attained by inserting a keyed locking strip into a mating keyed groove in one face of the gasket.

Masonry - construction, usually set in mortar, of natural building stone or manufactured units such as brick, concrete block, adobe, glass block, tile, manufactured stone, or gypsum block.

Mastic - a thick, pasty coating.

Mechanical Connection - a joining of two or more elements by means of mechanical fasteners, such as screws, bolts, or rivets but not by welding or adhesive bonding.

Metal Building System - a complete integrated set of mutually dependent components and assemblies that form a building including primary and secondary framing, covering and accessories, and are manufactured to permit inspection on site prior to assembly or erection.

Mullion - external structural member in a curtain-wall building. Usually vertical. May be placed between two opaque panels, between two window frames, or between a panel and a window frame.

Open Cell - a cell not totally enclosed by its walls and hence interconnecting with other cells.

Open-Cell Foam - a foam that will absorb water and air because the walls are not complete and run together.

Panel - (1) a portion of a surface flush with, recessed from, or sunk below the surrounding area: (2) a usually flat and rectangular piece of construction material made to form part of a surface (as of a wall, ceiling, or floor).

Parapet - that portion of the vertical wall of a building which extends above the roof line.

Preformed Sealant - a sealant that is preshaped by the manufacturer before being shipped to the job site.

Preshimmed Sealant - a sealant in tape or bulk form having encapsulated solids or discrete particles that limit its deformation within a joint under compression.

Pressure-Sensitive Adhesive - adhesive that retains tack after release of the solvent so that it can be bonded by simple hand pressure.

Primer - a compatible coating designed to enhance adhesion.

Purlin - a horizontal structural member which supports roof covering.

R-Value - a measure of the insulating value of a substance, or measure of a material's resistance to the flow of heat. It's reciprocal is referred to as an U-value.

Sandwich Panel - a panel assembly used as covering; consists of an insulating core material with inner and outer panels or skins.

Seal (noun) - a material applied in a joint or on a surface to prevent the passage of liquids, solids, or gases.

Sealant - a material that has the adhesive and cohesive properties to form a seal. Sometimes defined as an elastomeric material with a movement capability greater than + 10%.

Sealant Backing - a compressible material placed in a joint before applying a sealant.

Sealer - a surface coating generally applied to fill cracks, pores, or voids in the surface.

Sealing Tape - a preformed, uncured or partially cured material which when placed in a joint, has the necessary adhesive and cohesive properties to form a seal.

Shelf Life - the length of time a sealant or adhesive can be stored under specific conditions and still maintain its properties.

Shop Drawing - a drawing prepared by the fabricator based on a working drawing and used in a shop or on a site for assembly.

Shrinkage - percentage weight loss or volume loss under specified accelerated conditions.

Silicone Rubber - a synthetic rubber based on silicon, carbon, oxygen, and hydrogen. Silicone rubbers are widely used as sealants and coatings.

Silicone Sealant - a liquid-applied curing compound based on polymer(s) of polysiloxane structures.

Solvent - liquid in which another substance can be dissolved.

Solvent-release Sealant - a compound that cures primarily through solvent evaporation.

Spacer - a piece of resilient material placed to maintain space between a pane of glass or a panel and its supporting frame.

Spalling - a surface failure of concrete, usually occurring at the joint. It may be caused by incompressibles in the joint, by overworking the concrete, or by sawing joints too soon.

Stopless Glazing - the use of a sealant as a glass adhesive to keep glass in permanent position without the use of exterior stops.

Stress Relaxation - reduction in stress in a material that is held at a constant deformation for an extended time.

Structural Glazing Gaskets - a synthetic rubber section designed to engage the edge of glass or other sheet material in a surrounding frame by forcing an interlocking filler strip into a grooved recess in the face of the gasket.

Structural Sealant - a sealant capable of transferring dynamic or static ("live" or "dead", or both,) loads, or both, across joint members exposed to service environments typical for the structure involved, as in stopless glazing.

Substrate - (1) a material upon which films, treatments, adhesives, sealants, membranes, and coatings are applied; (2) materials that are bonded or sealed together by adhesives or sealants.

Tape Sealant - a sealant having a preformed shape, and intended to be used in a joint initially under compression.

Thermal Bridge - a heat-conductive element in a building assembly that extends from the warm to the cold side and provides less heat-flow resistance than the adjacent construction.

Thermal Conductance - the time rate of heat flow expressed in per unit area and unit temperature gradient. The term is applied to specific materials as used , either homogenous or heterogeneous for the thickness of construction stated, not per meter of thickness.

Thermal Conductivity - the time rate of heat flow, by conduction only, through a unit thickness of a homogenous material under steady-state conditions, per unit area, per unit temperature gradient.

Tolerance - the allowable deviation from a value or standard; especially the total range of variation permitted in maintaining a specified dimension in machining, fabricating, or constructing a member or assembly.

Tooling - the act of compacting and contouring a sealant in a joint.

Tooling Time - The time interval after application of a one-component sealant or after mixing and application of multi-component sealant during which tooling is possible.

U-Value - the capability of a substance to transfer heat. Used to describe the conductance of a material, or a composite of materials, in construction. Its reciprocal is referred to as an R-value.

Vapor Retarder - a material or construction that retards water vapor migration, generally not exceeding one perm for ordinary houses in non-extreme climates.

Wall - a part of a building that divides spaces vertically.

Bearing wall - a wall supporting a vertical load in addition to its own weight.

Curtain wall - a nonbearing exterior wall, secured to and supported by the structural members of the building.

Nonbearing wall - a wall that does not support a vertical load other than its own weight.

Water-Repellent - a material or treatment for surfaces to provide resistance to penetration by water.

Waterproofing - treatment of a surface or structure to prevent the passage of liquid water under hydrostatic, dynamic, or static pressure.

Weephole - a small hole allowing drainage of fluid.

Windows and doors -

Frame - an assembly of structural members that surrounds and supports the sash, ventilators, doors, panels, or glazing that is installed into an opening in a building envelope or wall.

Glazing - a material installed in a sash, ventilator, or panel such as glass, plastic, etc.

Head - an upper horizontal member of a window or door frame.

Jamb - a vertical member of a window or door frame.

Mullion - a member used between windows or doors as a means of connection, which may or may not be structural.

Muntin - a member used between lites of glazing within a sash, ventilator, or panel.

Operable - describing a sash, ventilator, or panel designed to be opened and closed.

Sill - a lower horizontal member of a window or sliding door frame.

Working Drawing - A detail drawing, usually produced by a draftsperson under direction of an architect, engineer, or other designer showing form, quantity, and relationship of construction elements and materials; indicating their location, identification, grades, dimensions, and connections.

Working Life - the time interval after opening a container of a single component sealant, or after mixing the components of a multi-component sealant, during which application and tooling is possible.

References

ASTM E241, Standard Practices for Increasing Durability of Building Constructions Against Water-Induced Damage.

ASTM E717, Standard Terminology of Building Seals and Sealants.

ASTM E631, Standard Terminology of Building Constructions.

Lstiburek, J., J. Carmody, Moisture Control Handbook, New, Low-Rise, Residential Construction, Report ORNL/Sub/89-SD350/1, Oak Ridge National Laboratory, 1991.

MBMA, Low Rise Building Systems Manual, Metal Building Manufacturers Association, Cleveland, Ohio, 1986.

Panek, J.R., J.P. Cook, Construction Sealants and Adhesives, 2nd Edition, John Wiley & Sons, New York, 1984.

PCI, Architectural Precast Concrete, Precast/Prestressed Concrete Institute, Chicago, 1989.

2.4 DESIGN AND CONSTRUCTION PROCESS

These guidelines primarily consist of design guidance and details directed towards the avoidance of air leakage and insulation system defects. While the use of sound design principles and details is essential to achieving good thermal performance, their use is not sufficient without a commitment to quality and performance in the design and construction processes. This commitment must begin in the first stages of design and continue throughout the construction of the building. The design and construction of office buildings is a complex process, involving building owners, architects, engineers, consultants, builders and subtrades, and all of these people have their individual motivations, concerns and experience. The CSI Manual of Practice presents a good discussion of these participants and the various relationships that exist between them. Sometimes the motivations of these participants, conflicts among their goals, and a lack of familiarity with thermal performance issues lead to some of the envelope performance problems that these guidelines are attempting to address. This section discusses the design and construction processes and their relationship to thermal envelope performance.

Motivations and Concerns

The design and construction of an office building is a very complex process involving numerous players, each with their own particular motivations, concerns and experiences. The process and the established roles of many of these players can contribute to the occurrence of thermal envelope performance problems. While the reasons are as complex as the process, part of the problem is that thermal envelope integrity is not emphasized and recognized as a critical factor throughout the design and construction of an office building. To some designers and builders, simply requiring a certain level of insulation, or the installation of an air barrier material or a quality sealant, is all that is needed. The importance of purposefully designing the insulation and air barrier systems as integral parts of the envelope is not recognized, nor is the need for a commitment to these systems from the very beginning or the necessity to develop straightforward, buildable details in order to make these systems work. Without a strong emphasis on thermal envelope integrity, decisions will be made or not made that result in thermal defects, and it will be too late for any alternative details to be developed to correct these defects.

When the commitment to thermal envelope integrity is lacking, problems arise in many areas. For instance, the efforts of the various design disciplines (architectural, structural, mechanical, electrical) will not be coordinated with the continuity and integrity of the air barrier and insulation systems in mind. Problems in these as well as other aspects of envelope performance will arise when the activities of these separate disciplines are not considered in relation to one another. Poor communication, a segregated approach to developing design details and a lack of commitment to thermal envelope integrity in the development of these details can result in envelope system that can not be effectively insulated or air sealed (Kudder). Kudder presents an example of such a problem that concerns the edge of a floor slab, as shown in Figure 2.4.1. The structural drawing showed only the spandrel beam supporting the floor slab, but did not show the wall. The architectural drawing included the wall, but did not show the beam located just inside the wall. The structural drawing implied that there was free access for the installation of fireproofing on both sides of the beam, and the architectural drawing implied that there was free access to the wall for the installation and finishing of the drywall all the way up to the floor slab. In fact, due to the location of the beam, the drywall screws could not be installed and the drywall joints could not be taped, leading to the leakage of interior air into the wall cavity. This problem occurred because their was no commitment to an air barrier system and because of poor coordination among the design disciplines.

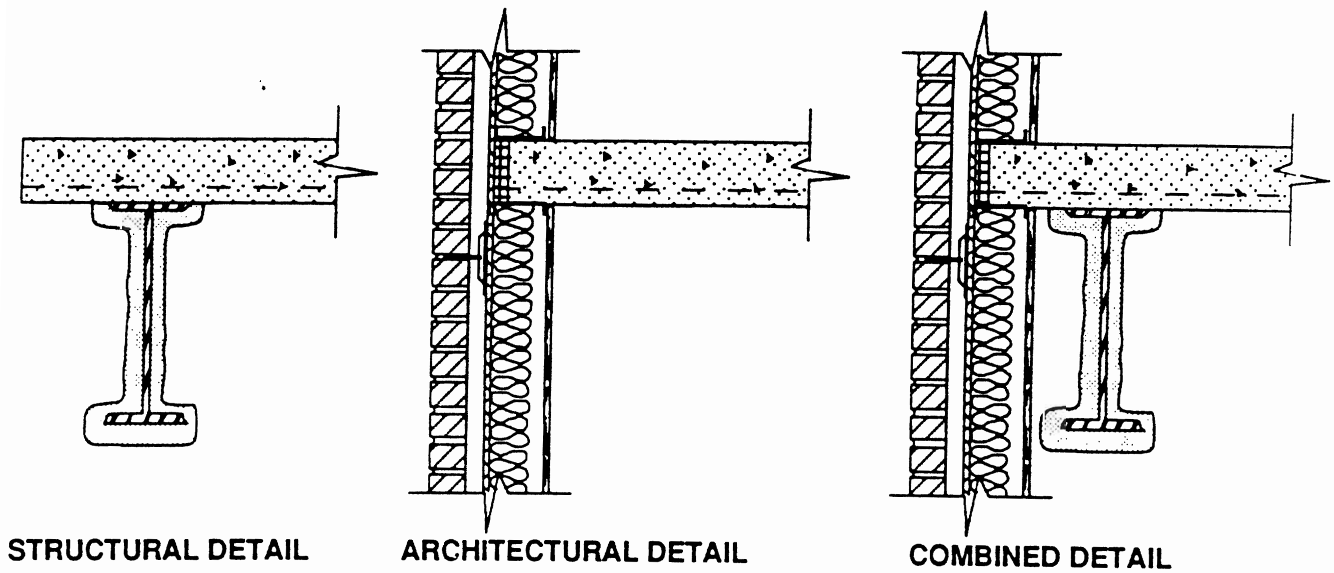

Figure 2.4.1 Example of Poorly Coordinated Detailing (Kudder)

It is important for the various participants in the design and construction process to understand each others roles, motivations, limitations and abilities. While this is more easily said than done, it is absolutely essential. Designers need to develop details with consideration of the fact that the construction workers have no design background and should not be forced to guess the designer's intention or play the role of designer. The role of construction worker should be to build as carefully as the details were developed. Therefore, construction details need to be precise, easy to understand and buildable, with no guesswork left to the workers (Perreault 1980). Too often, the design process involves copying design details from previous jobs or published details that contain no air barrier system and include significant thermal bridges, as opposed to designing the envelope as a system and considering each detail in relation to this system.

Similarly, the designer needs to recognize the importance of individual envelope elements and their impact on performance, and not compromise essential requirements for aesthetic or other considerations. For example, flashing must extend beyond the face of the facade in order to function properly, despite the fact that it might conflict with certain aesthetic goals. Similarly, designers will sometimes limit the width of sealant joints without an analysis of the relevant performance factors to determine if the width they select will be effective (O'Connor). The designer must understand that these thermal envelope design considerations and requirements are critical and must be incorporated into the envelope design.

As discussed in the section on air barriers, the importance of air leakage is not always appreciated in the design and construction of buildings. As stated throughout these guidelines, the control of air leakage through the use of an air barrier system is essential to good thermal envelope performance. There is an unfortunate lack of appreciation on the part of designers, builders and material suppliers as to the importance of air leakage (Handegord). It is sometimes assumed that simply by specifying a vapor retarder or an air barrier, one has dealt with the problem. In reality, achieving airtightness requires that an air barrier system is designed into the wall from the very beginning. There is also sometimes a resignation that air leakage is inevitable and in fact desirable. To the contrary, air leakage can and must be controlled to prevent a variety of performance problems.

The AAMA manual on the Installation of Aluminum Curtain Walls is an excellent reference on communication and coordination in the design and construction process. Although much of the discussion is specific to aluminum curtain walls, the manual discusses general issues relating to the responsibilities of architects, contractors and field personnel. The architect needs to be aware of field procedures and conditions and develop clear drawings and specifications based on this awareness. The architect should work closely with the contractor in developing the details to facilitate fabrication and installation. Inspection during construction is identified as critical to insuring that the specifications and shop drawings are closely followed. Architects should clearly define maximum permitted tolerances in the alignment of the building frame, and provide for these tolerances in the wall installation. The general contractor must develop the construction schedule in consultation with the other players in the project, allowing sufficient time for other steps in the process such as the development of the shop drawings, the fabrication of custom components, and the assembly and testing of a mockup.

Air Barrier Systems

Because of the importance of including air barriers in building envelopes, and their common omission in most buildings, this section gives special attention to how air barrier systems fit into the design and construction process. Many architects and designers are either unfamiliar with air barrier systems or do not consider them to be significant relative to the many other issues with which they must deal. This lack of familiarity exists because most discussions of air barriers exist in the technical literature, not in the publications to which designers are more often exposed. Also, the promotion of most new ideas within the construction industry is largely product or sales driven. Since an air barrier is a system as opposed to a single material, it is not promoted in new product columns or by writers of architectural publications.

Designers are often unfamiliar with the importance of air barrier systems and how to incorporate them into building envelope design. Before the design process even begins, it is relevant to determine whether anyone on the design team is aware of or experienced with air barriers and able to incorporate such a system into the envelope details and specifications. If not, it probably will not happen. If such a person is part of the team, he or she still may not have sufficient influence to pursue the issue. Once the design development phase has begun, the commitment to a continuous, well-supported and buildable air barrier should already be in place. This commitment is likely to be challenged with statements such as: "We have not done this before...We have a vapor retarder, what do we need this for?...It is not in the budget." The case for an air barrier must be made strongly and clearly; its function and requirements must be explained. When a commitment has been made to an air barrier system, its compatibility with the basic envelope design, the structural system, and the thermal insulation and vapor retarder systems must be reconciled early in the design process. An air barrier that is incorporated as an afterthought can not be effectively integrated with these other systems and will not perform adequately. The compatibility of the air barrier system and the major details, e.g., wall-floor, wall-window, corners, columns and parapets, should be examined early in the process.

As the working drawings are being produced it is important that the air barrier is correctly and consistently applied to all primary and derivative details. This is particularly important for masonry walls where the working drawings are used for construction without the benefit of separate construction drawings. All members of the design team must understand the principles of the air barrier so that all details are developed consistently, and all details must be reviewed with respect to the air barrier. As the specifications are developed, it is essential that they contain a requirement for an air barrier. The requirements should specify that the air barrier be identified on shop drawings and should address the structural adequacy of the air barrier system.

During the estimating and budgeting phase, it may become apparent that the construction managers and owner's representatives do not understand the principles of air barriers. They may regard them suspiciously as something they have never done before and a waste of money. The owner and construction manager may be likely to listen to the contractor's claims that such an elaborate air barrier system is unnecessary, and that they never include them in the walls they build. If building or energy codes mandated the inclusion of an air barrier, it would certainly strengthen the case of the air barrier proponent.

An air barrier will be incorporated into the shop drawings, and therefore into the building envelope, only if a specific requirement for an air barrier system is made by the wall designer. Shop drawings are generally not submitted for masonry walls, rather the working drawings are used during construction. It is therefore very important that the masonry contract drawings and specifications are thorough so that there are no questions regarding the existence of the air barrier, its location, materials and its treatment at junctions. Since masonry contractors typically do not develop shop drawings and design details in response to performance specifications, they are relying on the designer to develop these details. In other curtain wall systems the specifications are generally performance based and the manufacturer incorporates them into the engineering and shop drawings, which become the construction drawings. The air barrier will be correctly incorporated into the construction drawings only if the designer has included the system into their drawings and included appropriate language in the specifications.

If the commitment to an air barrier has survived to the construction phase, there are two remaining issues to deal with, education and supervision. All site personnel must be educated on the air barrier system and its importance to the project. An inspection agent should be employed and an inspection program developed to insure a proper installation of the entire wall, with special attention given to items that are new to the site worker. A field mock-up of the wall is a very good way to educate the site personnel and to identify construction problems with the system as designed.

Requirements and Recommendations

These guidelines are not able to offer a redirection of the process by which office buildings are designed and constructed. However, there are several essential design principles, stressed throughout these guidelines, that need to be incorporated into the design and construction processes. These include a modification of the rules stated by Brand for evaluating envelope designs and all associated details:

- Enclose the building in a continuous air barrier.
- Provide continuous support for the air barrier against wind loads.
- Ensure that the air barrier is flexible at joints where movement may occur.
- Provide continuous insulation.
- Design copings, parapets, sills and other projections with drips to shed water clear of the facade.
- Provide the means for any water that does penetrate the facade to drain back to the outside.

Thermal envelope design must also include a recognition that wall materials are not dimensionally stable and will move differentially from each other and from the structural frame. The location and extent of this movement must be anticipated. The air barrier element at these locations, whether it is an elastomeric sealant or a flexible membrane, must be designed to accommodate the anticipated degree of movement. If such movement is not adequately dealt with, the air barrier will fail at these locations and the continuity of the air barrier system will be lost. The need for continuity of the air barrier system can not be stressed enough. This continuity must also be maintained over wall areas, including those that are not readily accessible such as above suspended ceilings and behind convector cabinets.

The distinction between the control of water vapor diffusion and air leakage must be clearly understood. By definition a vapor retarder controls water vapor transport by diffusion, but not water vapor transport that occurs due to convection. An air barrier system is required to control convective moisture transport due to air leakage. The amount of water vapor transferred by air leakage is much larger than the amount transferred by diffusion, making the installation of an air barrier essential to the control of water vapor movement.

Perreault points out the importance of the environmental conditions during construction and the effect they can have on building components. Most building materials need to be protected from sun, heat, cold, wind and rain prior to their use and after they are installed, but before the exterior cladding is erected. Many of these materials will be affected by such exposure, degrading their in-use performance. These material issues can be dealt with through proper storage of construction materials, protection of partially completed work and scheduling of construction activities.

The CMHC Seminar on High-Rise Buildings makes a very valuable point on design philosophy, i.e., the designer must always assume that some degree of imperfection will exist in wall components. The design process must involve an evaluation of the locations and potential consequences of these imperfections, such as the degree and duration of wetness at critical locations, and then assure that the performance will not be compromised by these imperfections, or if it will, modify the design to accommodate them. The aim of the designer should be to minimize gross defects in the thermal envelope integrity and to tolerate the minor defects that inevitably occur.

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3.1 AIR BARRIERS

The purpose of an air barrier is too prevent airflow through the building envelope. This includes both the prevention of outdoor air from entering the building through walls, roofs and foundations, and the prevention of indoor air from exfiltrating through the building envelope to the outside. The inclusion of an air barrier system in the envelope design is essential to controlling air leakage and achieving good thermal envelope performance. Air leakage leads to excessive energy consumption, poor thermal comfort and indoor air quality, condensation within the envelope and the associated degradation of envelope materials, and interference with the proper operation of mechanical ventilation and smoke control equipment.

Even if an air barrier is not specified in the envelope, those elements which are most impermeable to airflow will be subjected to the envelope pressure differences. They will then "act" as the air barrier, most likely a poor one. The material experiencing the pressure difference, and its means of attachment, will probably not be adequate to withstand the pressure and it will be displaced. For example, rigid insulation board may be forced out of position by wind pressures when there is no air barrier system in the wall and the insulation attachment is not designed to withstand the wind pressures.

The air barrier system must be designed with full recognition that envelope materials are not dimensionally stable and that differential movements occur due to temperature effects and structural loads. The elements of the air barrier at locations where differential movement is expected to occur must be capable of accommodating this movement using systems and materials that will retain the essential performance requirements of the overall air barrier system.

Material and System Requirements

There are four basic requirements for an effective air barrier system: continuity, structural integrity, airtightness and durability.

Continuity: Continuity throughout the entire building envelope is one of the most important requirements of the air barrier system. It means much more than the various elements not having holes; continuity requires that all of the air barrier components are sealed together so there are no gaps in the envelope airtightness. The sealing of component connections is essential to air barrier design and construction, and a common source of failures. Areas where air barrier continuity must be given particular attention are at window frames, utility penetrations, wall-roof connections and the intersections of different wall systems.

The air barrier in each envelope component must be clearly identified during the design, and the manner in which they will be sealed together at component connections must be well thought out. Air barrier continuity can also be violated at locations that are hidden by other envelope components. For example when the interior finishing (e.g. gypsum) serves as the air barrier, if it is sometimes not finished above suspended ceilings or behind convector cabinets, there will be large gaps in the air barrier system's continuity.

Example: The sketch in Figure 3.1.1 shows a failure in air barrier continuity due to a lack of interior finishing (Kudder). In this wall the interior drywall served as the air barrier. However, due to the obstruction of the spandrel beam, the drywall could not be finished and severe air leakage occurred around the beam into the cavity behind the facade. Drywall screws were not installed behind the beam, and the joints were not taped all the way up the height of the wall.

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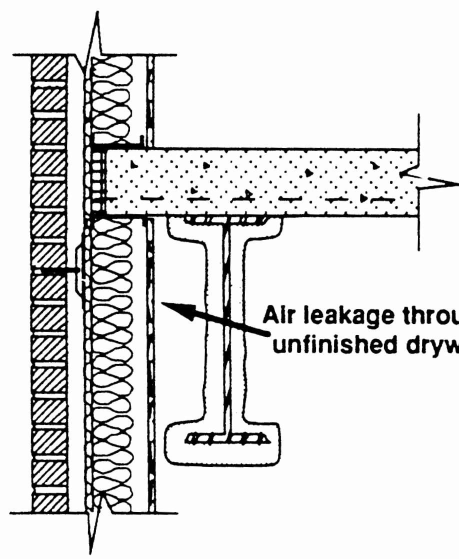

Figure 3.1.1 Failure of Air Barrier Continuity (Kudder)

Structural Integrity: All elements of the air barrier must be able to resist the imposed pressure loads or be supported by something that can resist these pressures. If the air pressure difference across the building envelope is not able to move air, it will work to displace those materials that are preventing this airflow. If the pressure exceeds the capability of the air barrier system to support this pressure load, then the system will fail, permanently destroying its ability to provide airtightness. In more specific terms, the air barrier system must resist peak wind loads, stack pressures and (de)pressurization by ventilation equipment without rupturing or detaching from its support and must not creep away from its supports or split at joints under sustained air pressures.

Example: A case of inadequate structural support of the air barrier in a parapet wall is shown in Figure 3.1.2 (Quirouette 1989). The wall consists of a brick veneer, an insulated steel stud wall, a polyethylene sheet air barrier/vapor retarder and an interior drywall finish. The parapet consists of a brick veneer, rigid insulation, polyethylene and concrete block backup. The rigid board parapet insulation was spot adhered to the polyethylene, which ran from the top of the wall studs, past the steel beam, and up the parapet where it was sealed to the parapet top plate. Because the polyethylene was not adequately supported, it moved back and forth with the wind pressures and eventually tore. The movement of the polyethylene pulled the rigid insulation from its original location, which in turn pulled the polyethylene further out of place. The parapet air seal was rendered totally ineffective, and the effectiveness of the insulation was severely degraded.

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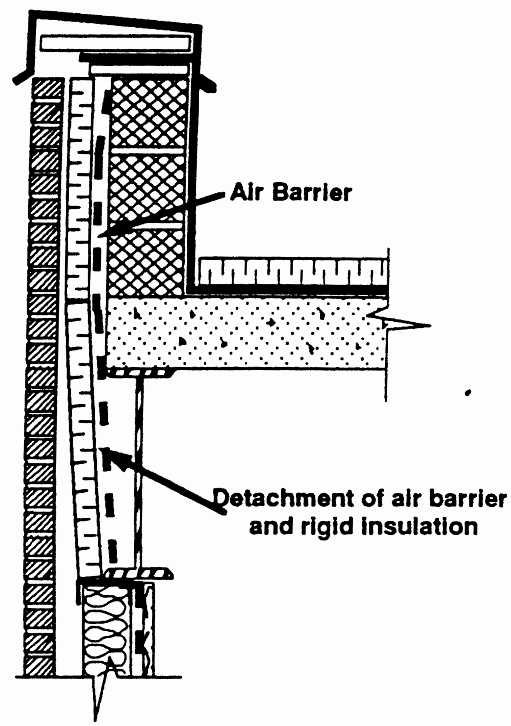

Figure 3.1.2 Failure of Air Barrier Integrity (Quirouette 1989)

Airtightness: The materials comprising the air barrier system obviously must be airtight, but more importantly these materials must be joined into a system such that the total assembly is equally airtight (continuity). Many building materials are clearly impermeable to airflow, e.g. glass, sheet metal and various membranes. Other materials are permeable to airflow, though this permeability is not always recognized, as in the case of a single wythe of masonry construction.

Example: The importance of air impermeability, specifically that of concrete blocks, is demonstrated by the example depicted in Figure 3.1.3 (Quirouette 1989). The figure shows a precast concrete panel wall with U-shaped column covers and C-shaped spandrel panels on a cast-in-place concrete frame with a concrete block infill wall. The blocks behind the convector cabinets were left exposed and untreated. Air passed through the blocks, into the space between the infill wall and the spandrel panel, and up behind the column covers. Severe condensation, freezing and melting problems occurred.

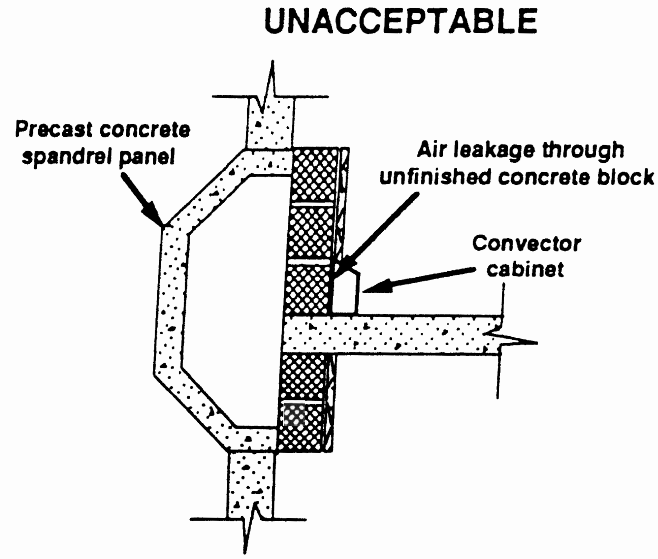

Figure 3.1.3 Air Barrier Permeability (Quirouette 1989)

Durability: The air barrier materials and the assembly must be known to have sufficient durability and demonstrated longevity in the field. If not, the air barrier materials should be positioned in the envelope such that they can be inspected and serviced as necessary. One must recognize that durability is not an inherent material property but is a function of how the material reacts to environmental exposures, i.e., temperature, moisture, radiation (UV) and adjacent materials.

Perreault and others have pointed out the use of inappropriate materials as air barriers:

- Insulation materials do not necessarily prevent the flow of air, unless specifically designed to serve as part of an air barrier system that meets all of the above requirements.
- Mastic is often used in masonry walls as an insulation adhesive and can serve as an adequate vapor retarder, but it cannot serve as an air barrier. As Perreault points out, mastic does not have the material properties required to bridge gaps and fissures on masonry surfaces, and therefore it cannot achieve the requirement of continuity.
- Polyethylene sheet or film is an effective vapor retarder material, but because it is not strong enough to withstand wind pressures, it is not suitable for controlling air leakage without adequate structural support. Polyethylene will perform if well-supported on both sides, but it is not strong enough to bridge openings. Another material could be used to bridge these openings, but it must be sealed to the polyethylene. In addition, the long-term durability of polyethylene has been questioned.

Air Barrier Location within the Envelope

From the perspective of controlling heat transfer alone, the location of the air barrier within the envelope is not important. However, from the perspectives of constructability, durability and envelope condensation, the location is very important.

From the perspective of durability, it is preferable to have the air barrier within the exterior cladding and outward of the structural frame. Having the air barrier within the cladding protects the air barrier materials from the detrimental affects of weather, i.e., sunlight, rainwater and extreme temperature fluctuations. The preferred approach to realizing this design is the use of a pressure-equalized rain screen cladding, as discussed in the section on Rain Penetration Control. In this approach a well vented cavity behind the facade controls pressure-driven rain penetration and a well protected air barrier controls air leakage.

Keeping the structural frame of the building within the air barrier makes the air barrier system design more straightforward in terms of maintaining continuity at penetrations associated with structural elements.

In cold climates, positioning the air barrier on the interior side of the insulation protects the air barrier from outdoor temperature fluctuations. Furthermore, the envelope elements to which it is attached are similarly protected, minimizing the thermally induced movement of these elements and the resultant physical stresses on the air barrier components. In this situation the air barrier can also serve as the vapor retarder since it is on the warm side of the insulation. In warm climates, it will generally be more advantageous to locate the air barrier outside the insulation from the perspective of airborne moisture transport. If the air barrier is located interior of the thermal insulation, special care is required to avoid infiltrating water vapor from condensing on the air barrier.

As discussed in the next section on Vapor Retarders, if the air barrier is not also serving as a vapor retarder, the relative position of these two elements must be given careful consideration. Whether or not this is the case, the position of the vapor retarder should be based on an analysis of the temperature and water vapor profiles through the building envelope, using the techniques presented in the ASHRAE Handbook of Fundamentals. If the two systems are separate, i.e., the air barrier is on the low vapor pressure side of the envelope, then the water vapor permeability of the air barrier must be well above the permeability of the vapor barrier. Recommendations on the permeability ratio of the air barrier to the vapor retarder range from 5 to 20, however, each system needs to be analyzed individually for its particular climate.

Application Examples

The particular air barrier system approach employed in a building envelope necessarily depends on the specific envelope system being used. Perreault (1989) has described the various air barrier systems in use, and they are discussed below:

Accessible Drywall: In this approach, shown in Figure 3.1.4 for a brick veneer/steel stud wall, the interior (exposed) drywall is the main component of the air barrier system. This approach relies on high performance sealants (see section Design/Sealants) to seal the drywall to other materials and to accommodate the large tolerances associated with commercial construction and the large differential movements associated with long spans. There is easy access to the air barrier from the building interior, facilitating inspection and repair. This system works well with concrete structures, as shown in the figure, but its application can be quite complicated in a steel structure.

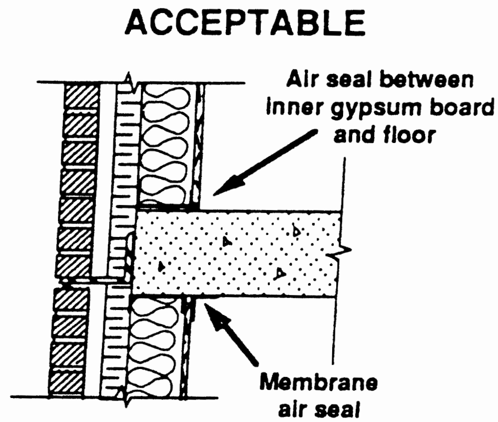

Figure 3.1.4 Accessible Drywall Air Barrier (Perreault 1989)

Non-accessible Drywall: In this approach, the exterior drywall sheathing serves as the main component of the air barrier system as seen in Figure 3.1.5. Joints between drywall boards are sealed with reinforced self-adhesive tapes, and joints between boards and other components are sealed using strips of elastomeric membranes. This system has the advantage over the accessible drywall approach of having fewer perforations of the air barrier from interior services such as electrical outlets. Because the gypsum sheathing and the air seals are inaccessible after construction, these materials must be durable and their attachment must be capable of long term performance. This approach works well in steel structures because the air barrier can be extended past steel columns and beams. The two details shown in the figure are examples of the application of this approach to a wall with a panel facade, insulation and a stud wall with gypsum board on both sides. The first case has a concrete frame and the second has a steel frame.

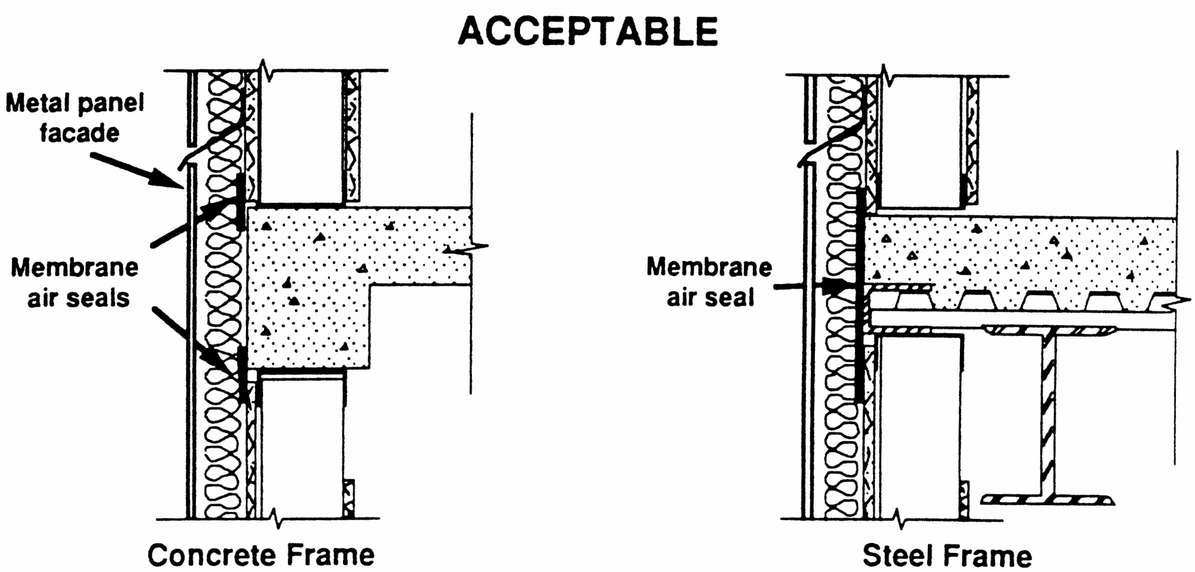

Figure 3.1.5 Non-Accessible Drywall Air Barrier (Perreault 1989)

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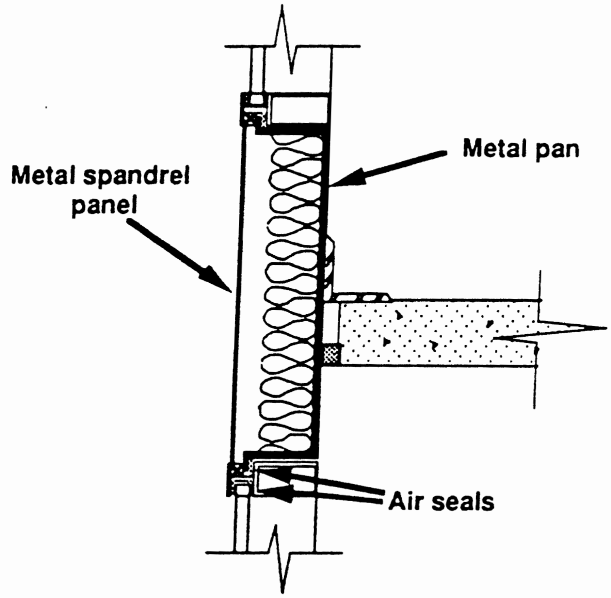

Curtain Walls: In curtain walls the air barrier consists of the glass, metal pan and extrusions, insulation and sealants. Figure 3.1.6 shows the basic approach to providing an air barrier in the system. The metal pan behind the spandrel insulation and the vision glass are the major elements of the air barrier; they must both be joined to the mullion using appropriate sealants to maintain the air barrier continuity.

Figure 3.1.6 Curtain Wall Air Barrier (Perreault 1989)

Metal Buildings: In metal building systems, the interior sheet steel liner serves as both an interior finish and a combined air/vapor barrier. Since the metal liner is airtight, the panel joints are the critical elements in the air barrier system. Care is also required in the design of wall/roof intersections and at the bottom of the walls in these systems.

Masonry Walls: Various approaches have been used for air sealing masonry walls. Factory-made elastomeric membranes provide a reliable air barrier, with the membrane being applied to the entire surface of the masonry backup wall as shown in Figure 3.1.7. These membranes may be thermofusible or peel-and-stick. Thermofusible membranes are adhered to the backup wall by heating the membrane backing with a propane torch. Insulation can be held in place with metal clips heat welded to the membrane. A sketch of an elastomeric membrane air barrier applied to a masonry wall is shown in the figure. The membrane runs continuously past the floor slab providing good continuity. Note the gap between the top of the backup wall and the bottom of the floor slab to accommodate deflection of the floor slab or other differential movement between the backup wall and the building structure.

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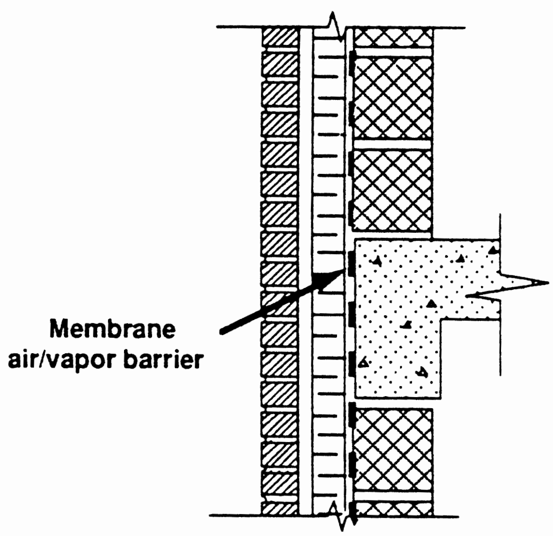

Figure 3.1.7 Masonry Wall Air Barrier (Perreault 1989)

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4.2 MASONRY

This section discusses wall systems in which a wythe (or wythes) of masonry constitutes the major component of the wall. There are many systems, which may appear to be quite different, that can be included under the general category of masonry walls. Such systems can range from a single wythe with no exterior or interior finish to a double wythe cavity wall with brick veneer and an interior finish of furring and gypsum. In general, most of the masonry walls of interest in commercial buildings fall into two categories. First, there are single wythe masonry walls with one of several different exterior and interior finishes. These exterior finishes include metal siding, stucco or paint, while the interior finishes can range from furring and gypsum wallboard to just paint. The second category of masonry walls are brick veneer walls which consist of a brick veneer, an air space, an inner wythe of masonry, and an interior finish. A great deal of design and construction information is available for brick veneer wall systems. This section does not cover brick veneer steel stud walls, as these are covered in the next section.

Guidance on the design and construction of masonry systems is available from a variety of sources including the Brick Institute of America (BIA), the National Concrete Masonry Association (NCMA), the Masonry Advisory Council and the Portland Cement Association (PCA). The BIA Technical Notes, the NCMA-TEK series and the PCA Concrete Technology Today series provide very practical information. While these materials do cover some issues of thermal integrity and envelope airtightness, they tend to concentrate on material properties, structural issues, rain penetration and construction techniques. While these issues are relevant to achieving good thermal performance in masonry walls, these guidance documents do not emphasize the prevention of air leakage and other thermal defects.

General Design Information

There is a great deal of design information available for masonry walls in publications such as the NCMA manual of construction details by Elmiger and the PCA Concrete Masonry Handbook by Randall and Panarese. These and other publications provide information on masonry units, mortar, properties of masonry walls, finishes and construction techniques. Other sources of general design information include BIA Technical Notes 21 and 21B. Grimm published a literature review on the durability of brick masonry in 1985 that discusses the agents and mechanisms that cause deterioration and how to increase durability through design, material selection, construction and maintenance.

In most of these masonry design references, the discussions of thermal issues are generally not extensive and do not stress problems of air leakage and thermal defects. While there is some discussion of insulation systems and thermal bridging, air barriers are rarely mentioned. Some of the guidance they provide is relevant to our discussion, including the issues of materials, crack control, water leakage, and construction technique. This section on design information contains brief discussions of materials and crack control, followed by a discussion of brick veneer walls since they constitute a significant portion of commercial building masonry construction.

Materials

The materials of masonry construction have been studied for many years, and the properties necessary for good performance are well established (see BIA Technical Note 21, NCMA-TEK No.85 and the PCA Concrete Masonry Handbook for more information). Quality materials are necessary to achieve good performance, and even the best design and construction will be compromised by poor materials. The materials of concern include the masonry units, mortar, coatings, ties and anchors, flashing, shelf angles, and joint materials. Specifications for many of these materials have been developed by ASTM and other organizations. Masonry unit specifications include strength, durability and water absorption, and provide guidance on the selection of units based on climate and anticipated loads. Specifications for masonry units are provided in ASTM C 55 (concrete building brick), C 90 (hollow load-bearing concrete masonry), C 129 (non-load-bearing concrete masonry) and C 145 (solid load-bearing concrete masonry). The important material properties of mortars include workability, water retentivity, strength, adhesion and durability. The various types of mortars and their properties are described in ASTM C 270 and C 476 for nonreinforced and reinforced masonry respectively. Additional material requirements exist for clear or opaque coatings used to provide watertightness or water resistance. The materials properties of ties, anchors, shelf angles, flashing and joint materials relate to strength, durability and corrosion resistance.

Crack Control

Cracking of masonry walls obviously impacts water and air leakage, and can lead to more serious problems of structural integrity for facades or whole walls. Grimm published a literature review of masonry cracking in 1986; the issue is also covered in BIA Technical Note 18 and NCMA TEK No.3 and No.53. Cracking occurs when the inevitable movement of building materials is restrained by the material itself or by adjacent elements. Such movement is caused by a variety of forces including temperature expansion and contraction, changes in moisture content, and structural loads. The differential movement of building components can be anticipated and must be accommodated for in design, otherwise cracking will result. Cracking can be controlled by the specification of materials that limit moisture-induced movement, the use of reinforcement such as bond beams, and the use of control joints or other devices to accommodate movement. In masonry veneer walls, the design of shelf angles that can accommodate movement is of particular importance and is described in Grimm and elsewhere. Crack control must be a part of the design of masonry walls, otherwise cracks will develop and both water leakage and air leakage will increase. As discussed in the section on water leakage, some fine cracking is inevitable, e.g. at mortar-unit interfaces, and adequate means must be provided for the drainage of the water that leaks through these cracks.

Brick Veneer Walls

Brick veneer walls employ a two-stage approach to the control of rain penetration. Figure 4.2.1 s a schematic of a brick veneer wall, showing the major components of the system. In this design approach, the veneer is intended to shed most of the rain water, at the same time acknowledging that some water will penetrate into the cavity. The veneer must still be designed and constructed to provide wind and water resistance so that the watertightness of the backup wall is not continuously tested. If the veneer is not at all watertight, then the backup wall really constitutes a single stage system. The cavity must be flashed at appropriate locations so that any water that does penetrate the veneer is drained to the outdoors. Ideally, the veneer should serve as a pressure-equalized rainscreen in which openings in the veneer keep the cavity pressure close to the outdoor pressure, preventing pressure driven rain penetration into the cavity. These openings must be designed to limit rain penetration due to capillary and gravity-driven flows. For the pressure-equalized rainscreen approach to be effective, the backup wall must be airtight.

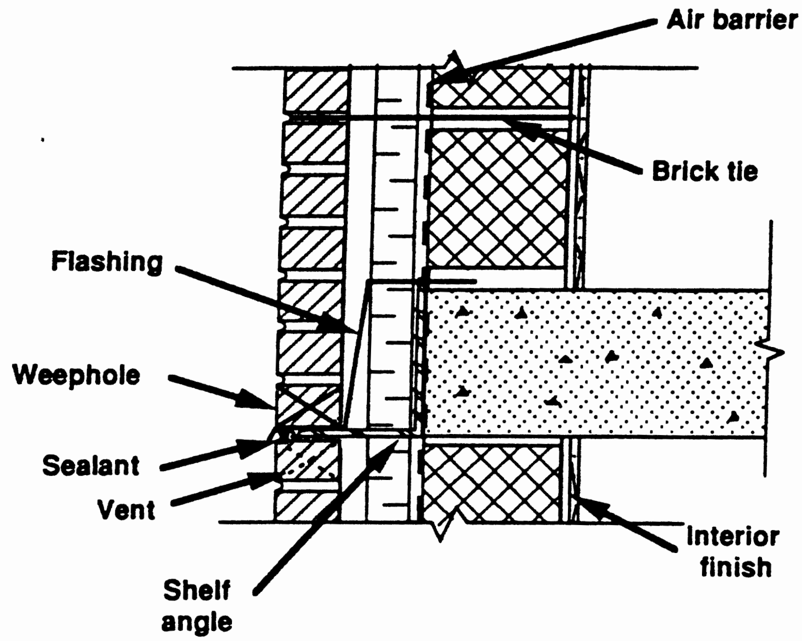

Figure 4.2.1 Brick Veneer Wall (CMHC 1989)

The design and performance of brick veneer walls is covered in BIA Technical Notes 21 and 21B, the Canada Mortgage and Housing Corporation (CMHC) Seminar on Brick Veneer Wall Systems, NCMA-TEK No.62 and No.79, and the PCA Concrete Masonry Handbook. The information in these documents concentrates on materials, structural issues and water leakage control. BIA 21B emphasizes structural issues and includes details of anchorage, expansion joints, foundations and window connections. Except for the CMHC document, design issues related to thermal envelope integrity are not emphasized in many of these guidance documents.

Water Leakage

While water leakage does not relate directly to airtightness and thermal performance, the interactions between the elements intended to control water and those intended to control air leakage and heat transfer must be addressed. Also, water leakage can lead to the deterioration of the elements controlling air leakage and heat loss.

Rain penetrates masonry walls through cracks at mortar-unit interfaces, unfilled mortar joints, movement and shrinkage cracks, and interfaces of the masonry wall with other wall components. The impact of raindrops directly on cracks is not a major contributor to water leakage, rather water running down the face of the masonry leaks through cracks due to capillary action and air pressures across the wall. Gravity can also be an important factor in larger openings that slant inwards. It is important to keep water off the wall through the use of properly designed drips on copings, ledges, sills and balconies, because any wall will leak if it is continuously flooded with water.

For a solid masonry wall, or any masonry wythe, to be watertight the masonry units and mortar must be compatible, the mortar joints must be completely filled and properly tooled, and the wall must be sufficiently thick. Compatibility between the units and mortar is necessary to achieve a good bond, otherwise there will be unbonded areas and cracks will be more likely to develop. In addition, the mortar joints need to be properly tooled in order to compact the mortar against the units and to close capillary cracks. If a masonry wall is sufficiently thick, then the water that does penetrate the facade will generally not reach the interior face before it is able to dry out. This is the approach that controlled rain penetration in older masonry construction, and it worked well in these very thick walls. In modern construction, masonry walls are generally not load-bearing and are therefore thinner and less forgiving of water leakage. In order to control water leakage in modern, masonry walls, industry guidance on mortar and joint tooling should be followed, but given the miles of mortar-unit interface it is unrealistic to expect to be able control all of the water leakage. Therefore, good masonry construction for rain penetration should be supplemented by the use of a facade or veneer that provides a second line of defense combined with a drainage system to remove the water that penetrates the facade. Design for the control of water leakage requires an understanding of how the cavity wall system is supposed to perform plus achieving the following key performance elements: the brick veneer should be as watertight as possible, flashing must be properly installed at all required locations, the cavity must be well drained and the backup wall must be airtight and watertight.

ASTM E 514 provides a test method for determining a masonry wall's resistance to water penetration subject to wind driven rain. This procedure involves a wall installed in a test chamber, as opposed to a field test.

Mortar Joints

Given compatibility between the mortar and the masonry unit, the joint must be full and properly tooled to control water leakage. Construction issues related to joint tooling are discussed below, but the type of mortar joint is key at the design stage (see NCMA-TEK 85 and the PCA Concrete Masonry Handbook). Figure 4.2.2 shows acceptable and unacceptable mortar joints for water leakage control. Concave and vee joints are generally recommended when the joint is exposed to rain. There is less consensus on beaded and weathered joints, with both reports of their providing adequate performance and recommendations against their use. Therefore they are labelled as marginally acceptable. Flush, raked, struck and extruded joints are not suitable unless weathertightness is not an issue, such as in interior construction. They should not be used on the exterior face of the inner wythe of a cavity wall.

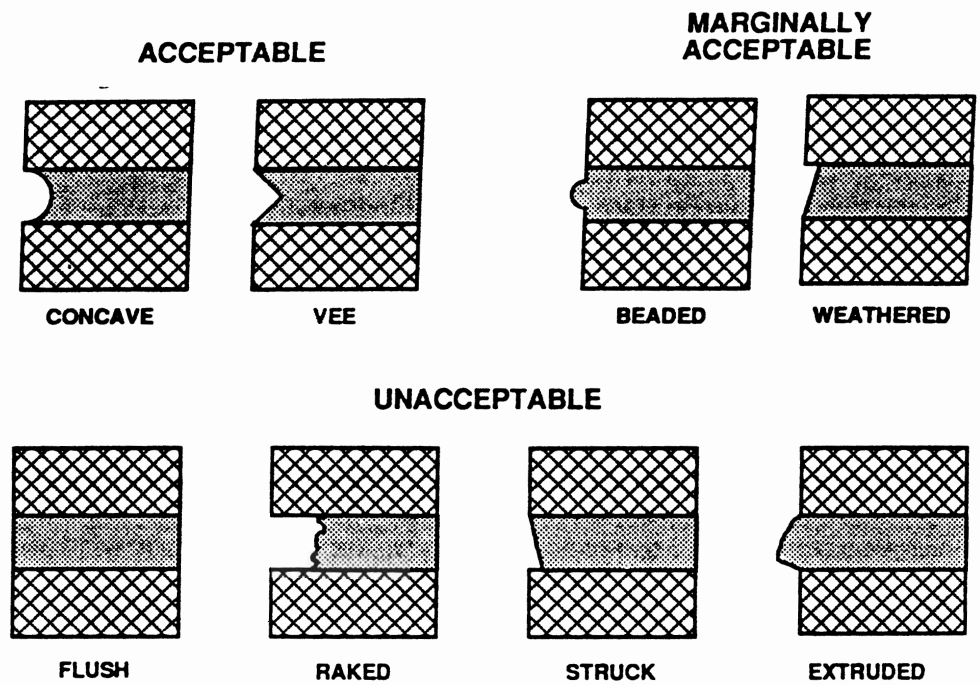

Figure 4.2.2 Mortar Joints for Water Leakage Control (Randall and Panarese)

Drainage and Flashing

Since it is practically impossible to make a watertight masonry wall, one must provide the means for the drainage of water that penetrates the facade. This design feature is recognized in the design of cavity walls, but drainage is also necessary in other masonry wall systems. Flashing is necessary at a variety of locations to direct this water flow to the outdoors through weepholes or some other such device. Good drainage requires the maintenance of an adequate space behind the facade, through which water can easily flow downward. Construction technique is important for keeping the cavity free from mortar droppings and installing the flashing such that it performs effectively, and these are covered in the section on construction. Many of the design aspects of drainage, flashing and weepholes are covered in available design guidance documents. Some of the key design requirements are outlined below, based on material contained in BIA Technical Note No.21B, NCMA-TEK No.13A and the PCA Masonry Construction Handbook.

Flashing is required anywhere water might otherwise accumulate or tend to enter the building interior. These locations include the following: above wall openings such as window heads, below wall openings such as window sills, where the wall structure rests on the foundation, at shelf angles, at wall-roof intersections and at parapet copings. A flashing material of good quality must be specified in the design, based on the following qualities: impervious to moisture penetration, resistant to corrosion from the atmosphere or caustic substances in mortar, strong enough to resist puncture, abrasion and other damage during installation, and both easily formed into the desired shapes and able to retain these shapes in use. Preformed copper sheet flashing, with soldered joints and expansion provisions, provides good performance. Galvanized sheet steel, aluminum and lead can be corroded from substances in the mortar and must have protective coatings. The flashing design must maintain continuity of the flashing at corners and other interfaces, and dams must be employed where flashing terminates such as beyond window jambs. In order to achieve the required continuity, flashing installations need to be carefully detailed at all interfaces such as windows, corners and columns. Adjoining pieces of flashing should be overlapped and properly sealed to each other. Potential interferences with other envelope elements that might damage or puncture the flashing, such as shelf angle bolts or ties, must be avoided. In cavity walls, the flashing should be carried up into a mortar joint of the inner wythe. And perhaps most important of all, the flashing must extend beyond the exterior face of the building. Aesthetic considerations are sometimes allowed to prevent this essential extension of the flashing, defeating its effectiveness.

Flashing will not be effective unless there are an adequate number of weepholes through which accumulated water can drain, located immediately above the flashing. Recommendations for the spacing of weepholes range from 400 to 600 mm (16 to 24 inches) on center. Weepholes can be provided by leaving mortar head joints open, using removable oiled rods or sashes, or installing plastic or metal tubes in the head joints. Weepholes can become plugged with mortar during construction, thereby losing their ability to drain. Construction techniques exist to prevent this problem, and these are described below in the section on Construction Requirements. Other weephole deficiencies include their complete omission or inadequate spacing or number.

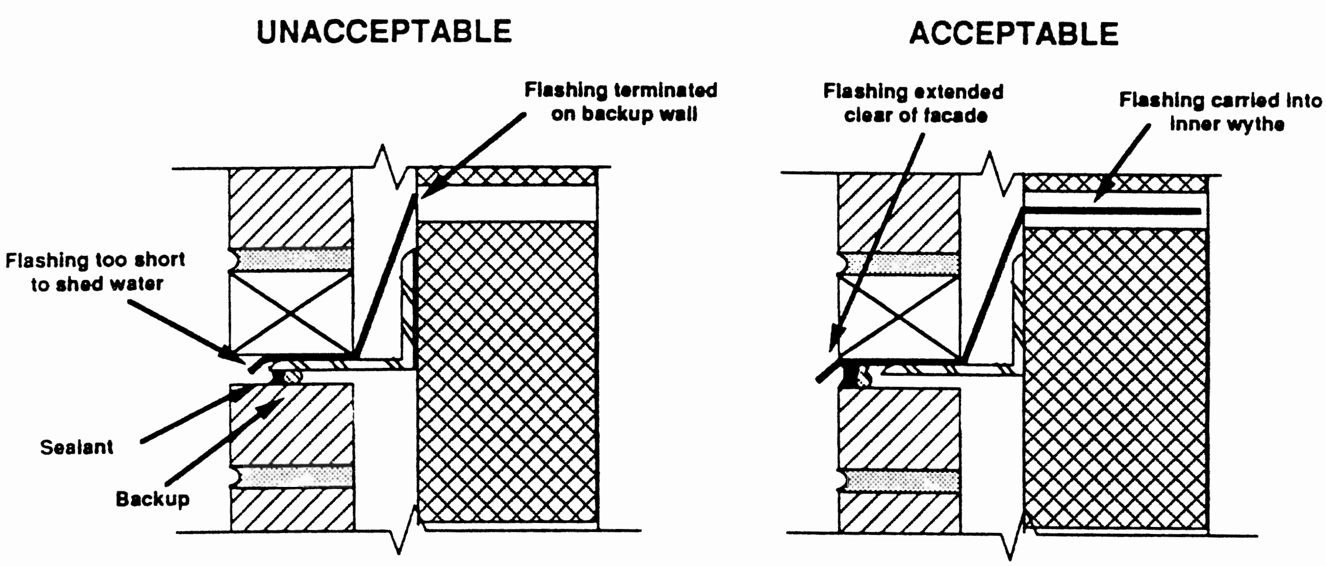

Figure 4.2.3 Unacceptable and Acceptable Flashing and Sealant Details (CMHC 1989)

Figure 4.2.3 shows unacceptable and acceptable flashing details at horizontal shelf angle joints. In the unacceptable case, the flashing is not extended beyond the face of the brick veneer, decreasing its ability to drain water to the outdoors. In the acceptable detail, the flashing is extended well beyond the face of the brick and is positively sloped to the outdoors. The flashing must not be terminated on the shelf angle because that will allow water to drain behind the sealant and into the cores of the brick veneer. Nor should the flashing be terminated against the inner surface of the backup wall, since water draining down the cavity will be able to get behind the flashing. Instead, the flashing must be carried up over the shelf angle and anchored at least 20 mm (8 in.) into the first course of the inner wythe. The relative positioning of the flashing and the anchor bolt must be considered to avoid puncturing the flashing. The flashing is sometimes placed in the second veneer mortar joint above the shelf angle for this reason. A compressible filler (e.g. neoprene) is placed under the shelf angle to keep debris, especially mortar, out of this space. If mortar does get under the shelf angle, differential movements result in unacceptable loads being imposed on the veneer.

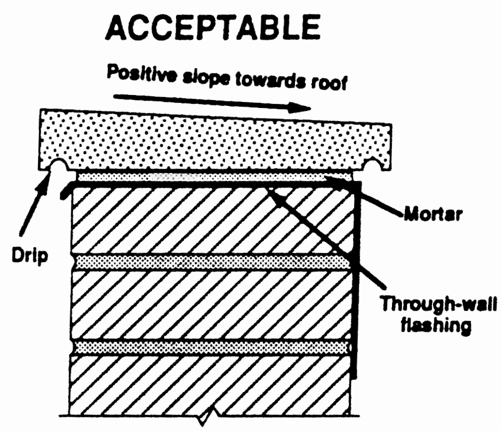

Figure 4.2.4 Flashing at Coping (CMHC)

Parapet flashing is extremely critical because of the exposure of these elements. In order to keep water out of the parapet and to prevent it from running down into the wall, through-wall flashing is required below copings and near the base of the parapet. Figure 4.2.4 shows such through-wall flashing below a pervious or segmental coping. Note that drips are included in the coping on both sides of the parapet, and that the coping slopes towards the roof to prevent water from running down the outer facade.

Figure 4.2.5 shows metal cap flashing over the top of a parapet and the through-wall flashing at the roof line. Figure 4.2.6 shows the flashing at a flashed curb at a roof edge.

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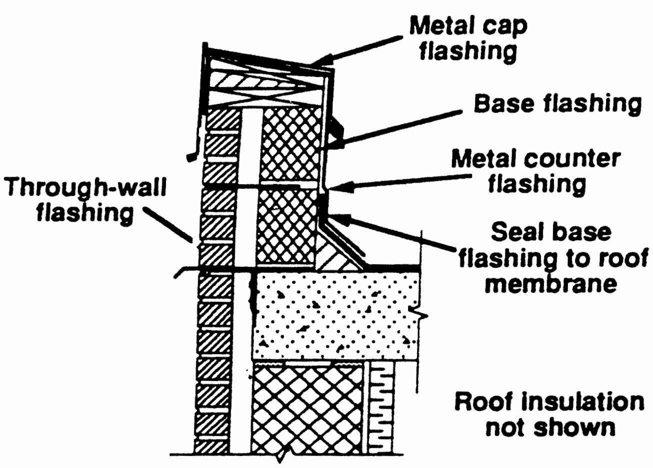

Figure 4.2.5 Parapet Flashing (CMHC 1989)

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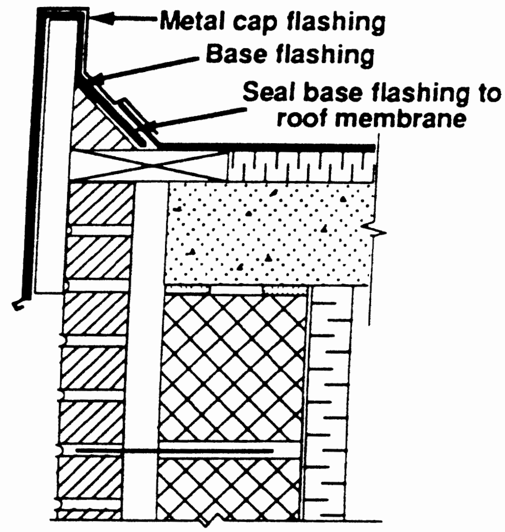

Figure 4.2.6 Flashed Curb (CMHC 1989)

The consequences of flashing deficiencies are well recognized, and as noted in the CMHC Advisory Document on Exterior Wall Construction these deficiencies may arise from several causes. First, flashing may not be called for in the design due to an oversight. In other cases, flashing is included in the design but is inadvertently omitted during construction. In some designs, the flashing is carried up a vertical surface to be tucked and sealed into a reglet or notch in the concrete structure or in a raked-out mortar joint. If this reglet is missing, the flashing may also be omitted or else not sealed properly, resulting in ineffective performance. Deficient flashing performance also results when the flashing is damaged during construction by wind or rough handling. A major cause of poor performance is insufficient flashing details that are oversimplified and neglect interference with other building elements. For example, flashing may interfere with the shelf angle bolt if the cavity is too narrow. Detailing problems also occur when flashing intersections with columns and other contiguous elements are ignored.

Coatings and Sealants

A wide variety of coatings are available for waterproofing masonry walls, as discussed in NCMA-TEK No.10A and the PCA Concrete Masonry Handbook. It is generally recognized that these coatings alone will not prevent water leakage, although they are necessary when a single wythe of concrete masonry constitutes the exterior facade. The other aspects of design and construction for controlling water leakage discussed in this section, i.e., surface drainage, mortar joints and flashing, must also be employed and in some cases can preclude the need for any surface coating. If these control measures are not taken and the wall does not adequately control cracking, then coatings alone will not prevent water leakage.

Surface coatings can be classified as opaque and clear. The opaque coatings can actually provide waterproofing because of their higher content of solids. Clear coatings tend to be less effective than opaque coatings, and are referred to as water repellents. Clear coatings employ a variety of materials, and work by changing the capillary angles of the pores in the masonry (see BIA Technical Note 7E). They will not normally fill cracks in masonry walls, and it is these cracks that are associated with most water leakage. Clear sealants do have their applications, but the inappropriate use of such materials can lead to problems. The performance limitations of clear sealants include an inability to stop moisture penetration through cracks and incompletely filled joints, the potential for contributing to spalling and/or disintegration of units; the inability to stop staining and efflorescence followed by interference with its removal; and making the wall almost impossible to tuck point. BIA recommends against their use except under very specific circumstances. Before considering their use for controlling water leakage, BIA recommends a careful inspection of the wall to investigate other potential sources of water leakage. Such an inspection should include the design and current condition of caps, copings, flashing, weep holes, sealant joints, and mortar joints. Any defects should be corrected, and these actions may control water leakage without the use of a coating. BIA Technical Note 7E provides a thorough checklist to use in determining the appropriateness of using a clear sealant. Many of these BIA limitations on the use of clear coatings also apply to opaque coatings.

Thermal Insulation

The key aspect of thermal insulation system performance is maintaining continuity over the entire building envelope. This involves placing and attaching the insulation so that there are no gaps between insulation elements, and between the insulation and its substrate. Thermal bridges must be avoided, and the insulation must remain in position over time. BIA Technical Note 21A discusses insulation of cavity walls, covering topics of materials and their properties, and points out two general criteria for cavity insulation. First, the insulation must allow the cavity to perform its function of providing a barrier to rain penetration and allow moisture to drain back to the outdoors. Also, its insulating properties must not be degraded by moisture in the cavity. Two other important issues regarding insulated cavity walls are the manner in which the insulation is attached and the position of the insulation, inside or outside the inner wythe.

The debate on whether to place insulation within the cavity or on the inside of the inner masonry wythe has been going on for decades. Both alternatives have advantages and disadvantages as discussed below. An advantage of interior insulation is that the insulation (and often the vapor retarder and air barrier) can be installed from the floors after the masonry work is complete. The installation can then be easily inspected and any defects repaired. One disadvantage of interior insulation is that the entire building envelope, and perhaps elements of the structural frame, are outside of the insulation and subjected to the full range of outdoor temperature fluctuations. This exposure increases the associated dimensional changes and places more severe requirements on materials. Also, the insulation (and again often the vapor retarder and air barrier) are not continuous over the building envelope but are interrupted by floor slabs, beams, columns and partition walls. These interruptions act as thermal bridges and require very careful attention in order to maintain the continuity of the air barrier system. Finally, when services such as electrical are installed they can end up being cut into the insulation and the air barrier.

Interior insulation often involves friction-fit batts installed between furring strips or studs. If this approach is used, the batt must fill the entire space to restrict any airflow, since airflow through or around the insulation will severely degrade its effectiveness. To this end, the spacing between the furring or studs must be kept uniform so that the batts are held securely. The insulation must be continuous over the entire interior surface, with no gaps at the floor or ceiling. If there is a dropped ceiling, the insulation must be carried past the ceiling to the slab above.

Cavity insulation also has advantages and disadvantages. On the plus side, the insulation can be applied over the entire backup wall, uninterrupted by floors, beams, columns and other elements, greatly reducing thermal bridging. The structural frame and the inner wythe are now separated from the outdoors by the insulation, providing a more stable temperature environment. The concern about electrical services, chases, ducts, etc. penetrating the insulation, vapor retarder and air barrier are eliminated. One disadvantage of cavity insulation is that since the insulation and masonry go up together, it is more difficult to inspect the work and repair any defects. The installation must be applied from a staging, and weather conditions can interfere with construction and affect the quality of the work. Also, the insulation must be worked around the veneer ties in a manner that does not compromise the insulation system effectiveness. Care is required in developing the flashing and insulation details so that they do not interfere with each other.

When insulation is placed in the cavity, a secure means of attachment is critical. The insulation within the cavity is subjected to outside wind pressures, and if it becomes displaced, it can interfere with the drainage of water from the cavity and lose its effectiveness as an insulator. In addition, there must not be any air gaps behind the insulation, otherwise air will then be able to flow around the insulation, severely degrading its effectiveness. Rigid insulation boards are often used as cavity insulation, and in order to be effective, these boards must be fixed tightly to the outside surface of the backup wall. Depending on the condition of the backup wall surface, it may be necessary to parge the backup wall to provide a flat surface for application of the insulation. Rigid insulation can be attached to the backup wall with adhesives, mechanical fasteners or a combination of both. When using adhesives it is important that the surface of the backup wall is clean and smooth. The back of the board must be fully buttered with adhesive, since spot adhering will result in air gaps behind the board. Weather conditions may restrict the use of some adhesives. One must also address their compatibility with the insulation and their long term stability and effectiveness with regards to aging, attack from biological organisms, and temperature and humidity cycling. Mechanical attachment using the brick ties or screw and washer assemblies has advantages over adhesives since they can be used under any weather conditions. Rigid, fibrous insulation is sufficiently flexible that mechanical anchors will pull the insulation into close contact with the backup wall.

When cavity insulation is used, the cavity must be wide enough to allow for the cleaning of any mortar droppings from the cavity. One can use insulations specifically designed to fill the cavity and allow for drainage, such as semi-rigid glass fiber boards. Such an approach also has the advantages of preventing mortar droppings since the insulation is in place when the veneer is installed.

In the case of rigid insulation boards, achieving secure attachment requires a solid surface for affixing the insulation and a means of attachment that can withstand the environment to which it will be subjected. Figure 4.2.7 shows an insulation adhesion failure caused when the brick ties prevented the insulation from achieving full contact with the backup wall. As a result, very little of the asphalt adhesive on the back on the rigid insulation actually contacted the block. Air moving through the block wall, due to the lack of an air barrier system, was free to move through the spaces on both sides of the insulation. In this case, severe condensation resulted on the outer surface of the backup wall. This problem could have been avoided through the use of an air barrier system and an alternative means of attaching the insulation.

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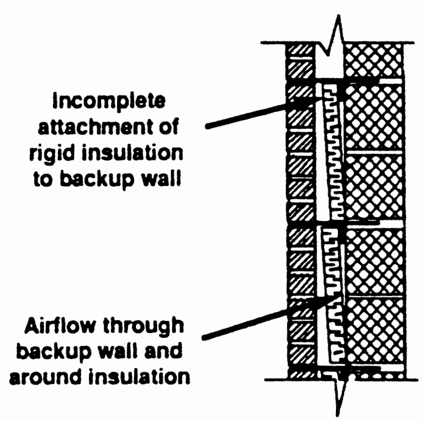

Figure 4.2.7 Insulation Attachment Failure

Figure 4.2.8 shows another case of insulation attachment failure (Quirouette 1989). In this case, the insulation was simply spot adhered to the polyethylene air barrier/vapor retarder which was attached to the top of the wall studs and the top of the parapet top plate. The insulation/ polyethylene was not adequately supported to withstand the wind pressures, and eventually it was displaced and tore.

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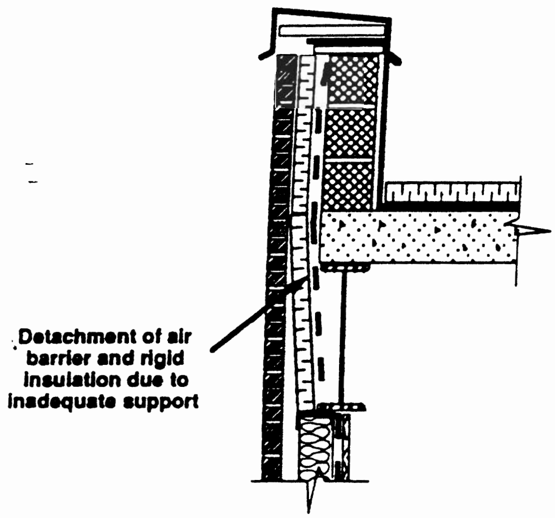

Figure 4.2.8 Insulation Attachment Failure (Quirouette 1989)

Given a well-attached insulation material, the concern over thermal bridges remains. Thermal bridging is not given much attention in existing construction guidance documents. In fact, these documents contain many examples of thermal bridges in their recommended design details. NCMA-TEK No. 151 is an exception, showing several examples of thermal bridges in masonry walls and pointing out the advantages of cavity insulation for avoiding such problems. Thermal bridges are discussed below in the section Examples and Details.

Air Barriers and Vapor Retarders

Masonry walls require air barrier systems to control air leakage as discussed in the section Design/ Air Barriers. Similarly, the design and installation of vapor retarders for masonry walls needs to follow the guidance given in the section Design/Vapor Retarders. To make a masonry wall airtight, one must reduce the permeability of the masonry wall itself and address the intersections between the masonry and other building elements. Mortar joints can not be made airtight because differential movements caused by temperature, moisture, shrinkage of blockwork and movement of other building elements inevitably lead to cracks in mortar joints. Since masonry itself is ultimately permeable to airflow, an air barrier material must be employed to seal the small openings at the unit/mortar joints. Air barrier materials used in masonry construction include layers of mortar, plaster, heavily textured paint or mastic, sheet material, interior gypsum board and various sealants. In order to achieve a continuous air barrier system, seams and joints must be meticulously sealed. Air barrier elements are also required at the interfaces between the masonry construction and other envelope components and must be able to accommodate the differential movement at these locations.

The following figures show air leakage defects in masonry construction, pointing out some of the key points in achieving an effective air barrier in masonry wall. Figure 4.2.9 shows a situation where air leakage occurred because the air barrier was omitted behind the convector cabinets (Quirouette 1989). Because the block behind the convector cabinets was left unfinished, interior air flowed through the unfinished block into the cold space behind the precast concrete spandrel panels and the column covers, resulting in severe condensation, freezing and melting problems. This case shows the importance of applying the air barrier continuously over the entire wall.

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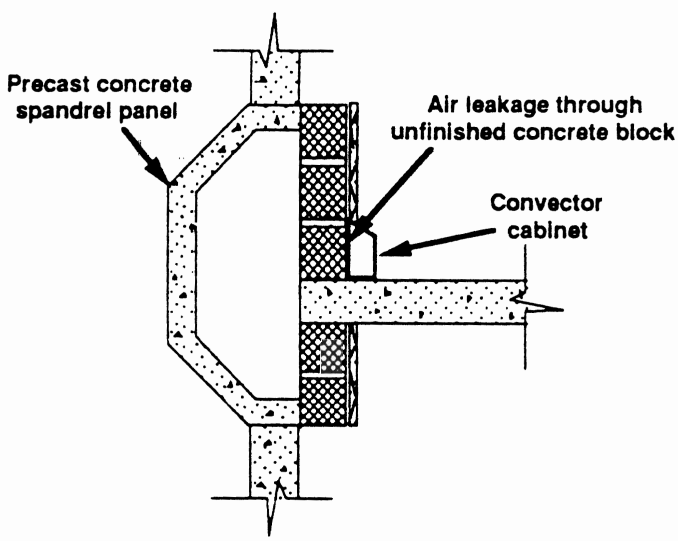

Figure 4.2.9 Air Leakage Through Unfinished Block (Quirouette 1989)

Figure 4.2.10 shows air leakage at the interface of steel columns and concrete block. The exfiltrating interior eventually condensed on the cold metal siding, resulting in severe crumbling of the block at the outer wythe. This case points out the need to provide an appropriate air barrier at the intersection between steel columns and masonry. The air barrier element must be able to compensate for construction tolerances, differential movement of the block wall and the structural elements, and block shrinkage. The intersection between masonry walls and other envelope elements is a key area for achieving air barrier continuity.

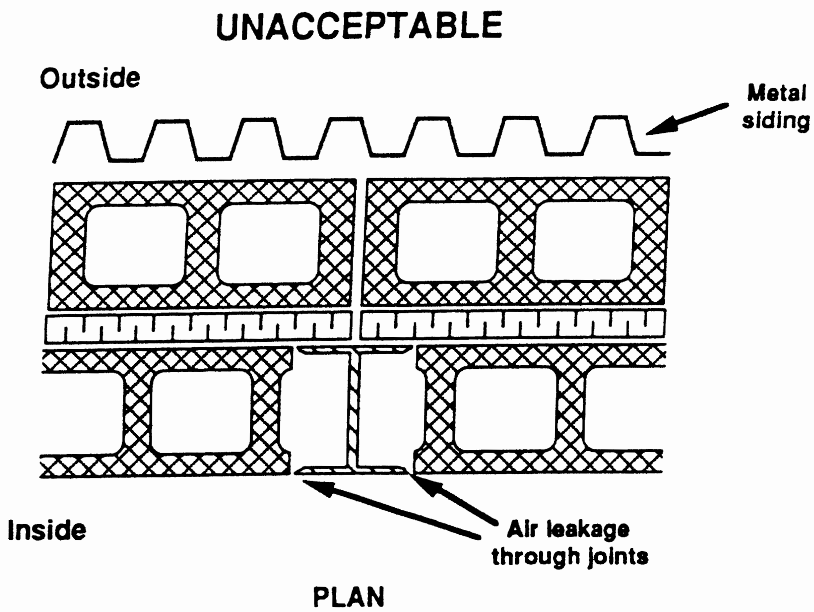

Figure 4.2.10 Air Leakage at Block / Column Joint (Quirouette 1983)

Figure 4.2.11 shows an example of an air barrier discontinuity at a window/wall interface (Quirouette 1983). In this case the wall air barrier and the window air seal are not in line with one another, resulting in a major discontinuity in the air barrier. Similarly, the wall insulation is out of line with the window thermal break. Quirouette points out that this design has been found to result in condensation on the inside mullion surface and efflorescence on the outside surface of the brick veneer.

As in the case of thermal insulation, the air barrier in a cavity wall can be placed either inside or outside of the backup wall and the insulation. The advantages of an inner air barrier include accessibility during construction and the associated ease of inspection and repair. In addition, if the air barrier and associated seals are positioned inside of the insulation then they are protected from outdoor temperature fluctuations, reducing the differential movement to which they are subjected and easing the material requirements on the sealants. The disadvantages of an interior air barrier involve the detailing required to seal the wall air barrier around columns, floor slabs and other structural members. The advantages of positioning the air barrier outside of the backup wall include having a continuous surface over which to apply the air barrier without having to work around interruptions from structural members. Whether the air barrier is inside or outside the insulation will determine the temperature environment to which it is subjected, affecting the material requirements for the air barrier.

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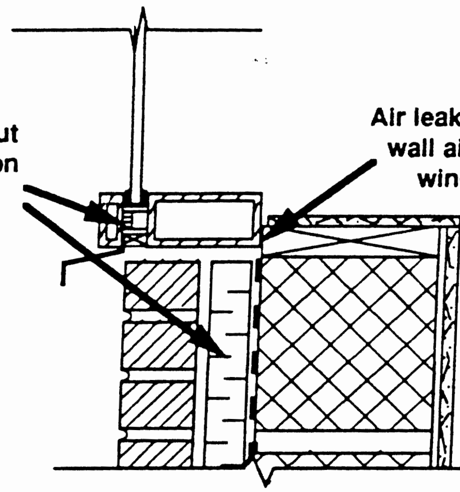

Figure 4.2.11 Air Leakage at Window/Wall Interface (Quirouette 1983)

Vapor retarder design for masonry walls must follow the guidance in the section Design/Vapor Retarders. The vapor retarder need not be absolutely continuous like the air barrier, but it must be applied to all portions of the envelope. Areas that are sometimes neglected include walls above suspended ceilings and behind convector cabinets. The position of the vapor retarder within the wall depends on the climate and the placement of the thermal insulation, and needs to be considered on a case by case basis as described in the section Design/Vapor Retarder. In some designs the air barrier is also intended to act as the vapor retarder, and in these cases the same analysis of vapor transport needs to be conducted.

There are several different options for providing a vapor retarder in terms of location and materials. The CMHC Seminar on brick veneer wall systems describes options for heating climates. First, the vapor retarder can be part of the interior finish, a necessity when the insulation is placed inside of the backup wall. Appropriate materials include oil or alkyd paint over gypsum board, polyethylene over the insulation, and impermeable insulation itself. If the insulation is positioned in the cavity, the vapor retarder can be located on the inside face of the backup wall using paint or other vapor retarding materials. A membrane on the exterior face of the backup wall can also serve as a combination vapor retarder and air barrier. Self-adhesive and torched-on membrane materials are effective. Since the membrane is serving as an air barrier, it must be continuous, able to accommodate movement cracks and remain firmly attached over time despite air and vapor pressures. When rigid insulation is applied to the external face of the backup wall, the mastic adhesive will serve as a vapor retarder. To be effective, a full bed of mastic must be applied and joints between insulation boards must be fully buttered.

Construction Requirements

There are several key requirements for building a masonry wall with good thermal and airtightness performance and with the ability to control water leakage. The following construction requirements are from the CMHC Seminar on brick veneer wall systems:

- Mortar joints must be completely filled and tooled on the exterior face to be resistant to rain penetration.
- Mortar joints on the backup wall must also be filled and properly tooled since it also forms part of the wall's moisture resistance.
- Mortar droppings within the cavity must be minimized and weepholes must be kept open.
- Securely anchor undamaged flashing to backup wall with properly lapped joints and extend sufficiently to clear the exterior face of veneer.
- Shelf angles must not tilt backwards. Sealant and backer rod must be installed below shelf angles to prevent water from entering the top of the veneer and cavity.
- Ties must not provide a path to carry water to the backup wall. Seal perforations of exterior components of backup wall caused by ties.
- Ensure that cavity insulation is fastened tightly to the backup wall.
- Avoid gaps between insulation units and gaps between wall insulation and insulation in other wall components.
- Maintain continuity in the insulation and air barrier systems, including intersections with other building components.
- Follow manufacturer's instructions for specified sealants
- Do not substitute any materials without approval of designer.
- Protect work in progress from damage due to weather and construction activities by other trades.

Several of these requirements are applicable to all wall systems. Those concerning mortar joints, mortar droppings, weepholes, flashing, shelf angles and ties are specific to masonry walls, and many of these are covered in industry guidance documents. Proper techniques for placing masonry units and tooling mortar joints are contained in BIA Technical Note 21C, the PCA Concrete Masonry Handbook and the PCA Concrete Information IS220.01M. These include minimizing the movement of the unit after placing in contact with the mortar, carefully filling head joints, covering newly erected masonry with a tarpaulin at the end of the day, and wetting exposed mortar joints for four days after filling or covering them with plastic.

Two key construction issues are keeping the cavity clean and reducing the impacts of weather on construction. The referenced construction guidance documents describe procedures to keep the cavity clean of mortar droppings and other foreign materials. Mortar within the cavity will create bridges that allow water to be carried across the cavity to the backup wall, preventing effective drainage of the cavity. Mortar droppings can also plug weepholes. Mortar droppings can be prevented by keeping a board in the cavity below the mortar application and progressively pulling the board up as the work is done. This technique is described in detail in the referenced documents. The impact of weather conditions on masonry construction are also covered in these guidance documents since both hot and cold weather impact material properties. These documents provide specific guidance on storage and handling of materials, and the construction of temporary enclosures to protect walls during construction.

Construction also impacts the integrity of masonry construction when time schedules and cost are allowed to compromise quality. As pointed out above, good construction technique is required to ensure maximum resistance to rain penetration and other aspects of performance, and good technique must not be sacrificed for speed. The use of good design and quality materials can not overcome excessively fast masonry construction.

Examples and Details

This section presents several examples of masonry construction with good thermal and air leakage performance, in some cases accompanied by examples of thermally defective designs. These examples involve the intersections between masonry walls and other envelope components, e.g., floors and windows. The connection between walls and roofs is covered in the section on Roofing Systems

The connection between walls and floors is a location that can be associated with discontinuities in the thermal insulation and air barrier system. Figure 4.2.12 shows an example of a thermal bridge at this intersection in which the concrete floor slab penetrates the wall insulation (Grot). The steel beam supporting the slab is insulated on the outside, but the beam still interrupts the insulation layer. Heat flux transducer measurements on these beams revealed that this insulation was not effective, if it was even installed. This detail also suffers from significant air leakage at the intersection of the floor and wall because there is no air seal at this location. This design, i.e., the floor slab penetrating the wall insulation, is a very common thermal bridge and appears in many design guidance documents without any acknowledgement of the thermal consequences.

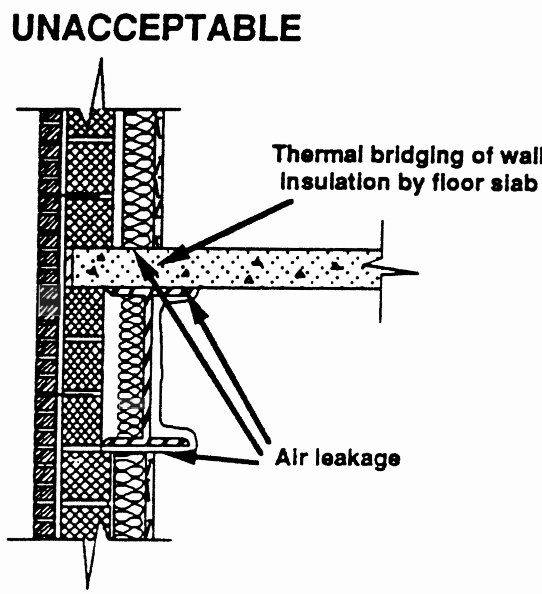

Figure 4.2.12 Wall-FloorConnection (Grot)

Figure 4.2.13 shows a typical floor/wall connection that suffers from thermal bridging and air leakage. In this design an insulated stud wall is located inside the masonry backup, and the studs act as thermal bridges through the insulation. There is no air barrier system in the wall to control air leakage. The slab bridges the wall insulation, and the shelf angles add to the heat loss effects. In addition, the "truss" type brick ties serve as an additional thermal bridge between the outside and the backup. An improved design is shown in Figure 4.2.14. Rigid insulation is added between the backup and the stud wall to reduce the thermal bridging from the studs. An air barrier is installed on the exterior side of the backup wall to control air leakage. "Pintel" type ties are used to reduce thermal bridging. The edge of the slab is insulated to reduce the thermal bridging effect of the slab, although discontinuities in the insulation system remain. Finally, high density plastic shims are used at the shelf angles to reduce the thermal bridging at this location.

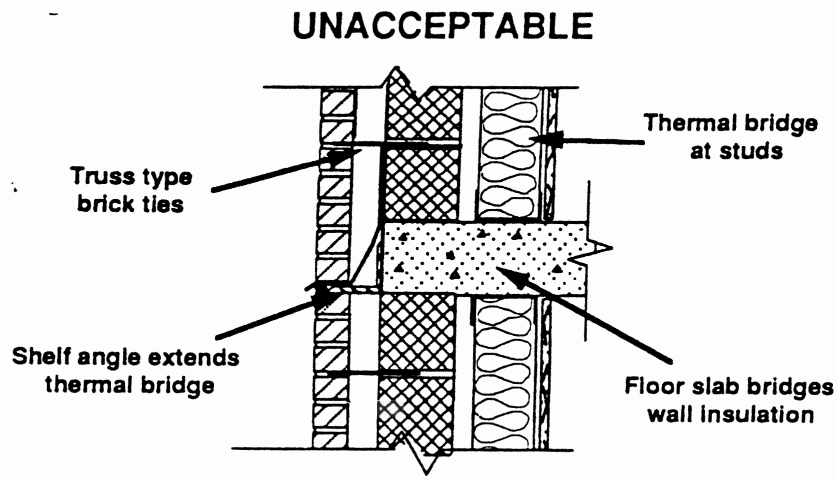

Figure 4.2.13 Wall/Floor Connection

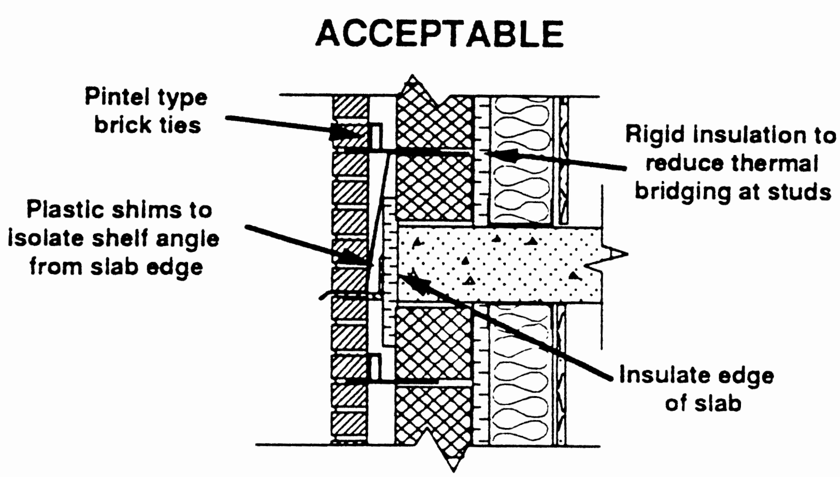

Figure 4.2.14 Wall/Floor Connection

A variety of thermally improved designs of floor/wall connections can be used to avoid the thermal bridging and the associated air leakage at this location. Additional alternatives are presented for concrete frame and steel frame buildings in Figures 4.2.15 and 4.2.16 respectively (Brand and Turenne). In both cases the insulation is positioned in the cavity to provide a continuous layer wall insulation with no thermal bridging by the floor slab. In addition, an air barrier is included in the wall to control air leakage. In the case of the concrete frame, the seal at the bottom of the floor slab and the masonry must be flexible to accommodate movement, and sufficient clearance must be provided at this location. In the steel frame case, the air barrier across the spandrel beam is supported by gypsum board on metal studs. The connection of the air barrier at the bottom of the beam must be flexible to accommodate movement., and sufficient space must be provided below the beam for deflection. The beam can also be set back from the backup wall, in which case the masonry is carried up to the floor slab. In this case the air barrier is installed similarly to the concrete frame case.

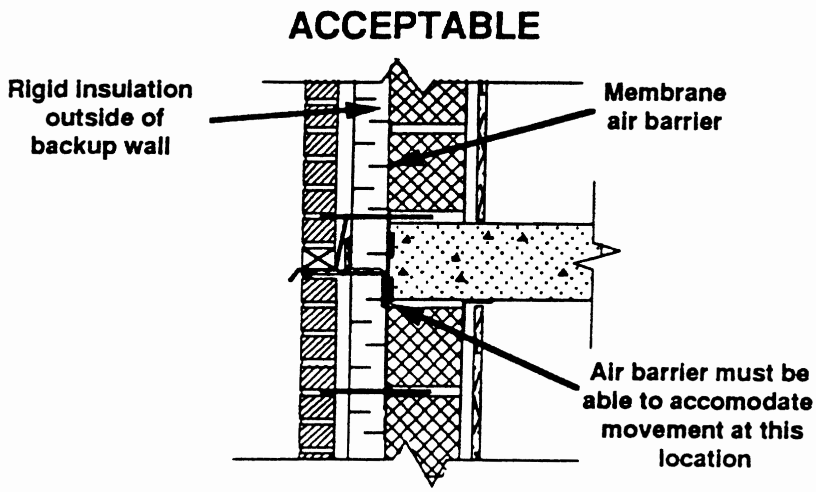

Figure 4.2.15 Wall/Floor Connection - Concrete Frame (Brand)

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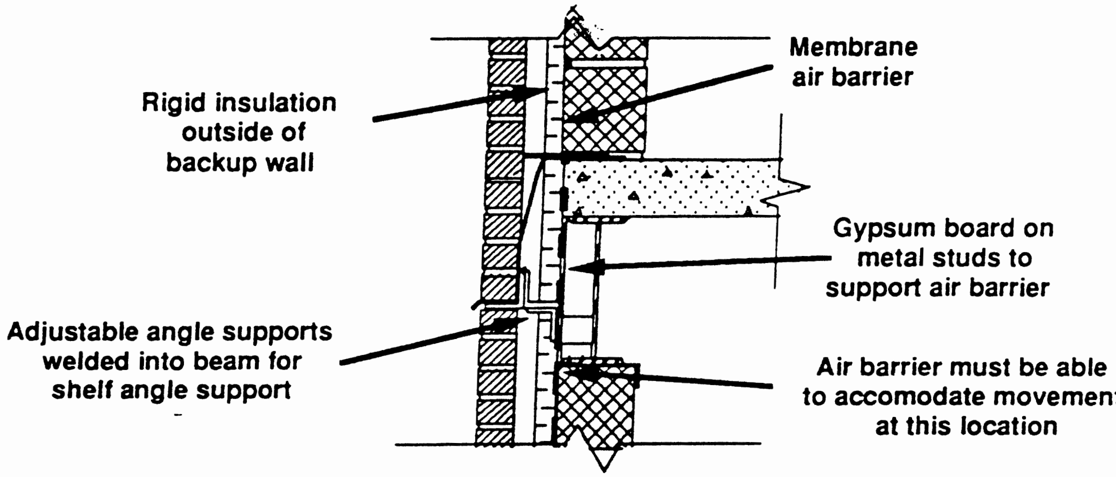

Figure 4.2.16 Wall/Floor Connection - Steel Frame (Brand)

The thermally defective design in Figure 4.2.11 pointed out the need to maintain continuity of the air barrier and insulation systems at window/wall intersections. Figure 4.2.17 shows an acceptable connection between the wall and the window head (Brand). The flashing above the windows is essential to control water leakage, and it must be straightforward to install to get good performance. The flashing is carried behind the insulation and sealed to the flexible membrane air barrier. In order to keep the frame close to the indoor temperature, it is positioned interior of the insulation. The wall air barrier is sealed to the window frame to maintain continuity. Compressible foam insulation is used to keep the air barrier warm between the wall insulation and the window frame.

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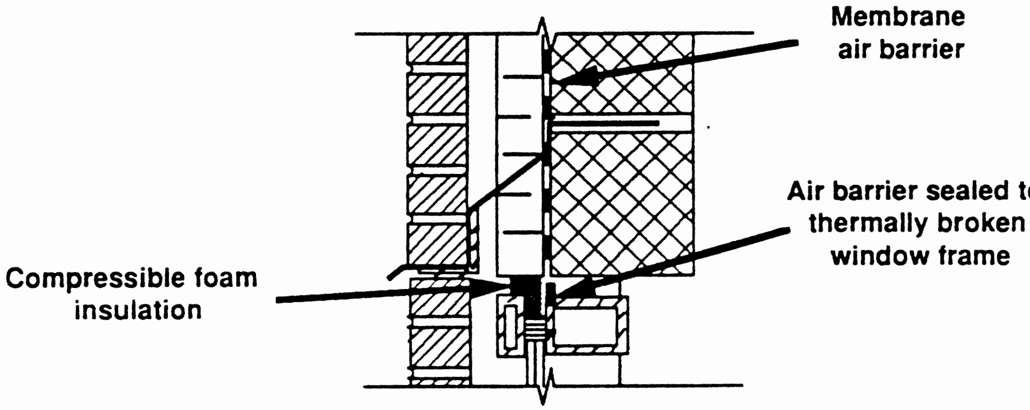

Figure 4.2.17 Wall/Window Head Connection (Brand)

Figure 4.2.18 shows a typical window jamb connection that suffers from thermal bridging and air leakage. This wall contains an insulated stud wall inside of the masonry backup and has no air barrier system. The cavity behind the veneer connects directly to the insulated stud space. Thermal bridging occurs at the studs, the "truss" type brick ties and the window frame. An improved design in shown in Figure 4.2.19. Rigid insulation is installed between the stud wall and the backup, and this insulation is carried to the window frame thermal break. Compressible gasketing is installed within the cavity to stop air movement from the cavity to the window frame. Also, "pintel" type brick ties are used to reduce thermal bridging across the cavity.

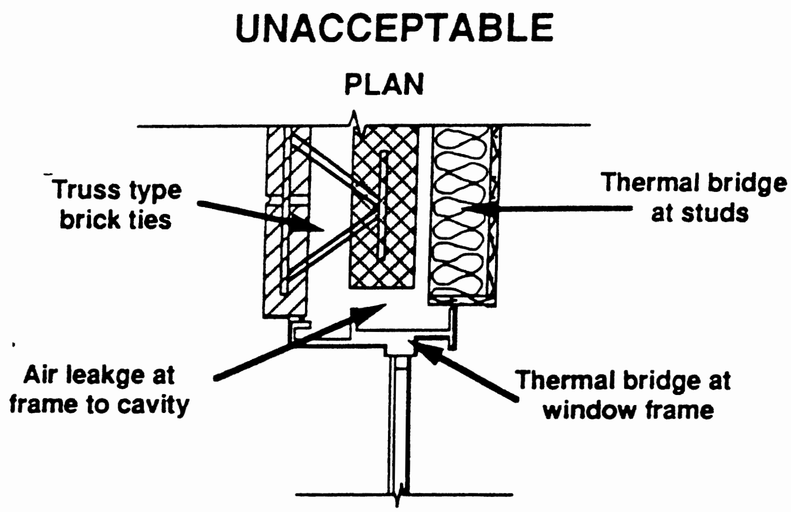

Figure 4.2.18 Wall/Window Jamb

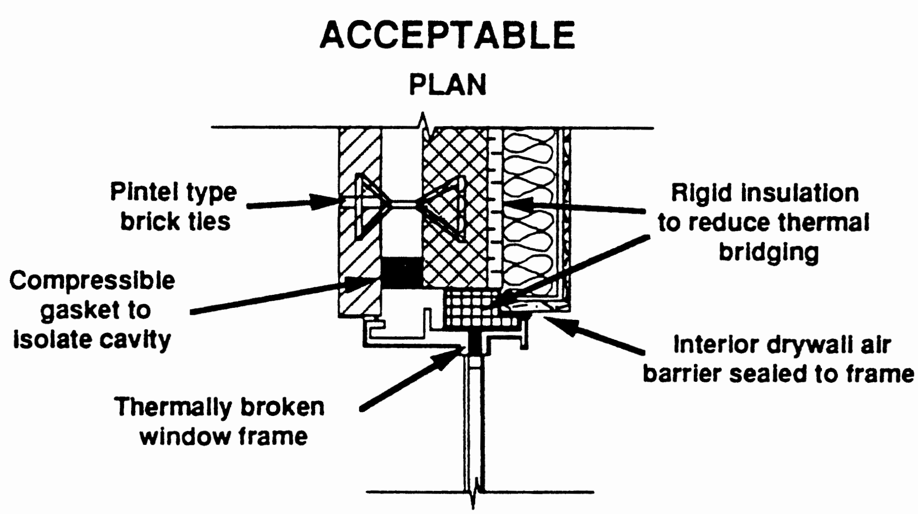

Figure 4.2.19 Wall/Window Jamb

Figure 4.2.20 shows another window jamb/wall connection (Brand and Turenne). In this detail the window thermal break is in line with the wall insulation. To maintain continuity of the insulation system, compressible foam insulation is applied behind the return bricks. This insulation also keeps the air barrier above the dewpoint temperature under heating conditions. This insulation must be held very close to the barrier to be effective.

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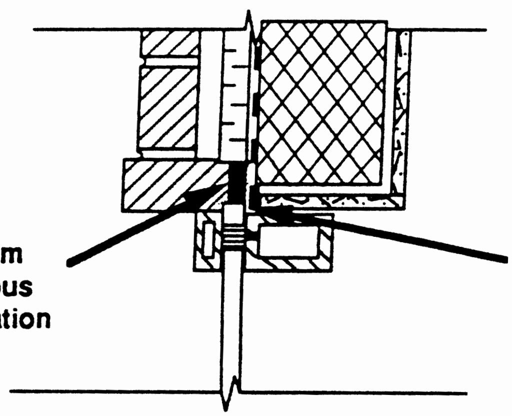

Figure 4.2.20 Wall / Window Jamb (Brand)

Many commercial buildings have fan coil units or convector cabinets installed wall-to-wall beneath the windows. In many designs these metal enclosures act as significant thermal bridges through the wall. While the concrete masonry behind the cabinet need not be finished, continuity of the air barrier and insulation systems must be maintained in these areas. In addition, it is important that the space behind the enclosure does not communicate with the room below through pipe chases and conduits. Such airflow paths increase stack pressures and compromise attempts for smoke control. Figure 4.2.21 shows a window sill with a convector cabinet. In this design thermal bridging occurs through the cabinet and the anchor clips. Air leakage occurs at gaps in the interior finish and continues into the cavity behind the brick veneer. Figure 4.2.22 shows a thermally improved design in which an air barrier is installed on the outer face of the backup wall and is sealed to the window frame by compressible foam. Rigid insulation is installed between the stud wall and the masonry backup. An improved arrangement is used to fix the cabinet in place, ending the direct metal connection from the interior to the outside.

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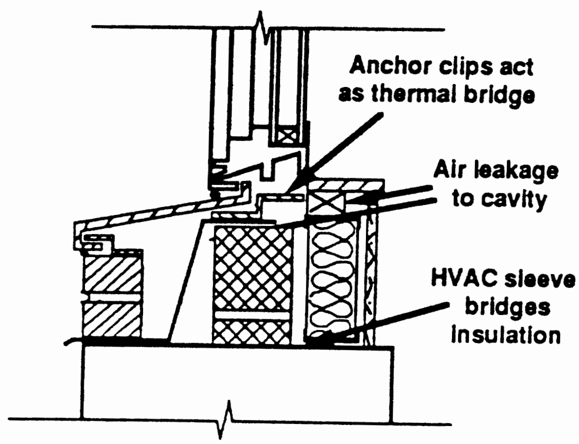

Figure 4.2.21 Wall/Window Sill Connection

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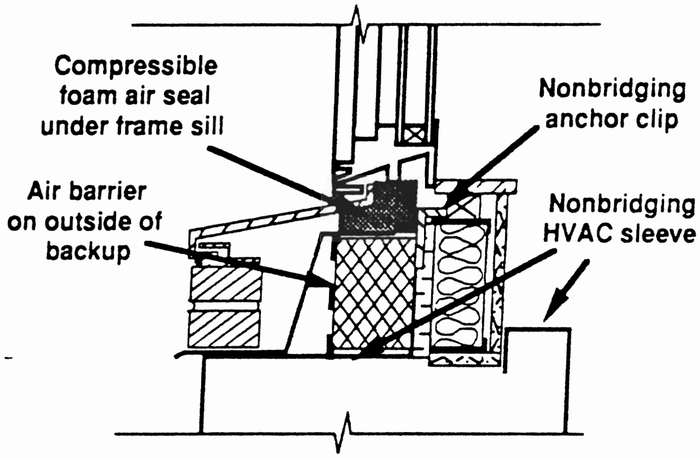

Figure 4.2.22 Wall/Window Sill Connection

Figure 4.2.23 shows the connection between the window sill and the wall (Brand). It is similar to the window head connection shown in Figure 4.2.17.

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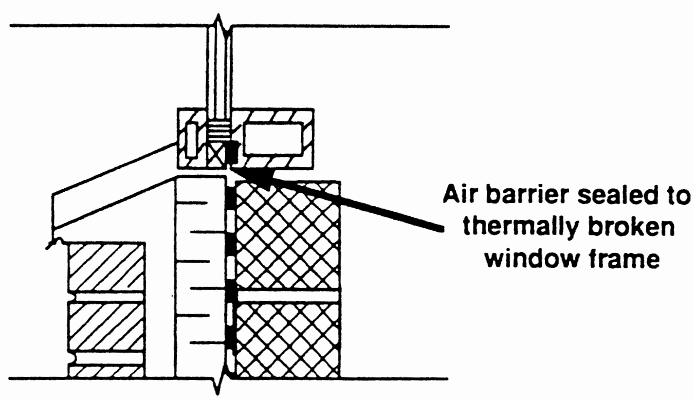

Figure 4.2.23 Wall / Window Sill (Brand)

Figures 4.2.24 and 4.2.25 show the intersection of a structural column with the wall construction for concrete and steel frame buildings respectively (Burn 1980). In both cases, the columns are in the plane of the backup wall. The air barrier must be flexible in order to accommodate differential movement between the column and the wall. A flexible membrane air barrier will perform well. In the case of the steel column, a piece of sheet steel bridges the outer flanges of the column, providing a structurally sound support for the air barrier. The columns can be set back from the backup wall, reducing floor space by a small amount. Setting back the column can simplify the design in the steel frame case, where the detail shown in Figure 4.2.25 requires an additional trade to install the sheet metal support for the air barrier.

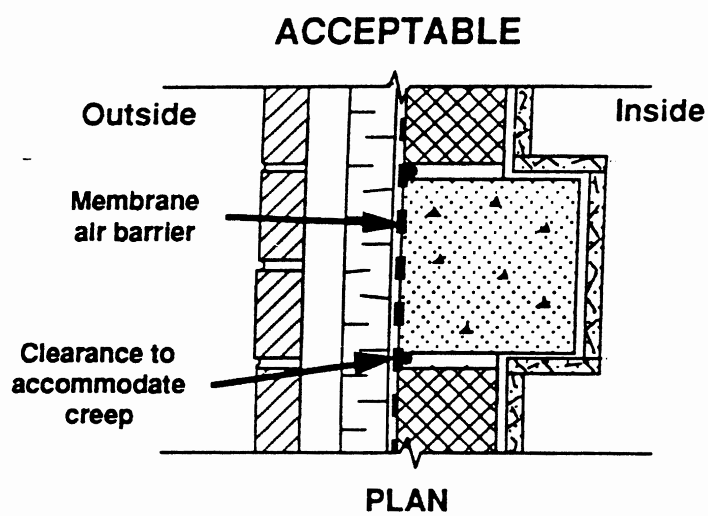

Figure 4.2.24 Wall/Column Connection - Concrete Frame (Burn 1980)

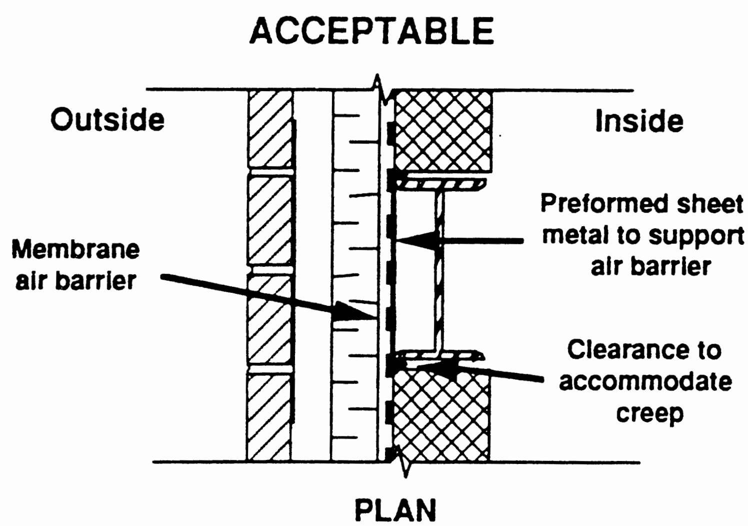

Figure 4.2.25 Wall/Column Connection - Steel Frame (Burn 1980)

The connection of a masonry wall and a concrete foundation is shown in Figure 4.2.26 (Brand). In this detail, the outer face of the backup wall and the outer face of the foundation wall are in the same plane and support the air barrier. The insulation below the termination of the brick veneer must be protected, for example with a cement coating.

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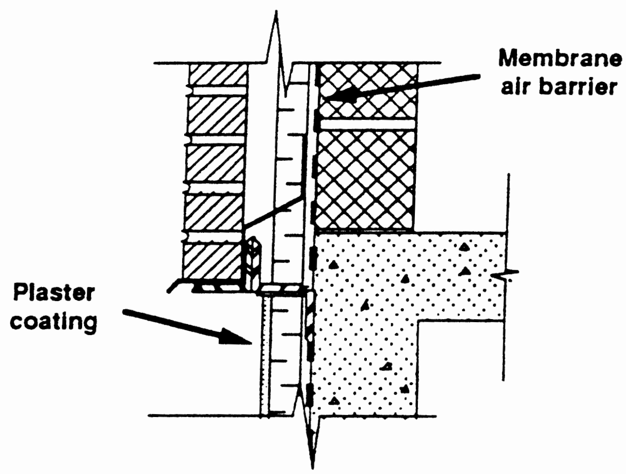

Figure 4.2.26 Wall / Foundation Connection (Brand)

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4.8 ROOFING SYSTEMS

The design and construction of roofing systems is discussed in the NRCA (National Roofing Contractors Association) Roofing and Waterproofing Manual. The NRCA manual contains a thorough treatment of roofing issues such as basic design options, membranes, insulation, sealants, flashing, drainage, and expansion joints This section concentrates on those issues that are crucial to the heat, air and moisture transfer performance of roofing systems through the maintenance of the continuity of the envelope insulation and air barrier systems.

Roofing System Design

Roofing system design issues related to thermal performance include the provision of thermal insulation, keeping rainwater out of the building, the prevention of condensation of water vapor within the roofing system and the maintenance of insulation and air barrier continuity at the roof edge and at roof penetrations. There are a wide variety of roofing systems and materials in use, and the NRCA Roofing and Waterproofing Manual is a good reference to roofing systems and their design. The manual discusses low-slope roofing systems with sections on decks, vapor retarders, insulation, membranes and specifications. There is also a section devoted to design details of flashings, joints, penetrations and drains for built-up and single-ply systems.

The basic roofing systems in commercial construction include so-called conventional systems in which the deck is covered with a vapor retarder, thermal insulation and a roofing membrane (either built-up or single-ply). This system has two disadvantages (Baker 1972). First, the membrane is fully exposed to the degrading effects of weather such as sunlight, temperature extremes and water. In addition, the insulation is contained between two membranes, the vapor retarder and the roofing membrane, which can act as a so-called "vapor trap" for interior moisture that penetrates the vapor retarder. Protected membrane systems, also referred to as inverted or upside-down roofs, offer some advantages by combining the vapor retarder and roofing membrane into a single layer with the insulation positioned outside of this membrane. Interior moisture that penetrates the membrane from inside can more easily evaporate, and the membrane material is protected from the elements. Of course the insulation must be durable given its exposure to weather. Also, the roof slope and drainage is more critical than in a conventional roof, and insulation attachment requires special consideration. Metal building systems, as well as other structures, employ standing seam metal roofs. These systems are discussed in the referenced article.

Single-ply roofing membranes, both in sheet form and liquid applied, have advantages in durability and installation (Brand, Laaly, and NRCA). A variety of single-ply materials and systems are available, but they do not have the history of performance of built-up membranes. Special attention is required in their attachment and in the sealing of lap joints, flashings and penetrations. Gish addresses sealant issues in single-ply roofing systems including lap joints, water stops, pitch pockets and night sealants.

Moisture Control

There are two prime moisture considerations in roofing system design, rain penetration and the condensation of water vapor within the roofing system (Handegord). Rain penetration is controlled by trying to keep water off the roofing membrane with adequate sloping and drainage in conjunction with carefully designed and installed flashing at roof edges and penetrations (Baker 1969, NRCA). Water vapor condensation within the roofing system is controlled by preventing water vapor from the building, or the outdoors in cooling situations, from entering the roof and reaching cold elements within the system. The control of water vapor transport must address both diffusion and air leakage. Diffusion can be controlled with a vapor retarder, but a vapor retarder is insufficient to control the greater amounts of water vapor that can be transported by air movement. As in the case with walls, the vapor retarder must be positioned in relation to the thermal insulation such that it is maintained at a temperature above the dewpoint of the moist air.

The decision on the necessity for a vapor retarder is the source of much discussion. The basic issue of concern is whether a sufficient quantity of water vapor will condense within the roofing system beyond the absorptive capacity of the materials and whether these materials will have an opportunity to dry out before any damage is done. An analysis of climate, conditions within the building and the thermal resistance and moisture absorptive properties of the roofing system elements is necessary to determine the need and appropriate position for a vapor retarder. Such an analysis of the need for a vapor retarder and its position within the roofing system should be conducted in all cases, following the examples contained in the NRCA manual. NRCA recommends that a vapor retarder be considered when the average January temperature is less than 5 °C (40 °F) and the interior relative humidity is at least 45% in the winter. While these general guidelines are useful, Tobiasson points out that these guidelines will result in the use of vapor retarders when they are not needed and their lack of specification when they should be used. He instead recommends the consideration of condensation potential during the entire winter and the drying potential during warm weather, and has developed a map of the U.S. that gives the relative humidity above which a vapor retarder should be specified. This map allows for corrections based on interior temperatures.

In order to control the great quantities of moisture transport due to air movement, a roofing system vapor retarder needs to be as airtight as the roofing membrane is watertight (Condren). As in the installation of an air barrier, extreme care must be taken to insure that the vapor retarder is fully continuous throughout the roofing system, including all seams, penetrations and roof edges. Condren stresses the need to maintain airtightness at all seals and terminations through the attention to detail during design and rigorous inspection during construction.

Regardless of how much care is taken in the design and construction of roofing systems, it is inevitable that some moisture will migrate into the roofing system from precipitation and condensation of water vapor. Some recommend the use of breather vents and air channels within the roofing system to remove such moisture (Condren). Others state that it is extremely difficult to ventilate a compact roof and that breather vents are apt to do more harm than good. Tobiasson holds the latter viewpoint and has done experimental work that shows it can take decades to dry out a compact roof with breather vents. He states further that he sees no evidence that unvented roofs perform any worse than vented roofs.

Roof/Wall Intersections

The intersection of the roof and the wall is a common site for discontinuities in the thermal insulation and air barrier systems. The key issue for controlling air leakage is sealing the wall air barrier to the roofing membrane, and doing so in a manner that will accommodate the differential movement that generally occurs at this junction. To control condensation at this junction, the vapor retarder needs to be kept warm by a continuous layer of thermal insulation. Continuity of the thermal insulation system also serves to control heat loss at this location. This section presents details of roof/wall intersections for various wall systems.

The first two examples, based on material in Riedel, are roof/wall intersections in masonry wall systems, although they relate to issues in other wall systems as well. These details concentrate on air sealing issues and do not include thermal insulation. The first example in Figure 4.8.1 shows a wall-roof connection consisting of metal edging extending from outside of the masonry wall over wood plates and attached to the roof membrane. Air leaks under the metal edging and between the wood plates, and can then flow under the roof membrane and into the roof insulation and the building interior. Riedel proposes a fix employing a vinyl membrane on the inside of the metal edging that is sealed to the roof membrane and the outside of the masonry wall. The sealant between the metal cap and the masonry wall must be able to accommodate differential movement at this location.

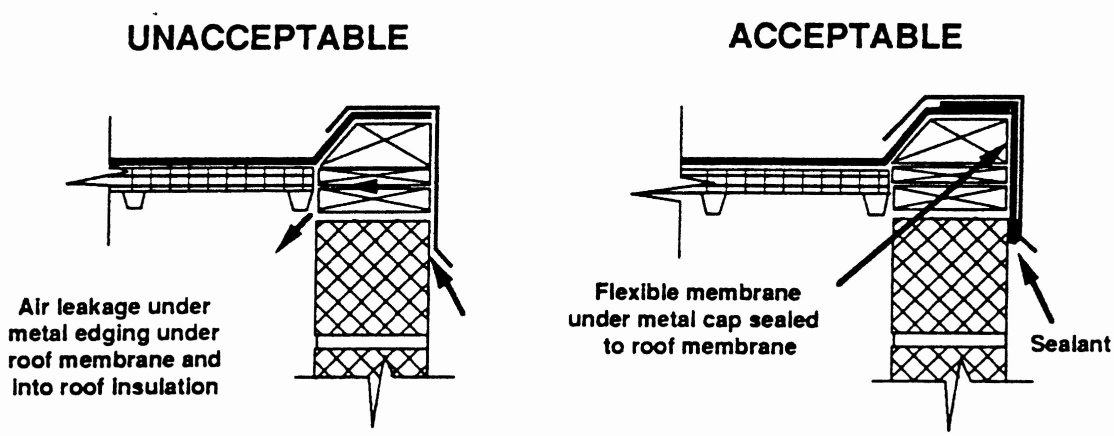

Figure 4.8.1 Air Leakage at Roof Edge (Riedel)

Air leakage at a steel roof deck with an overhang is shown in Figure 4.8.2. Air leaks into the overhang through the bottom and outer edges. This air then passes over the top of the outside wall and into the roof insulation. Air is also able to move past the building wall above the deck since the deck flutes may at best be only loosely stuffed with glass fiber insulation, not an adequate air seal. The suggested fix is to provide seals where the roof deck passes over the top of the outside wall, in this case foam insulation. This foam insulation seal should be in the same plane as the wall insulation. The top of the deck ribs should also be filled or sheathed to provide a flush surface for cementing the roof insulation.

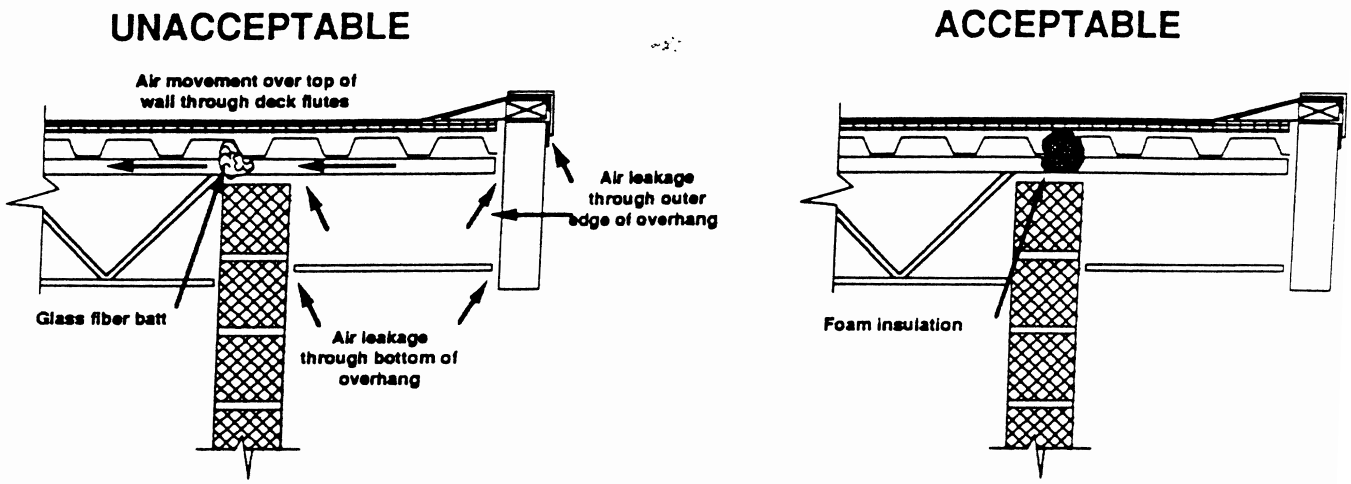

Figure 4.8.2 Air Leakage at Roof Overhang (Riedel)

The intersection between flat roofs and setback walls, for example at rooftop penthouses, is another location requiring careful detailing to maintain continuity. Figure 4.8.3 shows this intersection for a concrete frame building (Brand). In this detail, the setback wall air barrier is sealed to the roof membrane. There is no differential movement between the setback wall and the roof deck, simplifying the attachment of the air barrier and roof membrane. In a heating climate, it is very important that the air barrier insulation is completely continuous. The wall insulation below the termination of the brick must be covered to protect it from ultraviolet degradation.

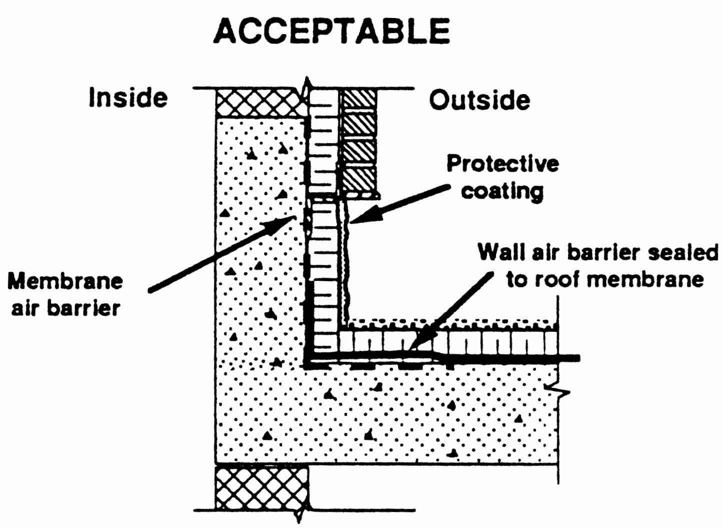

Figure 4.8.3 Masonry Setback Wall/Roof Connection - Concrete Frame (Brand)

A masonry setback wall/roof intersection in a steel frame building is shown in Figure 4.8.4 (Turenne). The roof membrane, located under the roof insulation, is sealed to the wall air barrier. A loop in the membrane is provided at the roof wall gap to accommodate differential movement between the roof and the wall.

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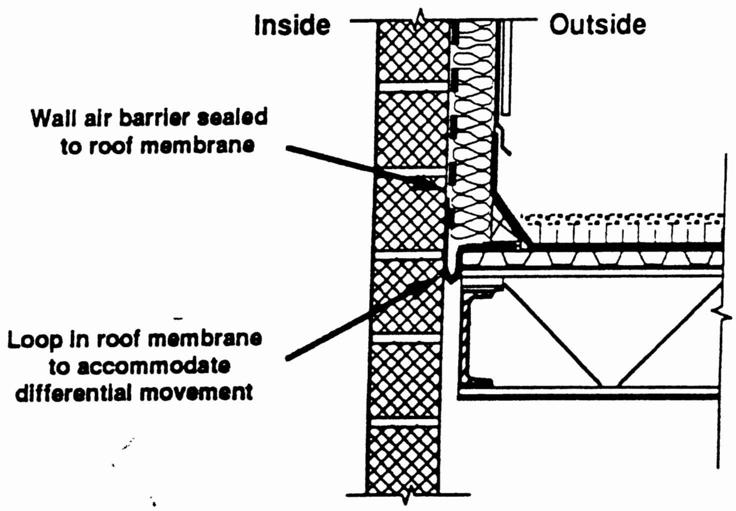

Figure 4.8.4 Masonry Setback Wall/Roof Connection - Steel Frame (Turenne)

Figures 4.8.5 (Burn) and 4.8.6 (Turenne) show intersections between masonry walls and flat roof edges in steel frame buildings. In the first case, Figure 4.8.5, the steel beam is in the plane of the masonry backup. A gap is provided between the top of the backup and the spandrel beam so that the beam can deflect freely without transferring any loads to the wall. The steel beam is faced with drywall, and a continuous strip of a flexible membrane is installed along the edge of the deck, sealing the drywall to the roof vapor retarder. Another strip of membrane is installed over the drywall and seals the gap at the top of the backup wall.

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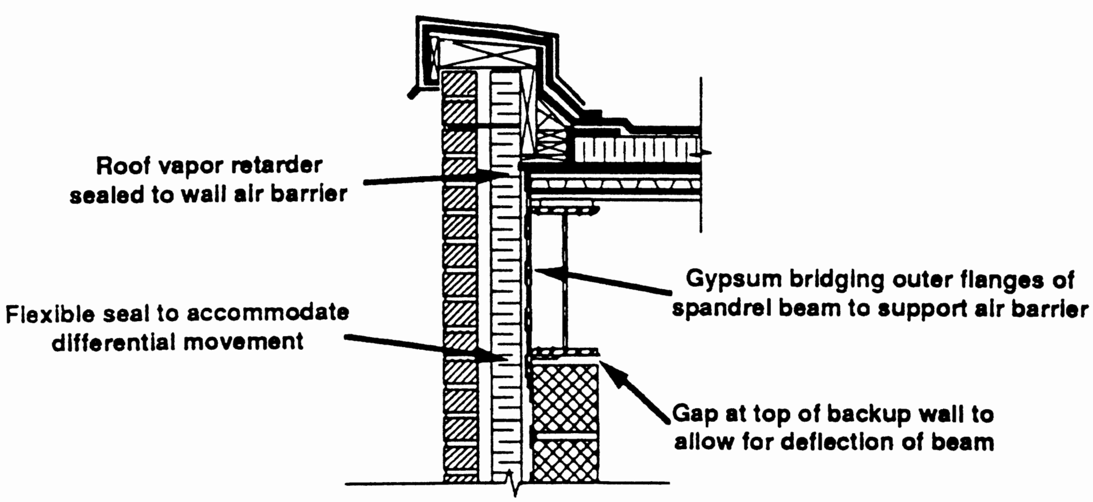

Figure 4.8.5 Masonry Wall/Roof Edge - Steel Frame (Burn)

in Figure 4.8.6 the steel frame is located inside of the masonry wall, again enabling the beam to deflect freely. The roof vapor retarder is sealed to the wall air barrier by a flexible membrane that is supported by a sheet metal closure supplied and installed by the steel deck contractor.

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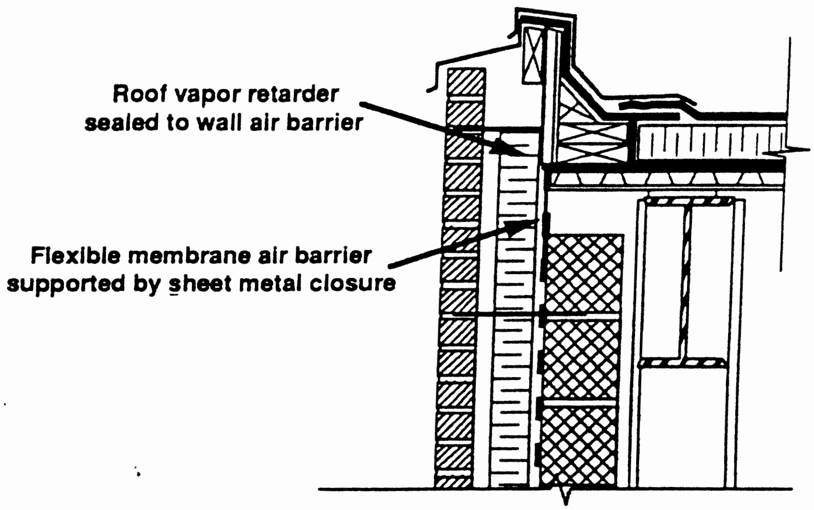

Figure 4.8.6 Masonry Wall/Roof Edge - Steel Frame (Turenne)

Figure 4.8.7 shows the intersection between a masonry wall and a roof edge for a concrete frame building. As in the steel frame case, a gap is provided at the top of the backup wall and a flexible membrane is used to seal this gap.

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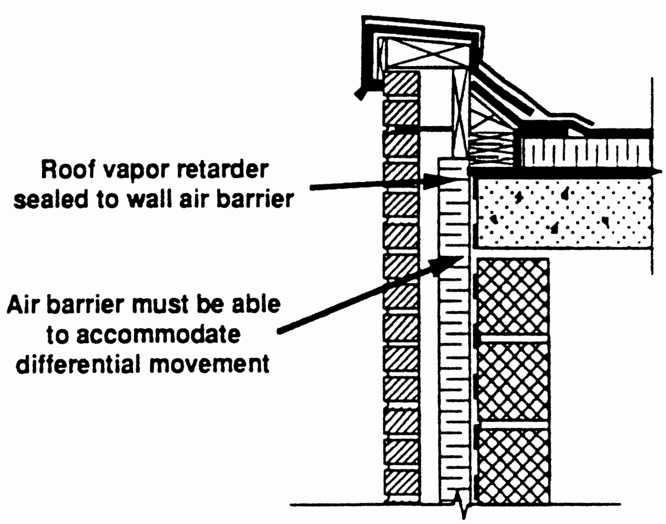

Figure 4.8.7 Masonry Wall/Roof Edge - Concrete Frame (Burn)

The details in Figures 4.8.5 through 4.8.7 still contain discontinuities in the thermal insulation system between the roof and wall insulation. Brand proposes the use of an insulated curb assembly at this location to solve this problem, as shown in Figure 4.8.8 for a steel frame building. The use of such a curb assembly is somewhat unusual, but it does have advantages. The insulation keeps the air barrier beneath it warm. Also, the assembly allows the roofing and flashing to be completed before the walls are erected.

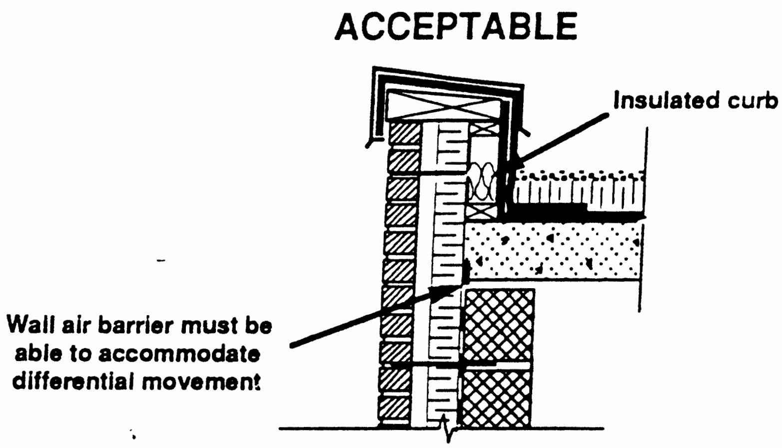

Figure 4.8.8 Masonry Wall/Roof Edge - Concrete Frame (Brand)

Figure 4.8.9 shows a wall/roof intersection for a metal stud wall (Quirouette). The exterior gypsum serves as the air barrier, running past the spandrel beam. Flexible membranes are used to seal the air barrier at the top of the stud wall. The wall air barrier is sealed to the roof membrane to prevent air leakage Shortened studs are used to allow deflection of the spandrel beam.

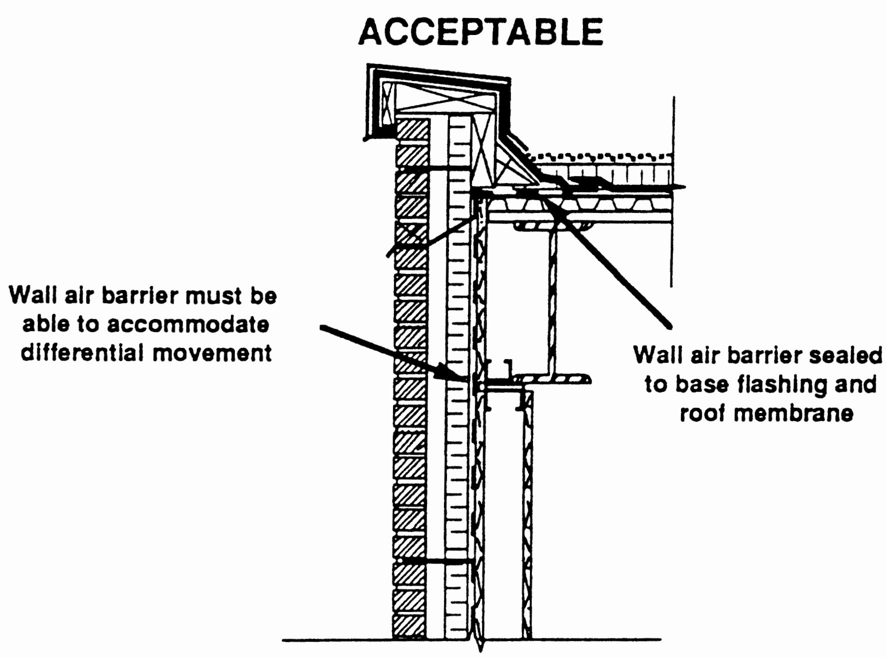

Figure 4.8.9 Metal Stud Wall/Roof Connection (Quirouette)

Similar details to those shown above can be developed for other wall systems. Examples of many such details are given in Brand.

Roof Penetrations

The continuity of the roof vapor retarder, thermal insulation and roofing membrane are inevitably violated by various penetration including equipment supports and drains. These penetrations can be the sites of both air and water leakage leading to a variety of problems, including thermal bridging, air leakage, condensation, and wetted insulation. Penetrations must be carefully designed and constructed with proper flashing, seals and thermal insulation. Flashing and sealant details for a variety of penetrations are contained in the NRCA manual. The examples below address primarily the continuity of the thermal insulation system.

The ORNL catalog of thermal bridges identified three common penetration designs that lead to thermal bridging and contains improved alternate design details (Steven Winter Associates). The first thermal bridge is at the penetration of the roof by a steel railing, which interrupts the thermal insulation, leading to increased heat loss and the potential for condensation. The alternate design substitutes glass fiber for steel in the railing and its connections to the deck.

Figure 4.8.10 shows a thermally bridging equipment support consisting of a column that extends through the insulated roof deck. In the alternative design, insulation is attached to the outside of the columns to reduce the heat transfer and decrease the condensation potential.

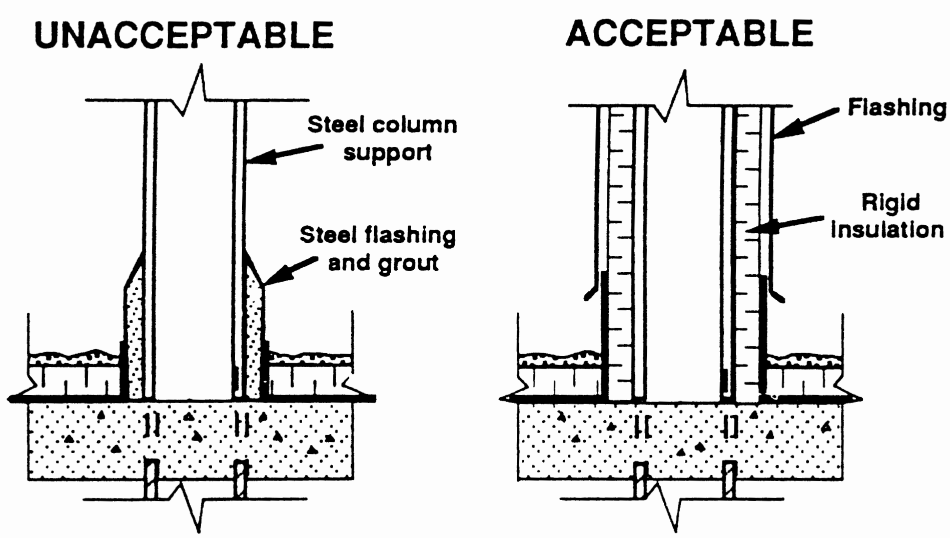

Figure 4.8.10 Heavy Structural Support (Steven Winter Associates)

A thermally bridging support for light equipment is shown in Figure 4.8.11. In the base case a steel support plate is mounted on a steel pipe, acting as a thermal bridge and increasing the condensation potential. In the alternative design, the outside of the pipe is insulated to reduce the heat transfer.

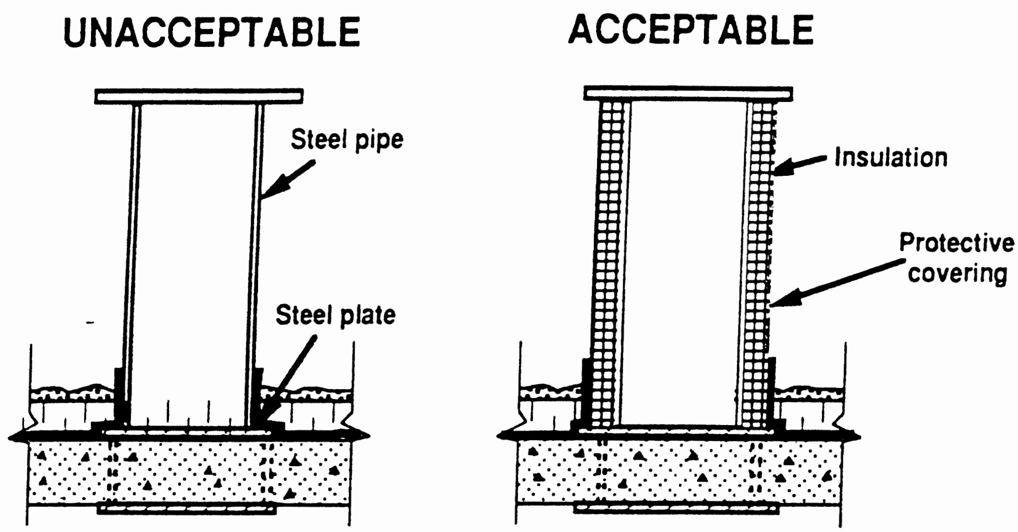

Figure 4.8.11 Light Structural Support (Steven Winter Associates)

Figure 4.8.12 shows a roof drain with a severe insulation discontinuity, along with a thermally improved alternative. In the base detail, the insulation stops far short of the drain and the space around the hub of the drain is open. The alternate detail includes a thermal break between the clamp and the slab, and the air space around the hub is filled with insulation.

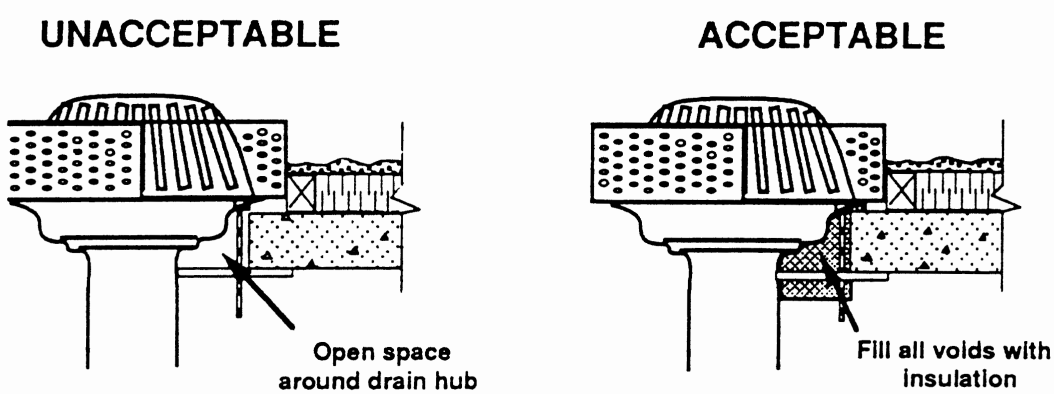

Figure 4.8.12 Roof Drain

The last penetration thermal bridge, shown in Figure 4.8.13, is at a roof expansion joint. In the base case the concrete block curbs on either side of the joint are uninsulated, resulting in thermal bridging. This is also a common situation in parapets, mechanical equipment curbs and various other roof penetrations. In the alternate detail, insulation is installed completely around the curbs, eliminating the thermal bridging except at the required fasteners.

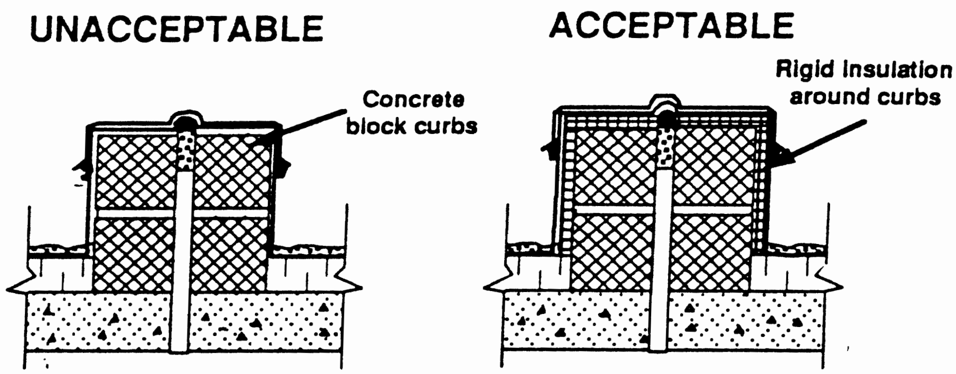

Figure 4.8.13 Roof Expansion Joint

Design and Construction Issues

The design and construction of a roofing system with good thermal performance and good air and water tightness requires the careful development of details and specifications at all penetrations. As the construction proceeds, all work needs to be carefully inspected. Special care must be exercised to protect work at the end of the day to prevent moisture intrusion into roofing materials. To that end, these same materials must be protected and kept dry prior to installation to keep water out of the roofing system at the construction stage. As good as the design and construction might be, a good roofing inspection and maintenance program should be established to identify and repair any problems that develop over the life of the roofing system.

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SECTION 4

HVAC DESIGN GUIDELINES

Section 4

HVAC Design Guidelines

Introduction

This section discusses the issues concerning the design of the HVAC system. This includes system sizing, types of air handlers, outdoor air pre-treatment/heat recovery devices, filters, dampers, damper actuators, fans, motors, ductwork, terminal devices, piping, pumps, insulation, valves, valve actuators, chillers, boilers, condensers, water treatment and HVAC control interfaces. Specific central plant issues are discussed in Section 9, Miscellaneous Design Issues.

HVAC System Overview

The College has standardized on low temperature Variable Air Volume(VAV) air handling systems with low noise series fan powered VAV terminal devices with hydronic reheats. A natural gas outdoor air desiccant pre-treatment unit with enthalpy wheel heat recovery unit will be used to remove moisture and latent load from the outdoor air stream and recover heat from the building's exhaust air stream. Low temperature chilled water(38F-40F) and low temperature(200F) hot water is supplied from a central plant, located in a remote building. In the case of the Health Sciences building, a portion of the central plant capacity will be installed in a mechanical room in the building and eventually act as a satellite plant to the larger plant intended to be installed in the new Student Services building on the campus. A four-pipe distribution system will be used to distribute chilled and hot water. Pumps and fans with variable loads will be driven with Variable Frequency Drives and use premium efficiency motors.

Building Loads & HVAC System Sizing

The College's building loads can vary considerably on both a daily and seasonal basis and the HVAC System must be sized to accommodate this fluctuation. It has been the College's experience that low occupancies during the Summer months, combined with HVAC systems sized for "worst case" design conditions contribute to occupant discomfort and Indoor Air Quality(IAQ) problems.

In order to ensure that the HVAC units are sized properly the College requests that the designer use moderate design conditions listed on Page 2, Attachment 4-1, EDG, HVAC Guidelines and actual lighting loads to calculate the design loads and energy analysis loads in DOE-2, size the equipment based upon a reasonable diversity and install outdoor air pre-treatment systems with heat recovery to minimize latent summer loads. Ventilation/IAQ are discussed in Section 6. The development of these loads and sizing shall be reported and tabulated in the Schematic Design and Design Development Energy

Analysis. Compliance with the specified equipment load shall be verified during the Construction Submittal process.

Based upon the more moderate "diversified" load sizing the designer shall further ensure that energy consumption is minimized in the distribution of the conditioned air by complying with the Baseline HVAC Air System Requirements Table, after Page 4, Attachment 4-1, EDG HVAC Guidelines.

The systems shall be appropriately zoned to optimize equipment operation, for load diversity and occupancy. The designer shall optimize the use of secondary air streams for conditioning and ventilating those areas such as restrooms, lobbies and hallways. Coordination with Section 3, Architectural Elements is required.

HVAC System Details

1. Roof Top AHU - The designer shall provide premium quality, penthouse style, roof top air handling units(RTU), mounted on a vibration isolated support structure. A list of acceptable manufacturer, makes and models will be provide by the College and the designer shall specify only those listed. The RTU shall have the following features:

    a. Cabinet - The cabinet shall be of space frame design and house the entire assembly of fan, motor, coils, plenums, VFDs, piping, maintenance hallways and ductwork. Exterior panels shall rigid double wall construction, tightly sealed, highly insulated and coated with a durable finish. Exterior access door shall have camlock style, heavy duty door latches and be tightly sealed. An interior maintenance hallway shall be provided for access to piping, VFDs and the airside, all interior surfaces shall be galvanized. Panels separating the maintenance hallway from the airside shall be galvanized, rigid double wall construction, tightly sealed and highly insulated. Access to the airside shall be from the maintenance hallway through tightly sealed, highly insulated, full size access doors with heavy duty camlock style latches. Fluorescent lighting with bulb shields shall be provided in all hallways and airside chambers. Maintenance receptacles shall be provided.

    b. Fan, VFD & Motor - There will be two fans, a supply air fan and a return air fan in the exhaust position. The fans shall high efficiency for the application and chosen to meet the optimum operating condition. Fan motors shall be controlled with low loss Variable Frequency Drives(VFD) integrated to the BAC via a Native BACnet interface. Motors shall be sized to meet the optimum loads, not oversized, and be premium efficiency and VFD duty. The designer shall evaluate the EDG requirement for blow through configuration. The designer shall specify these requirements in the specification and drawings and require Construction Submittal approval.

c. Filters, Filter Module, Coils & Drain Pans - Final filters shall be high efficiency Farr Rigiflo style bag filters with pleated media Farr 30/30 pre-filters, mounted securely in a Farr filter module rack. Two Magnahelic style differential pressure gages shall be provided to monitor pre-filter and final filter status. Coils shall be copper with alluminum fins configured to provide adequate pipe, valve and fitting access. Drain pans shall be stainless steel, insulated to prevent condensation and sloped to provide positive drainage. Provide a properly supported copper condensate drain to the nearest roof drain. The condensate pipe shall have a p-trap properly sized to provide a seal against the RTU static pressure and designed with a clean-out. Overall filter and coil face velocities shall be designed to be 300 fpm or less.

d. Dampers - The unit shall have high quality, low leakage, rigid frame dampers with pneumatic actuators. Gravity dampers are not allowed. The dampers shall have stainless steel perimeter seals and either stainless or vinyl blade lip seals. For more accurate control of outdoor air provide a minimum air damper and a separate maximum air damper. Dampers communicating with the outdoors shall have rain hoods or low pressure drop louvers and bird screens.

2. Ductwork - Ductwork shall be designed to minimize pressure drop and noise. Comply with Ductwork, Baseline HVAC Air System Requirements, Appendix 4-1, EDG HVAC Design Guidelines. The exception to this is that the designer shall provide "stealth" series fan powered VAV boxes with electronic fan speed controls. Ductwork shall be appropriately insulated for the low temperature air distribution. Insulation shall be specified with heavy duty vapor barrier with joints sealed with tape overlaid with a coating of Fosters Sealant.

3. Outdoor Air Energy Control - Comply with both items 1& 2, Outdoor Air Energy Control, Baseline HVAC Air System Requirements, Appendix 4-1, EDG HVAC Design Guidelines. An ATS, Desiccant/Enthalpy outdoor air pre-treatment system shall be specified with waste heat stream and natural gas desiccant regeneration system. The College shall assist the designer in configuring this system.

4. Exhaust Air Systems - Exhaust air streams shall be gathered and directed to the appropriate outdoor air pre-treatment/heat recovery unit. Exhaust air fans shall be designed for the optimal efficiency point, with premium efficiency motors and be interlocked with its respective RTU. All exhaust fans shall have tightly fitting dampers, pneumatically actuated, and interlocked with the fan.

4. Complete Air System - Comply with Complete Air System, Baseline HVAC Air System Requirements, Appendix 4-1, EDG HVAC Design Guidelines. Design for low temperature(40F) air distribution.

5. Piping, Pumps, Valves, Accessories & Insulation

a. Piping - the piping system shall be configured as a four pipe system with primary, secondary, tertiary loops and designed to minimize energy consumption. Tertiary pumping shall be controlled 2-way valves and VFDs. The College will provide details of their standard central plant piping distribution system. Details of this can be found in Section 9, Miscellaneous Design Issues. Piping for primary pressure systems shall be welded schedule 40 or sweat fit copper. Piping with mechanical gland seals shall be specifically excluded in the HVAC system. Central plant underground piping is discussed in Section 9, Miscellaneous Design Issues.

b. Pipe System Sizing - The designer shall design the piping system to meet the required flow rates and minimize horsepower requirements by optimizing the pipe size. Pumps shall be selected for optimum operation.

c. Pumps - Bell & Gossett base mounted end suction centrifugal pumps optimally sized for the application. Vendor to submit VFD pump performance curves. Fractional HP pumps may be in-line. Pumps should have matched end suction diffuser/strainers and matching triple duty check/shutoff/balancing valves on the discharge. High performance pressure gages shall be supplied and shall be installed according to the College's standard detail. Pumps shall be vibration isolated and mounted on housekeeping pads with bases grouted. Chilled water pumps shall be insulated with insulated sheet metal boxes, fabricated in a split configuration fastened with clips to be easily removed for service.

d. Pump Motors - shall not be oversized, be speed controlled by VFDs, be VFD duty and premium efficiency.

e. Pump VFD - Shall be high efficiency, noise filtered and be capable of Native BACnet communications with the BAC.

f. Valves - Valves shall be DeZurik pneumatic actuated as necessary, full lug, ANSI flange, butterflies for pipe 2" and larger. For 2" and smaller 2-way control bronze body, pneumatic globe valves. Isolation valves 2" and smaller shall be full port ball valves.

g. Accessories - Accessories such as in-line strainers, high point vent, low point drains, and domestic water make-up shall be included.

h. Insulation - All piping and pumping components shall be insulated. Piping insulation shall be optimized for the intended service and shall be formed fiberglass with integral vapor barrier and formed vinyl covers on fittings. All interior insulated piping shall be covered with a continuous(including fittings) canvas jacket lagged with two coats of thinned Foster's sealant and painted with two coats of paint. All exterior piping will be insulated and covered with a continuous aluminum jacket sealed with silicon.

6. Chillers - Chillers shall be Frick Open Drive Rotary Screw machines using Ammonia (R-717) as the refrigerant. The chiller shall use a plate and frame heat exchanger for its evaporator and reject heat to the atmosphere using an evaporative condenser. The College will assist the designer in establishing the details.
7. Condenser - The chiller shall use an evaporative condenser.
8. Boilers - Shall be Hydrotherm M-300 Pulse Combustion Boilers as indicated in Attachment 4-1, EDG HVAC Design Guidelines.
9. Refrigerant - Refrigerant shall be Ammonia (R-717)

Attachment 4-1, EDG Chapter 4, HVAC Design Guidelines

HVAC Design Guidelines

Contents

HVAC Design Quality Control Sheet

The design team shall review all requirements at the start of each phase. Before submitting the schematic design for review, the appropriate team member shall verify each point below to ensure completeness and correct procedure.

PreDesign

Phase	*Design Element*	*Synopsis*	*Method*	*Section*
PD	*Coordination*	***ENERGY Analyst** must meet with **DESIGN TEAM** for lighting, electrical, HVAC and architecture to review responsibilities by phase listed here.*	*Pre-Design Energy Meeting*	*Design Contract*
PD	*System Selection*	*Select minimum of 3 systems for schematic Life-Cycle-Cost analysis.*	*Use Technology Application Matrix*	*Guidelines Overview*

Schematic Design

Phase	*Design Element*	*Synopsis*	*Method*	*Section*
SD	*Preliminary Loads Calculation*	*Calculate block loads for preliminary equipment sizing and influence building orientation, glass area and overhangs.* *Produce the input and output reports specified in Schematic Energy Report format Section 5.*	*Hourly analysis program using prescriptive data on thermal envelope and lighting wattage budget.*	*Design Conditions* *HVAC Systems Criteria*
SD	*Coordination with Lighting and Electrical Design*	***HVAC Designer** must enter the lighting wattage budget (65% of ASHRAE max.) as the lighting power density for cooling load calculations.* ***ELECTRICAL Designer** must size electrical distribution based on the lighting wattage budget (65% of ASHRAE) and the HVAC power demand calculated by the HVAC designer. **Do not use rules of thumb for these quantities.*** ***ENERGY Analyst** must make sure the information is transmitted and used.*	*W/ft^2 entry into Carrier HAP or DOE2 block load*	*Lighting Guidelines A-3 & B-2*
SD	*Equipment Efficiency*	*Equipment efficiencies for heating and cooling equipment must meet minimum levels set by Energy Design Guidelines.*	*Find minimum efficiency required for each type of equipment*	*Equipment Efficiency Standards - Table 1*

HVAC Design Quality Control Sheet

The design team shall review all requirements at the start of each phase. Before submitting design development for review, the appropriate team member shall verify each point below to ensure completeness and correct procedure.

Design Development

Phase	Design Element	Synopsis	Method	Section
DD	HVAC System Standards	Design must now show compliance with requirements for sizing, zoning, controlling and insulating HVAC system.	ASHRAE 90.1-1989 Section 9	HVAC Systems Criteria
DD	Specifications	Provide draft specifications for each major mechanical item to meet all guidelines or required equipment types.		Equipment Efficiency Boilers Cooling Towers
DD	Efficiency Compliance	Demonstrate that actual equipment efficiencies exceed the minimums set at Schematic Design. List actual and minimums in Design Development Energy Report.	Compare actual equipment to minimum efficiencies	Energy Efficiency Standards
DD	Coordination	**HVAC Designer** must use actual lighting wattage for final cooling loads.	Enter actual W/ft2 room by room	Lighting Guidelines A-3
DD	Commissioning and Maintenance Training	Commissioning and CQC to be included in specifications if Owner has decided to use them on this project. Maintenance training is normally part of Commissioning but will be provided separately if formal Commissioning is not included on project.	Edit standard CQC and Commissioning specifications provided on diskette.	01440 - CQC 15995 - Mechanical 16995 - Electrical
DD	Refrigerant Selection	Use of R-11 and R-12 no longer permissable. Alternative refrigerants must be used due to ozone depletion and clean air act.	Consult Owner's Engineer for refrigerant to specify by equipment type	Refrigerant Types

Table 1 - Minimum Performance of Heating and Cooling Equipment.

Cooling Equipment Type	Condensing Method	Cooliing Capacity (Btu/hr)	Size (Tons)	Minimum Cooling Efficiency	Minimum Heating Efficiency
Air-Conditioners Heat Pumps Split-Systems	Air-cooled	< 65,000	0 to 5 tons	11.0 EER 12.5 SEER	2.2 COP
		> 65,000	> 5 tons	9.5 EER	2.2 COP
Hydronic Heat Pumps	Water-Source	All capacities	All sizes	11.5 EER	4.0 COP
Chillers	Air-Cooled		< 150 tons	< 1.25 kW/ton	
	Water-Cooled		> 150 tons	< 0.63 kW/ton	

Heating Equipment Type	Fuel	Heating Capacity (Btu/hr)	Minimum Thermal Efficiency	Minimum Annual Efficiency
Boilers	Gas	< 300,000		90 % A.F.U.E.
Boilers	Gas	> 300,000	0.88	
Furnaces	Gas	< 300,000		90 % A.F.U.E.
Service Water Heating	Gas	All	0.90	

HVAC Systems

HVAC Plant and Systems Types

Selection of the HVAC system and plant shall be by life-cycle-cost analysis at the schematic design phase.

Three permissable system types to be analyzed are shown for each size of building in the Technology Application Matrix in the Overview chapter, and on the back cover the *Energy Design Guidelines.* These selections may be modified with concurrence of the Owner in the Program of Requirements for the building or at the PreDesign meeting.

The following clarifications apply:

- Rooftop equipment is not permitted due to extreme temperatures encountered on the roof that reduce efficiency and equipment life, poor accessibility to maintenance, noise and vibration transmitted inside the building, and roof leaks due to punctures and foot traffic.
- All variable-air-volume air-handlers will be operated by Variable Frequency Drives to vary fan speed.
- Chilled water systems shall be designed to be drained for winter freeze protection. Glycol shall not be used as the means of freeze protection due to energy penalties in pumping and chiller efficiency and higher costs for larger coils, pumps and piping.
- Electric Resistance Heating is not permitted.

Equipment efficiencies must appear on drawings and specifications

Equipment Efficiency Standards

Equipment efficiency shall comply with the attached Table 1. The Energy Reports must show the minimum and actual equipment efficiencies for each item of HVAC equipment to be used.

Construction drawings and specifications must explicitly require the efficiency levels of the selected equipment.

Design Conditions

General design temperatures shall be as follows:

- Indoor Cooling: 78 F
  Indoor Heating: 70 F

- Outdoor Summer: 1% (1997 ASHRAE)
  Outdoor Winter: 99% (1997 ASHRAE)

Any exceptions to the above conditions must be justified by ASHRAE Standard 55 analysis and receive the Owner's approval at the PreDesign phase of the project. Winter humidification and summer dehumidification are not required.

Compliance with specific HVAC system standards must be documented in the Design Development Energy Report.

HVAC Systems Criteria

Design of the HVAC system shall follow ASHRAE Standard 90.1 section 9 in full. Document specific compliance on the following items:

1. Load calculations and safety factors (section 9.4.1). In the Design Development Energy Report, provide a table listing the calculated loads, allowed safety and pick-up factors applied, and capacity of the proposed equipment for heating and cooling.

2. Off-hour controls (section 9.4.4) and isolation zoning and damper controls for meeting rooms, auditoriums, gymnasiums, etc.

3. Duct and pipe insulation (section 9.4.8). In the Design Development Energy Report state the required insulation levels for pipes and ducts and indicate the page number where these levels are stated in the project specifications.

4. Zone Controls (section 9.5.2) - minimization of reheating in VAV systems.

5. Economizer controls (section 9.5.3) - Use differential sensible temperature type economizer controls integrated with mechanical cooling. Note exception: Do not use economizer controls on systems less than 7 1/2 tons (90,000 Btu/hr) of cooling capacity.

6. All Variable-Air-Volume air-handlers shall have variable speeds drives to control fan capacity. Inlet guide vanes shall not be used on any air handler.

Commissioning and Maintenance Training

All new buildings, and all major renovations, shall have a comprehensive commissioning specification, detailing performance testing of all building mechanical systems by the contractor and commissioning team over the first year of operation. The designer shall adapt the Owner's standard Commissioning specification to his design and coordinate it in all respects with the complete drawings and specifications for the project. Standard commissioning specifications are contained in files 15995 and 16995 on the "Required Specifications" diskette.

All buildings shall have a specification for Maintenance training and Operation and Maintenance Manuals. The designer shall adapt the Owner's Maintenance training and manuals specification to be specific in all respects to his design and include the entire text in the project specifications at Design Development.

Heating Equipment

Life-cycle-cost analysis supports the use of heating equipment more efficient than minimum ASHRAE standards. We require condensing boilers, furnaces and water heaters with minimum A.F.U.E. of 90 % or minimum thermal efficiency of 88 %.

Heating plant design shall be modular to provide redundancy with minimal total capacity and equipment room floor space. Typical design should be 3 to 5 boilers or furnaces with a maximum of 30% excess capacity compared to the calculated heating load. Boilers shall be HydroPulse model M-300 or approved equal. Furnaces shall be TRANE XE 90 or equal.

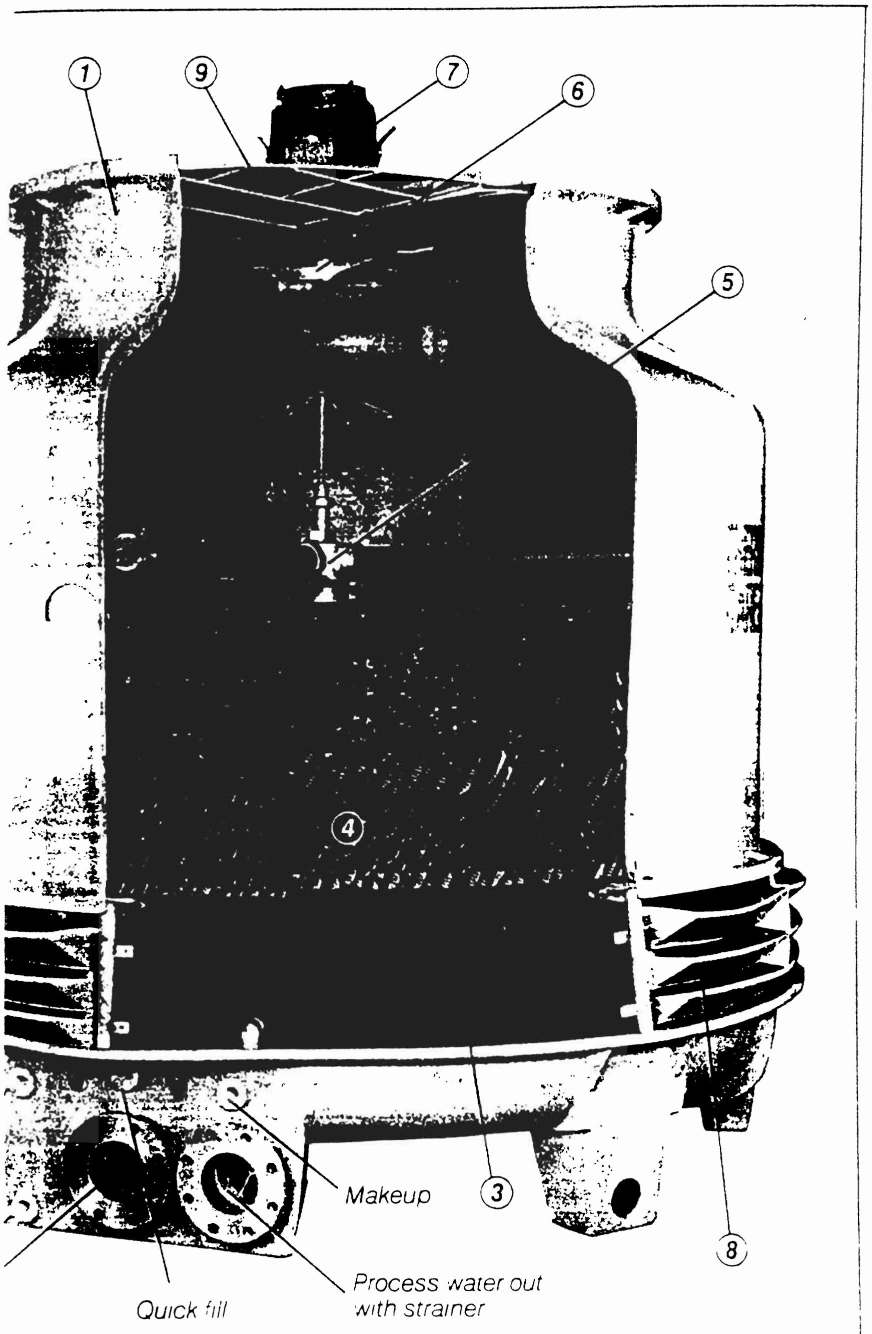
Cooling Towers

High-efficiency towers with draw-through propeller fans use only 1/5th as much fan energy as standard cooling towers.

Life-cycle-cost analysis supports the use of high- efficiency cooling towers on chillers larger than 150 tons. Tower type shall be FRP (fiberglass reinforced polyester) with draw-through propeller type fan and PVC fill. These towers typically require only 0.03 Horse Power per ton of heat rejection capacity, compared to 0.15 Horse Power per ton for conventional blow-through towers utilizing centrifugal fans. A five-to-one energy savings is achieved.

A guide specification and cutaway view for a typical tower are provided. A table of representative tonnages and fan horsepower is also provided.

Maintenance-saving features and construction make Thermal Care your best cooling tower investment



(1) **Rugged FRP shell** *resists corrosion and the toughest weather conditions. It always maintains its strength and appearance. The upper shell is bolted together so that individual panels can be removed for easy access.*

(2) **FRP water basin** *features integral sump and mounting feet for easy cleaning and low cost installation. Standard towers have openings for supply, return with strainer, overflow, makeup water and drain.*

(3) **360 degree air intake** *eliminates tower positioning problems due to prevailing winds or nearby structures. Reduced inlet velocity eliminates moist air recirculation problems.*

(4) **PVC fill** *is impervious to corrosion, rot, decay, and biological attack—designed for maximum air/water contact for efficient heat transfer.*

(5) **Self-rotating sprinkler system** *provides uniform water distribution—features non-clog openings and corrosion resistant, water lubricated construction for long service life.*

(6) **Cast aluminum direct drive fan** *has no belts or pulleys to align or replace—consumes less horsepower, reduces operating cost. Adjustable pitch blades enable fine tuning of capacity.*

(7) **Fully enclosed drip proof motor** *is designed for outdoor operation—stands up to severe service duty.*

(8) **FRP inlet louvers** *(optional on some sizes) won't corrode and are easy to detach for basin cleaning and fill inspection. They're designed to prevent "splash" and windage loss.*

(9) **Galvanized motor mounts and discharge grille** *resist corrosion, never need painting. Grille promotes safety and prevents entry of debris.*

(10) **Convenient inspection port** *for ease of sprinkler head checks, preventive maintenance and flow observation.*

(11) **Access ladder** *makes it easy to reach the fan and motor.*

Specifications - Fiberglass Cooling Tower

Tower Model	Nom. Tons *	Approximate Dimensions (Inch)		Connection Sizes (Inch)					Fan Motor HP	Weight (Lbs.)		Req'd Pump Head (FT.)	Flow Rate Min/Max (GPM)
		H	D	Outlet	Inlet	Over Flow	Drain	Make Up		Dry	Oper.		
FT8110	2	53	30	1 1/2	1 1/2	1	1/2	1/2	1/6**	70	150	4.5	5/35
FT8120	3	54	36	1 1/2	1 1/2	1	1	1/2	1/6**	100	265	4.5	5/35
FT8130	5	63	34	1 1/2	1 1/2	1	1	1/2	1/6**	125	265	4.3	10/70
FT8140	7	63	34	1 1/2	1 1/2	1	1	1/2	1/4**	150	290	5.9	10/70
FT8150	10	71	46	2	2	1	1	1/2	1/4**	225	465	5.6	20/90
FT8160	15	71	46	2	2	1	1	1/2	1/2	300	620	5.9	20/90
FT8180	22	66	62	2 1/2	2 1/2	1	1	1/2	1	375	1135	6.5	32/135
FT8210	30	70	75	3	3	1	1	3/4	2	600	1400	7.0	60/200
FT8220	38	74	75	3	3	1	1	3/4	2	600	1475	7.0	60/200
FT8230	45	76	85	4	4	1	1	3/4	2	750	2020	8.0	90/340
FT8240	53	76	85	4	4	1	1	3/4	2	750	2060	8.2	90/340
FT8250	60	79	85	4	4	1	1	3/4	2	750	2100	9.8	90/340
FT8260	80	95	95	5	5	1	1	1	3	1250	2780	9.8	180/500
FT8270	100	95	95	5	5	1	1	1	3	1300	2890	10.5	180/500
FT8310	120	97	129	6	6	2	2	1 1/4	5	2400	7165	10.5	270/750
FT8320	140	97	129	6	6	2	2	1 1/4	5	2500	7350	10.5	270/750
FT8330	160	107	148	6	6	2	2	1 1/4	5	2650	7850	12.0	330/750
FT8340	185	108	164	8	8	2	2	1 1/4	7.5	3400	9840	12.0	375/900
FT8350	200	108	164	8	8	2	2	1 1/4	7.5	3500	10000	12.0	375/900
FT8351	228	108	164	8	8	2	2	1 1/4	7.5	3500	10675	12.0	375/900
FT8353	228	108	164	8	8	2	2	1 1/4	10	3700	11000	12.0	375/900
FT8355	253	108	164	8	8	2	2	1 1/4	10	3700	11475	12.0	375/900
FT8421	275	148	192	8	8	4	2	1 1/4	10	4200	12800	14.0	600/1300
FT8510	325	153	220	8	8	4	2	2	15	5600	15500	15.0	650/1500
FT8511	367	153	220	8	8	4	2	2	15	5600	16460	15.0	650/1500
FT8521	416	153	220	10	10	4	2	2	15	5900	16350	15.0	1000/2000
FT8523	416	153	220	10	10	4	2	2	20	6100	16600	15.0	1000/2000
FT8525	457	153	220	10	10	4	2	2	20	6300	17100	17.0	1000/2000
FT8531	526	164	258	10	10	6	2	2	20	7900	25800	16.5	1200/2400
FT8541	532	164	258	10	10	6	2	2	15	8200	26000	16.5	1200/2400
FT8543	577	164	258	10	10	6	2	2	20	8200	26200	16.5	1200/2400
FT8551	660	198	300	12	12	6	3	2 1/2	25	11000	34300	19.0	1650/3000
FT8553	689	198	300	12	12	6	3	2 1/2	30	11300	35000	19.0	1650/3000
FT8555	734	198	300	12	12	6	3	2 1/2	40	11500	37000	19.0	1650/3000
FT8561	720	198	300	12	12	6	3	2 1/2	25	13100	35800	19.0	1650/3000
FT8563	747	198	300	12	12	6	3	2 1/2	30	13200	36100	20.5	1650/3000
FT8565	800	198	300	12	12	6	3	2 1/2	40	13500	36500	22.0	1650/3000
FT8567	800	198	300	12	12	6	3	2 1/2	30	14500	38000	22.0	1650/3000
FT8569	838	198	300	12	12	6	3	2 1/2	40	14700	38500	22.0	1650/3000

*95°F/85°F/78°F WB-3GPM/Ton

**Single phase

New A. O. Smith

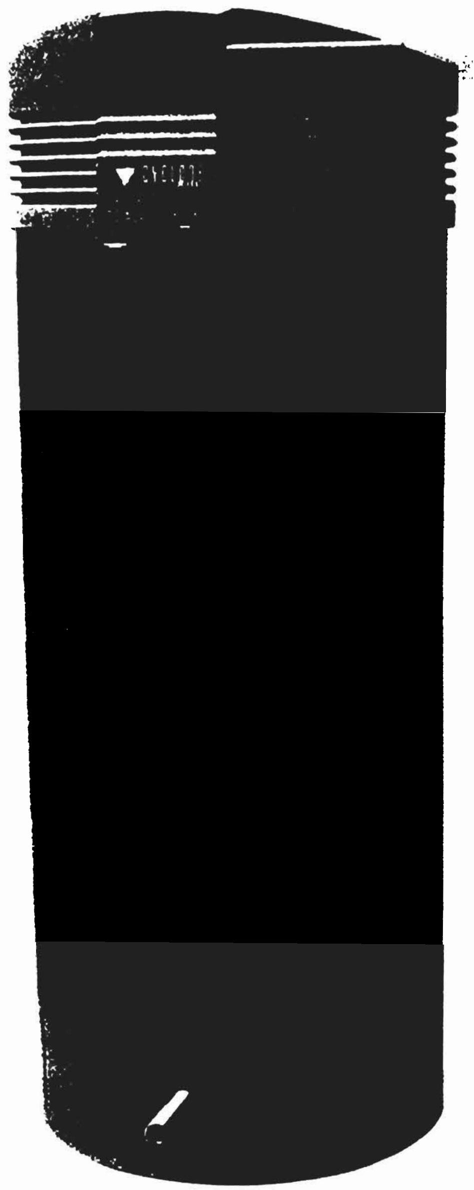
H-TRA HIGH EFFICIENCY XHE

Extra High 94% Thermal Efficiency. Without The Extra High Price Tag!

If commercial water heaters are vital to the success of your business, this new A.O. Smith Cyclone XHE may be just what you've been looking for.

XHE stands for extra high efficiency, in every sense of the word. 94% efficiency, in fact.

And nothing in the commercial water heater marketplace beats it for value and low price!



Affordable High Efficiency For Small Companies.

Until now, high prices have put the vast majority of high efficiency commercial water heaters out of reach of many thousands of small commercial companies that operate on limited budgets.

But now, thanks to the new A.O. Smith Cyclone XHE, these smaller companies are able to enjoy the very special benefits of a commercial water heater that is not just in a high efficiency category, but in an extra high 94% thermal efficiency range. And without a prohibitive, stratospheric price.

Good News For Larger Companies, Too!

For years, larger companies have been willing to pay a premium for the advantages of high efficiency in their commercial water heaters.

But now, on many applications, the Cyclone XHE can deliver that extra high efficiency larger companies are used to and prefer. Minus the extra high price!

Cyclone XHE Exceeds Federal Requirements By Wide Margin.

The Cyclone XHE exceeds the federally mandated ASHRAE 90.1b-1992 standard, requiring 78% thermal efficiency and a standby loss of 2.25%, by vast margins. The 100-gallon tank, insulated top to bottom with a thick 1-7/8" foam, plus the sealed, submerged combustion chamber, reduce heat loss to an absolute minimum.

ASHRAE Requirement	Cyclone Performance
Standby Loss of 2.25	1.06% (53% better)
Thermal Efficiency of 78%	94% (21% better)

Chillers

New Cooling Equipment must use Alternative Refrigerants

In addition to meeting minimum efficiency requirements, all chillers shall be specified to have an electronic interface package for remote monitoring and control through the building Energy Management System. Package shall provide continuous readout on internal chiller conditions, output, and electrical performance. Package shall enable chilled water temperature reset, ON/OFF control, and demand limiting through EMS command.

Refrigerant Types

Due to the imminent phase-out of CFC refrigerants, DO NOT specify R-11 or R-12 in any new chillers or air-conditioning units.

Options for new refrigerants are changing rapidly. Therefore, consult the Owner's Engineer for preferred alternative refrigerants at the time of specification.

Air System Design

Correct design and detailing of the air-distribution system is critical to achieving an energy-efficient building. The designer is required to follow recommended practices of ASHRAE "Energy Efficient Design and Retrofit of Air Systems", including:

Drawings must consistently show correct detailing of the air-distribution system.

- Air-Handling Units and fan type
- Ductwork accessories and details
- Terminal Devices and Diffusers
- Overall Airflow Efficiency

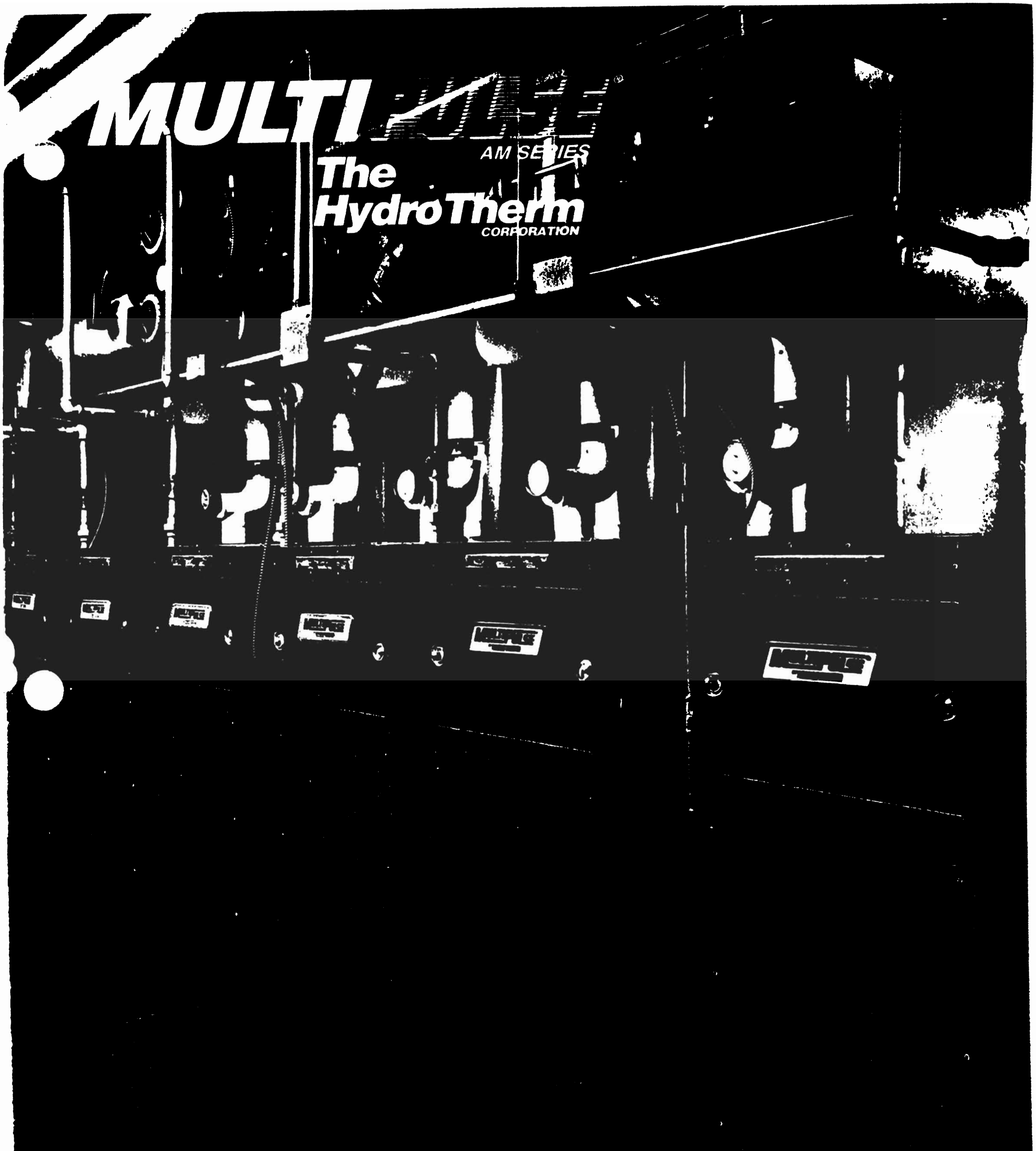
The designer shall review all these details and standards prior to starting air-system design. The design must be executed in accordance with the details and to minimize pressure losses throughout the air distribution system. The design drawings must consistently show correct detailing to be acceptable to the Owner.

The following table provides additional specifications required by the Owner on air system design.

BASELINE HVAC AIR SYSTEM REQUIREMENTS

System	Component	Criteria
Air Handler	Fan	Blow Through configuration. Backward-curved airfoil (unless CFM < 3,000)
	Drive	Variable Frequency Drive on all VAV AHU's. Soft start on all constant volume AHU's.
	Discharge	Minimum length of four equivalent diameters before any obstructions or take offs at discharge of fan.
	Housing	Double-wall construction. IAQ drainpan design.
	Motor	Premium efficiency.
	Outside Air Intake	Outside air must mix in the return air duct to eliminate temperature stratification prior to entering the AHU.
	Filter and Coil Face Velocity	300 fpm or less maximum design velocity.
	Filtration	65% dust spot efficiency minimum. Provide filter module with pre-filters.
Duct work	Type	Main ducts to be Round spiral (preferred) or Oval spiral. Do NOT use Rectangular. Branch ducts to be round spiral.
	VAV Boxes	Full DDC boxes. Do NOT use fan-powered boxes.
	Diffusers	Louvered cone diffusers, stamped one-piece construction with coanda pockets - no mitered pieces. Do NOT use perforated diffusers.
	Takeoffs	Minimum straight, unobstructed duct run of 4 to 6 (preferred) duct diameters before any takeoffs bends or transitions. Takeoffs require 45 degree boots.
	Transitions	Expansions in duct diameter must include a transition not exceeding 20 degrees divergence angle.
	Lining	No interior lining may be used unless contained in double-wall construction.
	Flex Duct	Maximum run of 6 feet on flex duct connections. Show hard duct up to 6 feet of any diffuser. Show a segemented elbow detail for connection between flex duct and diffusers.

System	Component	Criteria
Outdoor Air Energy Control		On air handlers with greater than 3000 CFM outside air relief requirements, ONE of the following options must be used:
1)	Energy Recovery	Dessicant wheel energy recovery system. (Resize heating and cooling capacity to include effect of energy recovery and reduce first cost.)
2)	CO2 Sensing	Modulate AHU outdoor and return air dampers with PID loop to maintain 1000 PPM CO2 in the return air.
Complete Air System	Overall Airflow Efficiency	**VAV** - Less than 1.0 HP per 1000 CFM **Constant Volume** - Less than 0.6 HP per 1000 CFM
	Controls	Complete DDC for automatic temperature control, valves and acutators, and energy management functions. Provide complete point list on drawings.
	Sequence of Operation	Use Owner's Standard Sequence of Operation for VAV systems (see EMS section). Provide logic diagram on drawings supporting the verbal sequence of operation.



The most energy-efficient commercial modular gas-fired hot water heating plant available today!

MULTI-PULSE MODULAR HEATING PLANT

AM SERIES

Reduce fuel costs dramatically

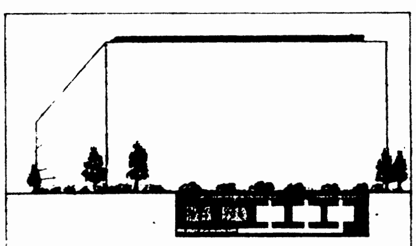
- **For space heating, volume water heating or the combination of both.**
- **In light commercial, industrial & institutional buildings.**
- **For new and replacement installations.**

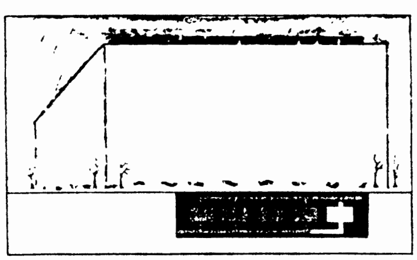
It's a fact that the Multi-Pulse modular heating plant concept, developed by Hydrotherm more than 10 years ago, has been proven throughout a wide variety of commercial applications, saving our customers thousands of dollars annually in energy costs.

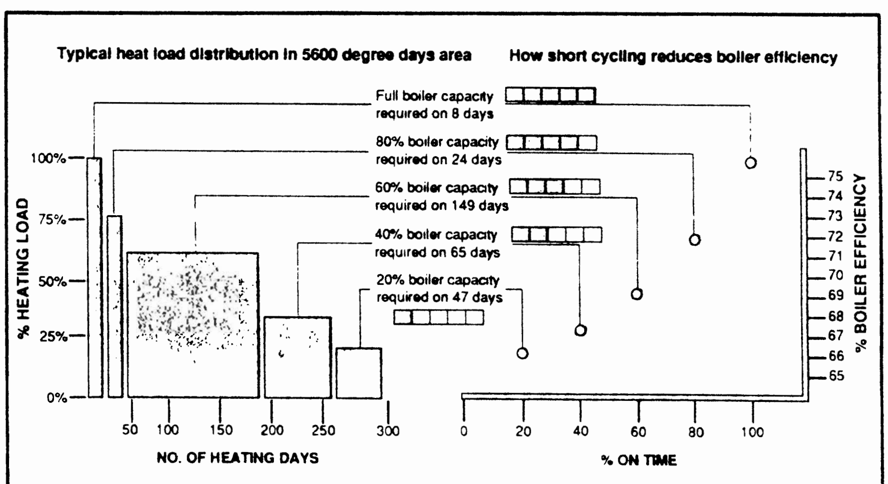
First, there has never been a more fuel efficient commercial modular hydronic gas heating system than Multi-Pulse. With a seasonal efficiency of more than 90% (AFUE), Multi-Pulse owners have cut their heating bills by up to 35% and more when replacing conventional gas-fired single input boilers, and up to 70% when replacing old oil-fired or electric heating plants.

Multi-Pulse boilers employ the principle of pulse combustion. It's a sealed combustion process, without pilot lights or burners, that virtually eliminates typical energy losses inherent in conventional systems. Each module burns only a small amount of gas during operation, resulting in ultimate fuel combustion. And the heat transfer process produces low exhaust temperatures which can be easily vented outdoors through small diameter plastic pipe—thus eliminating the need for a chimney and the associated large up-the-chimney heat losses.

Multi-Pulse heating plants use individual, low-water content, smaller capacity boilers, such as this M-300 modular installation, where off-cycle losses are substantially reduced and dissipated heat from stored water is much less than large capacity, single input units.







HOW HEAT LOAD DISTRIBUTION AFFECTS CONVENTIONAL BOILER EFFICIENCY

Second, Multi-Pulse heating plants consist of individual self-contained modules which provide the same unique, fuel-saving, step-firing design pioneered more than 30 years ago by Hydrotherm in its Multi-Temp modular systems.

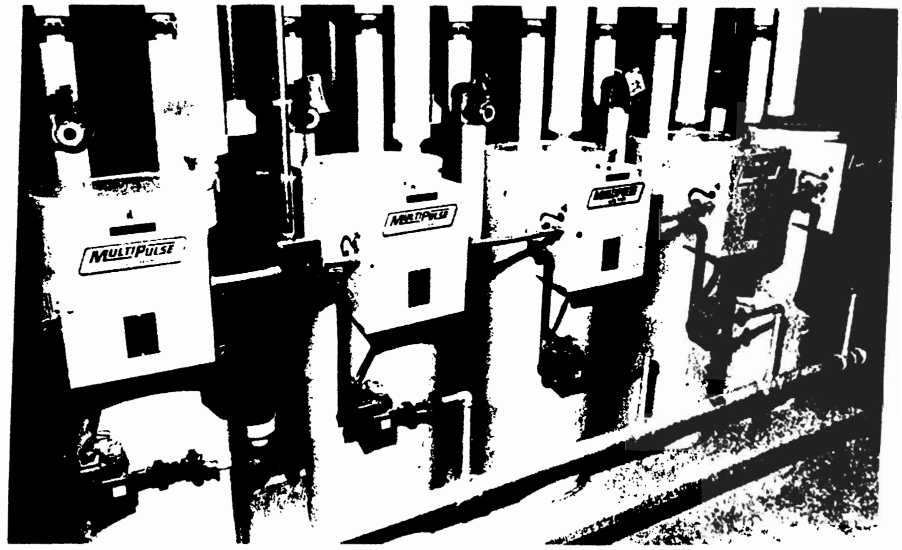
Each Multi-Pulse module operates completely independent of the other modules; this modular concept permits the system to meet low demand requirements more efficiently as it eliminates the energy-wasting "all-on/all-off" firing characteristics of single input boilers and it varies the input in relation to the demand.

Individual heating modules are step-fired, only as required to meet the load. As the demand increases, the number of modules fired increases proportionately. And conversely, as the demand decreases, the number of modules firing are decreased proportionately.

In any boiler, maximum performance is attained only when it fires continuously. With typical heating season load requirements (as shown in the heat load distribution chart on the previous page) a single-input, large capacity boiler must operate intermittently—without reaching its rated efficiency during the major part of the heating season. However, the Multi-Pulse modular system achieves its rated efficiency because it fires only the exact number of modules required to satisfy the heating load in long operating cycles at full capacity.

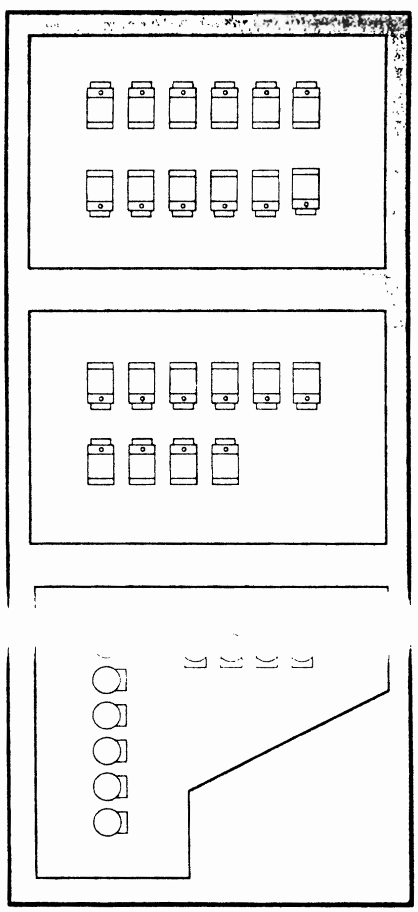
And since they are designed as condensing boilers, Multi-Pulse heating plants are particularly well suited for use in low water temperature heat pump systems, too. Because low water temperatures increase flue gas condensation which extracts more latent heat from combustion, thus providing even more efficiency and customer fuel savings.

Altogether, Multi-Pulse systems represent a genuine owner investment. With its energy savings, the payback for first-cost installation expenditures of the Multi-Pulse heating plant is usually within five years or less, depending on the amount of fuel being used. And with every increase in energy prices, customers save even more money.



Model AM-150 modular installation, like all Multi-Pulse systems, provides built-in, standby capacity without the need for excess equipmemt. Even if a module requires service, the total Multi-Pulse heating plant continues to operate at or near normal output capacity.

Provide installation flexibility, cost-savings



Since all modules are direct vent, Multi-Pulse heating plants do not require a chimney, providing substantial new installation savings. And using 100% outside air for combustion, they can be installed within a closed boiler room. In addition to the usual water and gas piping, installation of factory-assembled, individually-cartoned modules simply requires the addition of exhaust and combustion air piping which can be vented through the roof, through a dormant chimney or through an outside wall. It is possible, under certain conditions, to manifold each module's air intake piping and exhaust piping.

Plus, their relatively light weight permits installation in any location such as basements (without cost excavation), intermediate floors penthouses or rooftops, with a minimum floor load.

Heating plants can be tailored to boiler room shapes and areas in nearly any configuration as shown in the adjoining schematic. And for replacement, if desired, there is no need to remove the existing large single input boiler.

MULTIPULSE AM SERIES MODULAR HEATING PLANTS

Feature state-of-the-art Model S electronic control

Designed for minimizing fuel usage by specifically resetting supply water temperature in relation to outdoor air temperature, Hydrotherm's solid state Model S control equalizes individual boiler usage within the modular system for longer equipment life. The micro-computer based Model S control step-fires only the number of modules required to satisfy the system supply temperature. It can control up to eight input steps in accordance with a pre-programmed operation.

The Model S control features L.E.D. indicating lights for visual indication of steps that are firing; supply and air temperature digital read out; outdoor actuated system heat starter; power-off alarm relay; contained system power and circulator start control; with options such as night setback and boiler service on-time and cycle counter.

And the Model S control can also be used for constant supply water temperature control without outdoor reset when desirable.

MODEL	NO. OF MODULES	NATURAL GAS RATINGS (MBH) A.G.A. INPUT	NATURAL GAS RATINGS (MBH) HEAT CAPACITY	PROPANE GAS RATINGS (MBH) A.G.A. INPUT	PROPANE GAS RATINGS (MBH) HEAT CAPACITY
AM-300	1	299	272	—	—
	2	598	544	—	—
	3	897	816	—	—
	4	1196	1088	—	—
	5	1495	1360	—	—
	6	1794	1632	—	—
	7	2093	1904	—	—
	8	2393	2176	—	—
AM-150	—	150	132	135	122
	2	300	264	270	244
	3	450	396	405	366
	4	600	528	540	488
	5	750	660	675	610
	6	900	792	810	732
	7	1050	924	945	854
	8	1200	1056	1080	976
	9	1350	1188	1215	1098
	10	1500	1320	1350	1220
AM-100	—	100	88	90	80
	2	200	176	180	160
	3	300	264	270	240
	4	400	352	360	320
	5	500	440	450	400

For larger sizes, consult Hydrotherm sales representative.

ASME

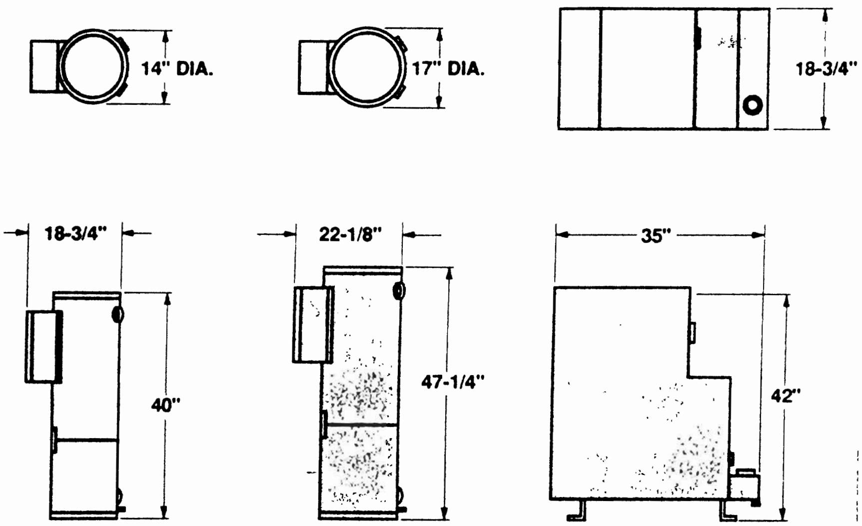
MEMBER gama

MEA New York City

The HydroTherm CORPORATION

260 NORTH ELM STREET
WESTFIELD, MA 01085
(413) 568-9571 FAX: (413) 568-9613

425 ADMIRAL BLVD. UNITS 3 & 4
MISSISSAUGA, ONTARIO CANADA L5T 2N1
(416) 564-5990 FAX: (416) 564-6008

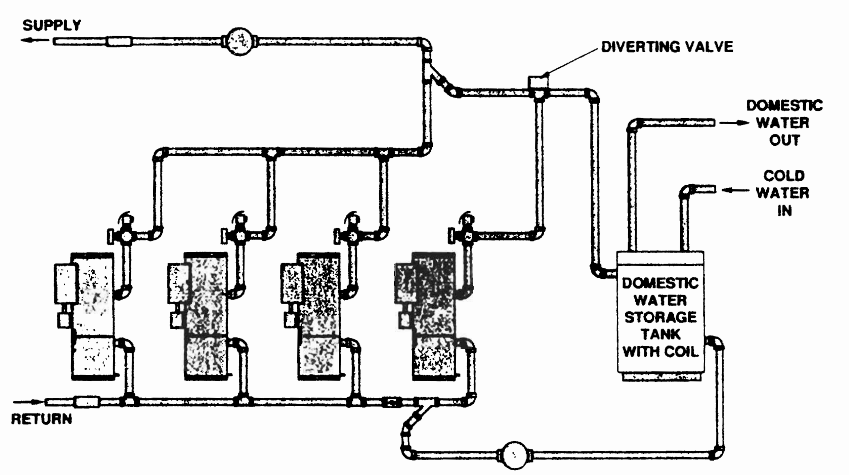


AM-100 MODULE **AM-150 MODULE** **AM-300 MODULE**

Compact, low-profile boiler modules are less than 48" high by 19" wide and can be wheeled on a hand truck through standard 30" doorways, which eliminates expensive rigging and heavy equipment movement costs.

Supply volume water heating more efficiently

Multi-Pulse modules may be piped with a heat exchanger or a water storage tank with an internal coil, as shown in the diagram below, to provide the most efficient system available for any volume water heating only or combination space and volume water heating application. Unique to the modular heating plant, combination Multi-Pulse systems can usually meet the capacity requirements of volume water heating applications with only a small increase (if any) in the number of modules required for space heating. Multi-Pulse boilers with multiple heat exchangers or tanks can be manifolded together to satisfy large domestic hot water heating demands.

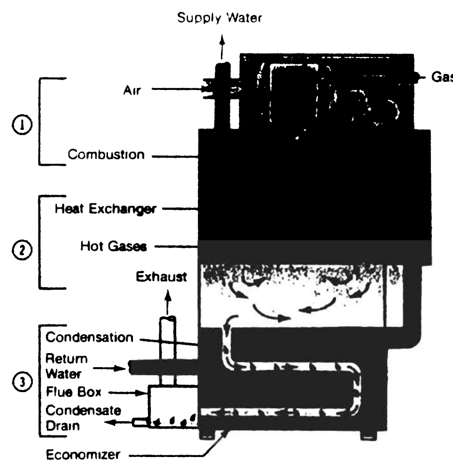


Work like no other boilers

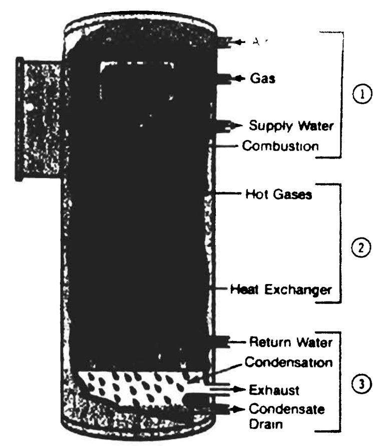
1. Each module draws air from outside the building structure through small diameter PVC pipe which is mixed with gas and passed into the combustion chamber, where the mixture is ignited by a spark plug on the initial cycle only. Each air-gas mixture/burn cycle, thereafter, is ignited by the residual heat from the previous cycle.

2. Pressure resulting from the combustion process forces hot gases down through the heat exchanger tubes inside the boiler. And heat is transferred to the surrounding boiler water, which is circulated throughout the structure's heating system (or hot water heat exchanger coil) in the same manner as with a conventional heating plant.

3. As hot gases are cooled below the dew point, condensation of water vapor in flue gases takes place, releasing the latent heat of vaporization, which can amount to an increase in efficiency up to 9-1/2% of the fuel input. The condensate is removed by a drain located at the boiler's base. And the low temperature exhaust is safely vented outside through small diameter CPVC pipe.



MODEL AM-300 SCHEMATIC



MODEL AM-150/AM-100 SCHEMATIC

Offer advanced design

Environmentally clean. Because of the high efficiency of the pulse combustion process, Multi-Pulse modules produce Low-NOx emissions of less than 30 to 40 ppm (parts per million).

And each module features state-of-the-art hydronic unit design, such as operation sequence indi- [illegible] control box [illegible] pre- [illegible] iron [illegible] stainless steel pulse combustion chamber; and secondary economizer absorption [illegible] fire tubes. [illegible]

Using one standard heating module as the building block, Multi-Pulse heating plants can be built up to virtually unlimited output capacity. Modules available include AM-300 (299,000 Btuh input), AM-150 (150,000 Btuh input) and AM-100 (100,000 Btuh input) with AS[illegible] code construction of 30 or 1[illegible]

SECTION 5

BUILDING AUTOMATION AND CONTROL (BAC)

Chapter 5

Building Automation Controls(BAC)

Introduction

The College will be developing a Building Automation Control(BAC) Network(Net) that will comply with ASHRAE Std. 135-1995, A Data Communication Protocol for Building Automation and Control Networks(BACnet). The BACnet data communication protocol is an open protocol that is capable of Internet communications.

BACnet System Overview

The College will begin the BACnet installation with the construction of the Health Science Building and integrate the remainder of the Takoma Park Campus as future buildings are constructed or renovated. The BACnet systems will be capable of stand alone operations and be networked via the Internet through a server in the Computer Sciences Building on the Rockville Campus. Global access to the system will be through desktop PCs via the internet. Building systems will be Direct Digital Control with BACnet interconnections to chillers, boilers, VFDs, elevators, fire, and security systems.

BACnet Design

The designer shall develop a DDC design, standard sequence of operations, a point list and a schematic controls diagram for the equipment being controlled. The College will assist the designer in defining the BACnet system and provide a standard BACnet specification for the designer to include in his documents. Specific control issues shall be addressed:

1. Lighting Control - The majority of spaces will have occupancy sensors controlling the lighting. The designer specify auxiliary contacts from the sensors and wire these contacts to the DDC terminal controllers in the spaces. The occupancy sensor can then serve multi-purposes of light control, HVAC control and Security.

Attachment 5-1, Native BACNet Specification

Note: This specification is in "rough draft" form. Final form will be sent separately in hard and electronic copy.

SECTION 6

VENTILATION/INDOOR AIR QUALITY

Chapter 6

Ventilation/IAQ

Introduction

Ventilation and good Indoor Air Quality(IAQ) increase occupant productivity and contribute to student success. It is the College's goal to provide a clean indoor air environment free from contaminants and odors. Proper design of the building envelope will minimize infiltration of untreated air and minimize migration of moisture. Proper design of HVAC systems will provide the proper amount of ventilation air and condition that air to the proper temperature and humidity levels to meet the comfort conditions. Pans and drains that collect condensate shall be properly designed to drain and eliminate stagnant pools of water. This section discusses the requirements for meeting these goals.

Ventilation Rates

The designer shall use ASHRAE Std. 62(latest edition), A Standard for Indoor Air Quality as the basis for determining the required amount of ventilation air. The designer shall further calculate and apply the 50% diversity values allowable under the standard. Ventilation systems shall be calculated to provide positive pressurization and be properly balance in order to minimize infiltration of un-conditioned air.

Outdoor Air Pre-Treatment System

The designer shall incorporate a desiccant outdoor air pre-treatment system with enthalpy wheel heat recovery in to the design of his HVAC system. The College will assist the designer in specifying an acceptable system. The system shall use both rejected heat from a roof mounted micro-turbine and auxiliary natural gas heated air to regenerate the desiccant. Ventilation air streams shall be collected from the appropriate zones and directed into the enthalpy heat recovery wheel.

Carbon Dioxide(CO_2) Sensors

High quality CO_2 sensors shall be installed in the return air stream and control outdoor air ventilation rates based upon concentrations of CO2.

Building Materials

Building materials shall be specified that do not contain harmful contaminants that will degrade the quality of the indoor environment.

Attachement 6-1, EDG Ventilation/IAQ

Ventilation / IAQ

CFM Per Person

The design CFM of outdoor air shall follow ASHRAE 62-1989 "Ventilation for Acceptable Indoor Air Quality" Table 2. The most frequently needed sections are attached for reference.

Determining Design Occupancy

Design Occupancy must be reduced for intermittent-use spaces.

When estimating occupants per room, attention must be paid to paragraph 6.1.3.4 "Intermittent or variable occupancy", which states:

> "Where peak occupancies of less than 3 hours duration occur, the outdoor air flow rate may be determined on the basis of average occupancy for buildings for the duration of operation of the system, provided the average occupancy used is not less than one-half the maximum."

The above provision shall be applied to reduce the ventilation requirements of the following types of spaces in the Owner's facilities:

- Conference Rooms
- Auditoriums and Theaters
- Cafeteria dining space
- Assembly rooms

NOTE: Some code versions of Standard 62 do not include the above reduction for intermittent use. In this case the designer must take care to select a category for the space that reflects actual average occupancy without the intermittent use factor.

Filtration

Minimum filtration at all air-handling units for office space shall be of 65% or greater "dust spot efficiency" per ASHRAE Standard 52-76 methods. Filter type shall be extended surface, cartridge, bag-type or electronic with manually cleaned or replaceable media.

Additional Energy Control Measures

- Use a CO_2 sensor to control outside air in air handlers for Intermittent use, High-Occupancy areas (see example areas quoted above) exceeding 3,000 CFM relief air requirements. A single CO_2 sensor should be used in the return air duct.

- Evaluate Energy Recovery, including dessicant wheel type, for continuously occupied areas with 3,000 CFM or more of relief air requirements.

- Directly exhaust high-contaminant areas such as smoking lounges, restrooms, printing and photo processes, locker rooms, and so on. Use transfer air from other spaces for exhaust air in these applications.

- Inject 80% of Make-Up Air directly at Exhaust Hoods to avoid the need to temper the air. Applies to Kitchen hoods, Laboratory hoods, Painting processes, etc.

  NOTE: BOCA code does not require make-up air for hoods to be conditioned if it does not enter the occupied space.

Common Mistakes to Avoid

- Do not assume more people than necessary in the space:

  Table 2 sets the Maximum Occupancy in Net Space. Use a lower occupancy estimate if available. Use net space rather than gross space.

- Do not misclassify or lump spaces together that have distinct classifications.

  For example, the "Library" classification and occupant density (20 people / 1000 ft^2) applies to library stack areas and should not be used for staff "Office" areas within a library which have much lower densities (7 people / 1000 ft^2).

- Do not create HVAC zones that span areas with high and low outside air requirements. This practice will introduce unnecessary amounts of outside air to some areas.

I. CARBON DIOXIDE (CO_2) SENSORS

A. Carbon Dioxide sensors shall be suitable for duct mounting. Sensing method shall utilize non-dispersive infrared technology. Sensors shall have the following minimum performance and application criteria:

1. Input range: 0 to 2000 PPM (0.2%) CO_2 .

2. Accuracy: 5% of reading from 1000 PPM to 2000 PPM and plus or minus 50 PPM below 1000 PPM.

3. Repeatability: 1% of full scale.

4. External power source: 24 AC or DC at 0.5 amps maximum.

5. Power consumption: 6 Watts maximum.

6. Output signal: 0 to 10 volts or 4 to 20 mA representing 0 to 2000 PPM linear scale.

7. Zero drift at constant temperature: Less than 100 PPM per year.

8. Zero noise at constant temperature: Less than 20 PPM peak to peak measured during any 10 to 20 second period.

9. Zero drift due to ambient temperature changes: Less than 10 PPM per degree C.

10. Operating range: 0 to 50 C (32 to 122 F) and 0 to 95% RH non-condensing.

B. Duct mounted sensor shall mount to duct surface and shall include a rubber gasket seal and insulator. Sensor probe shall be approximately 1.125" diameter and 4" long.

C. Acceptable manufacturers: Valtronics, Johnson Controls.

JOHNSON CONTROLS

CDS-2000 Series Carbon Dioxide Sensors

The CDS-2000 Carbon Dioxide Sensor is designed to measure the CO_2 concentration of air and is intended for use as a CO_2 monitoring or high limit sensor. When used as part of an indoor air quality control system, it can also serve as a surrogate indicator of occupancy for use in determining a building's ventilation requirements.

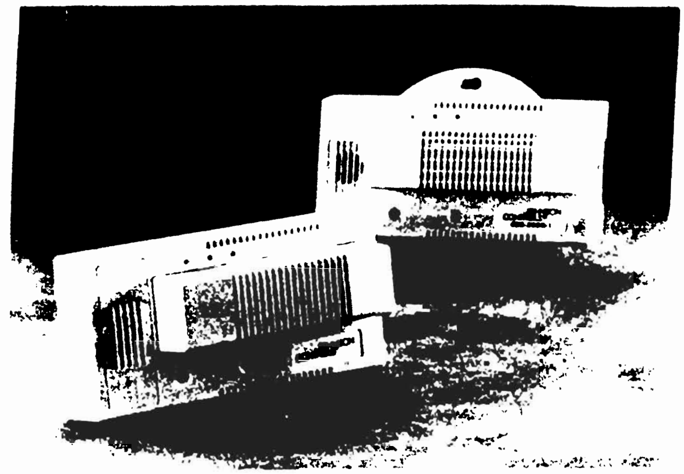


Figure 1: CDS-2000 CO_2 Sensors

Features and Benefits

❑ **Microprocessor-based offset algorithm automatically compensates for drift**	Results in a uniquely stable and accurate (±100 ppm/year) output signal.
❑ **0 to 10 VDC proportional output signal and SPDT alarm contacts**	Provides compatibility with most monitoring and controlling devices including Metasys™ and other direct digital and analog electronic controllers.
❑ **Adjustable alarm limit**	Allows tailoring of alarm indication to system configuration or type of space being sensed.
❑ **Short response time of 20 seconds (maximum)**	Enables system changes to closely track space needs.
❑ **Patented membrane filter protects sensor from dust, moisture and smoke particles**	Prolongs unit life and contributes to sensing accuracy.
❑ **Integral mounting base with terminal-block wiring connections**	Speeds and simplifies installation.

ASHRAE™ STANDARD

Ventilation for Acceptable Indoor Air Quality

Approved by the ASHRAE Standards Committee March 1, 1989; approved by the Board of Directors June 29, 1989.

ASHRAE Standards are updated on a five-year cycle; the date following the Standard number is the year of approval. The latest copies may be purchased from the ASHRAE Publications Sales Department, 1791 Tullie Circle, NE, Atlanta, GA 30329.

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AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS, INC.
1791 Tullie Circle, NE • Atlanta, GA 30329

systems should be treated to avoid microbial buildup. If the relative humidity in occupied spaces and low velocity ducts and plenums exceeds 70%, fungal contamination (for example, mold, mildew, etc.) can occur. Special care should be taken to avoid entrainment of moisture drift from cooling towers into the makeup air and building vents.

6. PROCEDURES

Indoor air quality is a function of many parameters including outdoor air quality, the design of enclosed spaces, the design of the ventilation system, the way this system is operated and maintained, and the presence of sources of contaminants and the strength of such sources. This Standard deals with the design of a ventilation system as it is affected by all these factors, so that an acceptable level of indoor air quality can be provided. Design documentation shall clearly state which assumptions were used in the design so that the limits of the system in removing contaminants can be evaluated by others before the system is operated in a different mode or before new sources are introduced into the space.

Indoor air should not contain contaminants that exceed concentrations known to impair health or cause discomfort to occupants. Such contaminants include various gases, vapors, microorganisms, smoke, and other particulate matter. These may be present in makeup air or be introduced from indoor activities, furnishings, building materials, surface coatings, and air-handling and air treatment components. Deleterious factors include toxicity, radioactivity, potential to induce infection or allergies, irritants, extreme thermal conditions, and objectionable odors.

The Ventilation Rate Procedure (6.1) provides one way to achieve acceptable air quality. This procedure prescribes the rate at which ventilation air must be delivered to a space and various means to condition that air. The ventilation rates in Table 2 are derived from physiological considerations, subjective evaluations, and professional judgments (see Refs 12-18).

The Indoor Air Quality Procedure (6.2) provides an alternative performance method for achieving acceptable air quality. This procedure uses one or more guidelines for the specification of acceptable concentrations of certain contaminants in indoor air but does not prescribe ventilation rates or air treatment methods.

TABLE 1
National Primary Ambient-Air Quality Standards for Outdoor Air as Set by the U.S. Environmental Protection Agency (Ref 19)

Contaminant	Long term: Concentration ug/m³	Long term: Concentration ppm	Long term: Averaging	Short term: Concentration ug/m³	Short term: Concentration ppm	Short term: Averaging
Sulfur dioxide	80	0.03	1 year	365	0.14	24 hours
Total Particulate	75[a]	—	1 year	260	—	24 hours
Carbon monoxide				40,000	35	1 hour
Carbon monoxide				10,000	9	8 hours
Oxidants (ozone)				235[b]	0.12	1 hour
Nitrogen dioxide	100	0.055	1 year			
Lead	1.5	—	3 months			

[a] Arithmetic mean

[b] Standard is attained when expected number of days per calendar year with maximal hourly average concentrations above 0.12 ppm (235 ug/m³) is equal to or less than 1, as determined by Appendix H to subchapter C, 40 CFR 50

Three-month period is a calendar quarter.

6.1 Ventilation Rate Procedure: This procedure prescribes:

- the outdoor air quality acceptable for ventilation
- outdoor air treatment when necessary
- ventilation rates for residential, commercial, institutional, vehicular, and industrial spaces
- criteria for reduction of outdoor air quantities when recirculated air is treated by contaminant-removal equipment
- criteria for variable ventilation when the air volume in the space can be used as a reservoir to dilute contaminants.

6.1.1 Acceptable Outdoor Air. This section describes a three-step procedure by which outdoor air shall be evaluated for acceptability:

Step 1: Contaminants in outdoor air do not exceed the concentrations listed in Table 1 as determined by one of the following conditions:

(a) Monitoring data of government pollution-control agencies, such as the U.S. Environmental Protection Agency (EPA) or equivalent state or local environmental protection authorities, show that the air quality of the area in which the ventilating system is located meets the requirements of Table 1. Conformity of local air to these standards may be determined by reference to the records of local authorities or of the National Aerometric Data Bank, Office of Air Quality Planning and Standards, EPA, Research Triangle Park, NC 27711, or

(b) The ventilating system is located in a community similar in population, geographic and meteorological settings, and industrial pattern to a community having acceptable air quality as determined by authorities having jurisdiction, or

(c) The ventilating system is located in a community with a population of less than 20,000 people, and the air is not influenced by one or more sources that cause substantial contamination, or

(d) Air monitoring for three consecutive months, as required for inclusion in the National Aerometric Data Bank, shows that the air quality meets or exceeds the requirements of Table 1 (as specified in Ref 19).

Step 2: If the outdoor air is thought to contain any contaminants not listed in Table 1, guidance on acceptable concentration levels may be obtained by reference to Appendix C.

Outdoor air requirements for ventilation of industrial building occupancies not listed in Table 2 may be determined by procedures presented in *1986 Industrial Ventilation—A Manual of Recommended Practice*, 1986 ed., published by the American Conference of Governmental Industrial Hygienists (ACGIH) (Ref 7).

Step 3: If after completing steps 1 and 2 there is still a reasonable expectation that the air is unacceptable, sampling shall be conducted in accordance with NIOSH pro-

TABLE 2
OUTDOOR AIR REQUIREMENTS FOR VENTILATION*
2.1 COMMERCIAL FACILITIES (offices, stores, shops, hotels, sports facilities)

Application	Estimated Maximum** Occupancy P/1000 ft² or 100 m²	Outdoor Air Requirements cfm/person	L/s person	cfm/ft²	L/s·m²	Comments
Dry Cleaners, Laundries						Dry-cleaning processes may require more air.
Commercial laundry	10	25	13			
Commercial dry cleaner	30	30	15			
Storage, pick up	30	35	18			
Coin-operated laundries	20	15	8			
Coin-operated dry cleaner	20	15	8			
Food and Beverage Service						
Dining rooms	70	20	10			
Cafeteria, fast food	100	20	10			
Bars, cocktail lounges	100	30	15			Supplementary smoke-removal equipment may be required.
Kitchens (cooking)	20	15	8			Makeup air for hood exhaust may require more ventilating air. The sum of the outdoor air and transfer air of acceptable quality from adjacent spaces shall be sufficient to provide an exhaust rate of not less than 1.5 cfm/ft² (7.5 L/s·m²).
Garages, Repair, Service Stations						
Enclosed parking garage				1.50	7.5	Distribution among people must consider worker location and concentration of running engines; stands where engines are run must incorporate systems for positive engine exhaust withdrawal. Contaminant sensors may be used to control ventilation.
Auto repair rooms				1.50	7.50	
Hotels, Motels, Resorts, Dormitories						
				cfm/room	L/s-room	Independent of room size.
Bedrooms				30	15	
Living rooms				30	15	
Baths				35	18	Installed capacity for intermittent use.
Lobbies	30	15	8			
Conference rooms	50	20	10			
Assembly rooms	120	15	8			
Dormitory sleeping areas	20	15	8			See also food and beverage services, merchandising, barber and beauty shops, garages.
Gambling casinos	120	30	15			Supplementary smoke-removal equipment may be required.
Offices						
Office space	7	20	10			Some office equipment may require local exhaust.
Reception areas	60	15	8			
Telecommunication centers and data entry areas	60	20	10			
Conference rooms	50	20	10			Supplementary smoke-removal equipment may be required.
Public Spaces						
Corridors and utilities				0.05	0.25	
Public restrooms, cfm/wc or urinal		50	25			Mechanical exhaust with no recirculation is recommended.
Locker and dressing rooms				0.5	2.5	
Smoking lounge	70	60	30			Normally supplied by transfer air, local mechanical exhaust; with no recirculation recommended.
Elevators				1.00	5.00	Normally supplied by transfer air.

* Table 2 prescribes supply rates of acceptable outdoor air required for acceptable indoor air quality. These values have been chosen to control CO_2 and other contaminants with an adequate margin of safety and to account for health variations among people, varied activity levels, and a moderate amount of smoking. Rational of CO_2 control is presented in Appendix D.

**Net occupiable space.

cedures (see Refs 21 and 22). Local and national aerometric data banks may contain information on some unregulated pollutants. Finally, acceptable outdoor air quality should be evaluated using the definition for acceptable indoor air quality in Section 3.

2.1 COMMERCIAL FACILITIES (offices, stores, shops, hotels, sports facilities)

Application	Estimated Maximum** Occupancy P/1000 ft² or 100 m²	Outdoor Air Requirements cfm/person	L/s person	cfm/ft²	L/s·m²	Comments
Retail Stores, Sales Floors, and Show Room Floors						
Basement and street	30			0.30	1.50	
Upper floors	20			0.20	1.00	
Storage rooms	15			0.15	0.75	
Dressing rooms				0.20	1.00	
Malls and arcades	20			0.20	1.00	
Shipping and receiving	10			0.15	0.75	
Warehouses	5			0.05	0.25	
Smoking lounge	70	60	30			Normally supplied by transfer air, local mechanical exhaust; exhaust with no recirculation recommended.
Specialty Shops						
Barber	25	15	8			
Beauty	25	25	13			
Reducing salons	20	15	8			
Florists	8	15	8			Ventilation to optimize plant growth may dictate requirements.
Clothiers, furniture				0.30	1.50	
Hardware, drugs, fabric	8	15	8			
Supermarkets	8	15	8			
Pet shops				1.00	5.00	
Sports and Amusement						
Spectator areas	150	15	8			When internal combustion engines are operated for maintenance of playing surfaces, increased ventilation rates may be required.
Game rooms	70	25	13			
Ice arenas (playing areas)				0.50	2.50	
Swimming pools (pool and deck area)				0.50	2.50	Higher values may be required for humidity control.
Playing floors (gymnasium)	30	20	10			
Ballrooms and discos	100	25	13			
Bowling alleys (seating areas)	70	25	13			
Theaters						Special ventilation will be needed to eliminate special stage effects (e.g., dry ice vapors, mists, etc.)
Ticket booths	60	20	10			
Lobbies	150	20	10			
Auditorium	150	15	8			
Stages, studios	70	15	8			
Transportation						Ventilation within vehicles may require special considerations.
Waiting rooms	100	15	8			
Platforms	100	15	8			
Vehicles	150	15	8			
Workrooms						
Meat processing	10	15	8			Spaces maintained at low temperatures (−10°F to +50°F, or −23°C to +10°C) are not covered by these requirements unless the occupancy is continuous. Ventilation from adjoining spaces is permissible. When the occupancy is intermittent, infiltration will normally exceed the ventilation requirement. (See Ref 18).

* Table 2 prescribes supply rates of acceptable outdoor air required for acceptable indoor air quality. These values have been chosen to control CO_2 and other contaminants with an adequate margin of safety and to account for health variations among people, varied activity levels, and a moderate amount of smoking. Rational of CO_2 control is presented in Appendix D.

**Net occupiable space.

6.1.2 Outdoor Air Treatment. If the outdoor air contaminant levels exceed the values given in 6.1.1 (Table 1), the air should be treated to control the offending contaminants. Air-cleaning systems suitable for the particle size encountered should be used. For removal of gases and vapors, appropriate air-cleaning systems should be used. Where the best available, demonstrated, and proven technology does not allow for the removal of contaminants, the amount of outdoor air may be reduced during periods of high contaminant levels, such as those generated by rush-hour

TABLE 2
OUTDOOR AIR REQUIREMENTS FOR VENTILATION* (*Concluded*)
2.1 COMMERCIAL FACILITIES (offices, stores, shops, hotels, sports facilities)

Application	Estimated Maximum** Occupancy P/1000 ft² or 100 m²	Outdoor Air Requirements cfm/person	L/s person	cfm/ft²	L/s/s·m²	Comments
Photo studios	10	15	8			
Darkrooms	10			0.50	2.50	
Pharmacy	20	15	8			
Bank vaults	5	15	8			
Duplicating, printing				0.50	2.50	Installed equipment must incorporate positive exhaust and control (as required) of undesirable contaminants (toxic or otherwise).

2.2 INSTITUTIONAL FACILITIES

Application	Estimated Maximum** Occupancy P/1000 ft² or 100 m²	cfm/person	L/s person	cfm/ft²	L/s/s·m²	Comments
Education						
Classroom	50	15	8			
Laboratories	30	20	10			Special contaminant control systems may be required for processes or functions including laboratory animal occupancy.
Training shop	30	20	10			
Music rooms	50	15	8			
Libraries	20	15	8			
Locker rooms				0.50	2.50	
Corridors				0.10	0.50	
Auditoriums	150	15	8			
Smoking lounges	70	60	30			Normally supplied by transfer air. Local mechanical exhaust with no recirculation recommended.
Hospitals, Nursing and Convalescent Homes						
Patient rooms	10	25	13			Special requirements or codes and pressure relationships may determine minimum ventilation rates and filter efficiency. Procedures generating contaminants may require higher rates.
Medical procedure	20	15	8			
Operating rooms	20	30	15			
Recovery and ICU	20	15	8			
Autopsy rooms				0.50	2.50	Air shall not be recirculated into other spaces.
Physical Therapy	20	15	8			
Correctional Facilities						
Cells	20	20	10			
Dining halls	100	15	8			
Guard stations	40	15	8			

* Table 2 prescribes supply rates of acceptable outdoor air required for acceptable indoor air quality. These values have been chosen to control CO_2 and other contaminants with an adequate margin of safety and to account for health variations among people, varied activity levels, and a moderate amount of smoking. Rationale for CO_2 control is presented in Appendix D.

**Net occupiable space.

traffic. The need to control offending contaminants may depend on local regulations that require specific control measures.

6.1.3 Ventilation Requirements. Indoor air quality shall be considered acceptable if the required rates of acceptable outdoor air in Table 2 are provided for the occupied space.

Exceptions:

1. Where unusual indoor contaminants or sources are present or anticipated, they shall be controlled at the source or the procedure of 6.2 shall be followed.

2. For those areas within industrial facilities not covered by Table 2, refer to footnote 15 of *Threshold Limit Values and Biological Exposure Indices for 1986-87*, American Conference of Governmental Industrial Hygienists (Ref 23).

Table 2 lists the required ventilation rates in cfm (L/s) per person or cfm/ft² (L/s·m²) for a variety of indoor spaces. In most cases, the contamination produced is presumed to be in proportion to the number of persons in the space. In other cases, the contamination is presumed to be chiefly due to other factors and the ventilating rates given are based on more appropriate parameters. Where appropriate, the table lists the estimated density of people for design purposes.

Where occupant density differs from that in Table 2, use the per occupant ventilation rate for the anticipated occupancy load. The ventilation rates for specified occupied spaces listed in Table 2 were selected to reflect the consensus that the provision of acceptable outdoor air at these rates would achieve an acceptable level of indoor air quality by reasonably controlling CO_2, particulates, odors, and other contaminants common to those spaces. (Appendix D shows the outdoor air needed to control occupant-generated CO_2 under various conditions.)

Human occupants produce carbon dioxide, water vapor, particulates, biological aerosols, and other contaminants. Carbon dioxide concentration has been widely used as an indicator of indoor air quality. Comfort (odor) criteria are likely to be satisfied if the ventilation rate is

OUTDOOR REQUIREMENTS FOR VENTILATION OF RESIDENTIAL FACILITIES
(Private Dwellings, Single, Multiple)

Applications	Outdoor Requirements	Comments
Living areas	0.35 air changes per hour but not less than 15 cfm (7.5 L/s) per person	For calculating the air changes per hour, the volume of the living spaces shall include all areas within the conditioned space. The ventilation is normally satisfied by infiltration and natural ventilation. Dwellings with tight enclosures may require supplemental ventilation supply for fuel-burning appliances, including fireplaces and mechanically exhausted appliances. Occupant loading shall be based on the number of bedrooms as follows: first bedroom, two persons; each additional bedroom, one person. Where higher occupant loadings are known, they shall be used.
Kitchens[b]	100 cfm (50 L/s) intermittent or 25 cfm (12 L/s) continuous or openable windows	Installed mechanical exhaust capacity[c] Climatic conditions may affect choice of the ventilation system.
Baths, Toilets[b]	50 cfm (25 L/s) intermittent or 20 cfm (10 L/s) continuous or openable windows	Installed mechanical exhaust capacity[c]
Garages: Separate for each dwelling unit	100 cfm (50 L/s) per car	Normally satisfied by infiltration or natural ventilation
Common for several units	1.5 cfm/ft² (7.5 L/s/ft²)	See "Enclosed parking garages," Table 2.1

[a] In using this table, the outdoor air is assumed to be acceptable.
[b] Climatic conditions may affect choice of ventilation option chosen.
[c] The air exhausted from kitchens, bath, and toilet rooms may utilize air supplied through adjacent living areas to compensate for the air exhausted. The air supplied shall meet the requirements of exhaust systems as described in 5.8 and be of sufficient quantities to meet the requirements of this table.

set so that 1000 ppm CO_2 is not exceeded. In the event CO_2 is controlled by any method other than dilution, the effects of possible elevation of other contaminants must be considered (see Refs 12-18).

6.1.3.1 Multiple Spaces. Where more than one space is served by a common supply system, the ratio of outdoor to supply air required to satisfy the ventilation and thermal control requirements may differ from space to space. The system outdoor air quantity shall then be determined using Equation 6-1 (see Refs 24 and 25).

$$Y = X/[1 + X - Z] \quad (6\text{-}1)$$

where

$Y = V_{ot}/V_{st}$ = corrected fraction of outdoor air in system supply

$X = V_{on}/V_{st}$ = uncorrected fraction of outdoor air in system supply

$Z = V_{oc}/V_{sc}$ = fraction of outdoor air in critical space. The critical space is that space with the greatest required fraction of outdoor air in the supply to this space.

V_{ot} = corrected total outdoor air flow rate

V_{st} = total supply flow rate, i.e., the sum of all supply for all branches of the system

V_{on} = sum of outdoor air flow rates for all branches on system

V_{oc} = outdoor air flow rate required in critical spaces

V_{sc} = supply flow rate in critical space

Equation 6-1 is plotted in Fig. 3. The procedure is as follows:

1. Calculate the uncorrected outdoor air fraction by dividing the sum of all the branch outdoor air requirements by the sum of all the branch supply flow rates.

2. Calculate the critical space outdoor air fraction by dividing the critical space outdoor air requirement by the critical space supply flow rate.

3. Evaluate Equation 6-1 or use Fig. 3 to find the corrected fraction of outdoor air to be provided in the system supply.

Rooms provided with exhaust air systems, such as kitchens, baths, toilet rooms, and smoking lounges, may utilize air supplied through adjacent habitable or occupiable spaces to compensate for the air exhausted. The air supplied shall be of sufficient quantity to meet the requirements of Table 2. In some cases, the number of persons cannot be estimated accurately or varies considerably. In other cases, a space may require ventilation to remove contamination generated within the space but unrelated to human occupancy (e.g., outgassing from building materials or furnishings). For these cases, Table 2 lists quantities in cfm/ft² (L/s·m²) or an equivalent term. If human carcinogens or other harmful contaminants are suspected to be present in the occupied space, other relevant standards or guidelines (e.g., OSHA, EPA) must supersede the ventilation rate procedure.

When spaces are unoccupied, ventilation is not generally required unless it is needed to prevent accumulation of contaminants injurious to people, contents, or structure. Design documentation shall specify all significant assumptions about occupants and contaminants.

6.1.3.2 Recirculation Criteria. The requirements for ventilation air quantities given in Table 2 are for 100% outdoor air when the outdoor air quality meets the specifications for acceptable outdoor air quality given in 6.1.1. While these quantities are for 100% outdoor air, they also set the amount of air required to dilute contaminants to acceptable levels. Therefore, it is necessary that at least this amount of air be delivered to the conditioned space at all times the building is in use except as modified in 6.1.3.4.

Properly cleaned air may be recirculated. Under the ventilation rate procedure, for other than intermittent variable occupancy as defined in 6.1.3.4, outdoor air flow rates may not be reduced below the requirements in Table 2. If cleaned, recirculated air is used to reduce the outdoor air flow rate below the values shown in Table 2, the Air Quality Procedure, 6.2, must be used. The air-cleaning system for the recirculated air may be located in the recirculated air or in the mixed outdoor and recirculated airstream (see Fig. 1).

The recirculation rate for the system is determined by the air-cleaning system efficiency. The recirculation rate must be increased to achieve full benefit of the air-cleaning system. The air-cleaning used to clean recirculated air should be designed to reduce particulate and, where necessary and feasible, gaseous contaminants. The system shall be capable of providing indoor air quality equivalent to that obtained using outdoor air at a rate specified in Table 2. Appendix E may be referenced for assistance in calculating the air flow requirements for commonly used air distribution systems.

6.1.3.3 Ventilation Effectiveness, Ev: Outdoor air for controlling contaminant concentration can be used for dilution or for sweeping the contaminants from their source. The values in Table 2 define the outdoor air needed in the occupied zone for well-mixed conditions (ventilation effectiveness approaches 100%). The ventilation effectiveness is defined by the fraction of the outdoor air delivered to the space that reaches the occupied space.

Ventilation effectiveness may be increased by creating a plug flow situation. If the flow pattern is such that the ventilation air flows past the contaminant source and sweeps the contaminant toward an exhaust, the contaminant concentration in the exhaust can be greater than that for the well-mixed condition. Ventilation effectiveness can then be greater than that which would be realized with perfect mixing. Local exhaust systems operate in this way. With perfect mixing between the ventilation air and the air in a space, ventilation effectiveness is 100%. With perfect mixing, $E_v = 1.0$. It is, however, not uncommon to find some of the ventilation air bypassing the occupants (moving from supply to exhaust without fully mixing in the occupied zone) and achieving Ev values as low as 0.5 (see Ref 26). Such flow conditions should be avoided. The ability of the ventilation air to mix in the occupied zone can be improved through recirculation or active mixing of the air in the space. Additional information about ventilation effectiveness can be found in Appendix F.

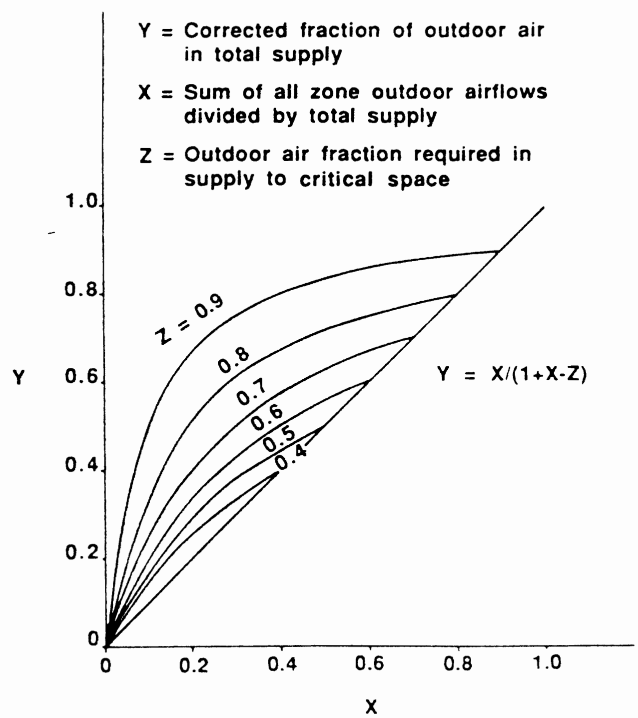

Fig. 3 Ventilation Reduction in Multiple Zones Supplied from a Common Source

6.1.3.4 Intermittent or variable occupancy. Ventilating systems for spaces with intermittent or variable occupancy may have their outdoor air quantity adjusted by use of dampers or by stopping and starting the fan system to provide sufficient dilution to maintain contaminant concentrations within acceptable levels at all times. Such system adjustment may lag or should lead occupancy depending on the source of contaminants and the variation in occupancy. When contaminants are associated only with occupants or their activities, do not present a short-term health hazard, and are dissipated during unoccupied periods to provide air equivalent to acceptable outdoor air, the supply of outdoor air may lag occupancy. When contaminants are generated in the space or the conditioning system independent of occupants or their activities, supply of outdoor air should lead occupancy so that acceptable conditions will exist at the start of occupancy. Figures 4 and 5 show lag or lead times needed to achieve acceptable conditions for transient occupancy (see Appendix G for rationale). Where peak occupancies of less than three hours duration occur, the outdoor air flow rate may be determined on the basis of average occupancy for buildings for the duration of operation of the system, provided the average occupancy used is not less than one-half the maximum. Caution should be exercised for spaces that are allowed to lag and may be affected, due to pressure differences, by contaminants entering from adjacent spaces, such as parking garages, restaurants, etc.

6.2 Indoor Air Quality Procedure: This procedure provides an alternative performance method to the Ventilation Rate Procedure for achieving acceptable air quality. The Ventilation Rate Procedure described in 6.1 is deemed to provide acceptable indoor air quality, ipso facto. Nevertheless, that procedure, through prescription of required ventilation rates, provides only an indirect solution to the control of indoor contaminants. The Indoor Air Quality Procedure provides a direct solution by restricting the concentration of all known contaminants of concern to some specified acceptable levels. It incorporates both quantitative and subjective evaluation.

6.2.1 Quantitative Evaluation. Table 1 furnishes information on acceptable contaminant levels in outdoor air. This table also applies indoors for the same exposure times. For additional information on contaminants in the outdoor air, see 6.1.1. Table 3 contains limits for four other indoor contaminants. Three of these are limits set by other bodies as indicated in the table. The limit for CO_2 was selected based on the rationale outlined in Appendix D. Other potential contaminants for which definite limits have not been set are discussed in Appendix C. Tables C-1 and C-3 do not include all known contaminants that may be of concern, and these concentration limits may not, ipso facto, ensure acceptable indoor air quality with respect to other contaminants.

Human occupants produce carbon dioxide, water vapor, particulates, biological aerosols, and other contaminants. Carbon dioxide concentration has been widely used as an indicator of indoor air quality. A limit of 1000 ppm CO_2 is recommended to satisfy comfort (odor) criteria. In the event CO_2 is controlled by any method other than dilution, the effects of the possible elevation of other contaminants must be considered.

In recent years a number of indoor contaminants have received increased attention and emphasis. Some of these contaminants, such as formaldehyde or other vapor phase organic compounds, are generated by the building, its contents, and its site. Another important group of contaminants is produced by unvented indoor combustion. The presence and use of consumer and hobby products, as well as cleaning and maintenance products, introduce a range of largely episodic releases of contaminants to the indoor environment (see Ref 30).

There are also complex mixtures, such as environmental tobacco smoke (see Ref 31), infectious and allergenic biologic aerosols, emanations from human bodies, and

PROCEDURE

a. Compute the air capacity per person in the space in ft^3 (m^3).
b. Find the required ventilation rate, in cfm (L/s) per person.
c. Enter Figure 2 with these values and read the maximum permissible ventilation lag time after occupancy from the intersection of a and b.

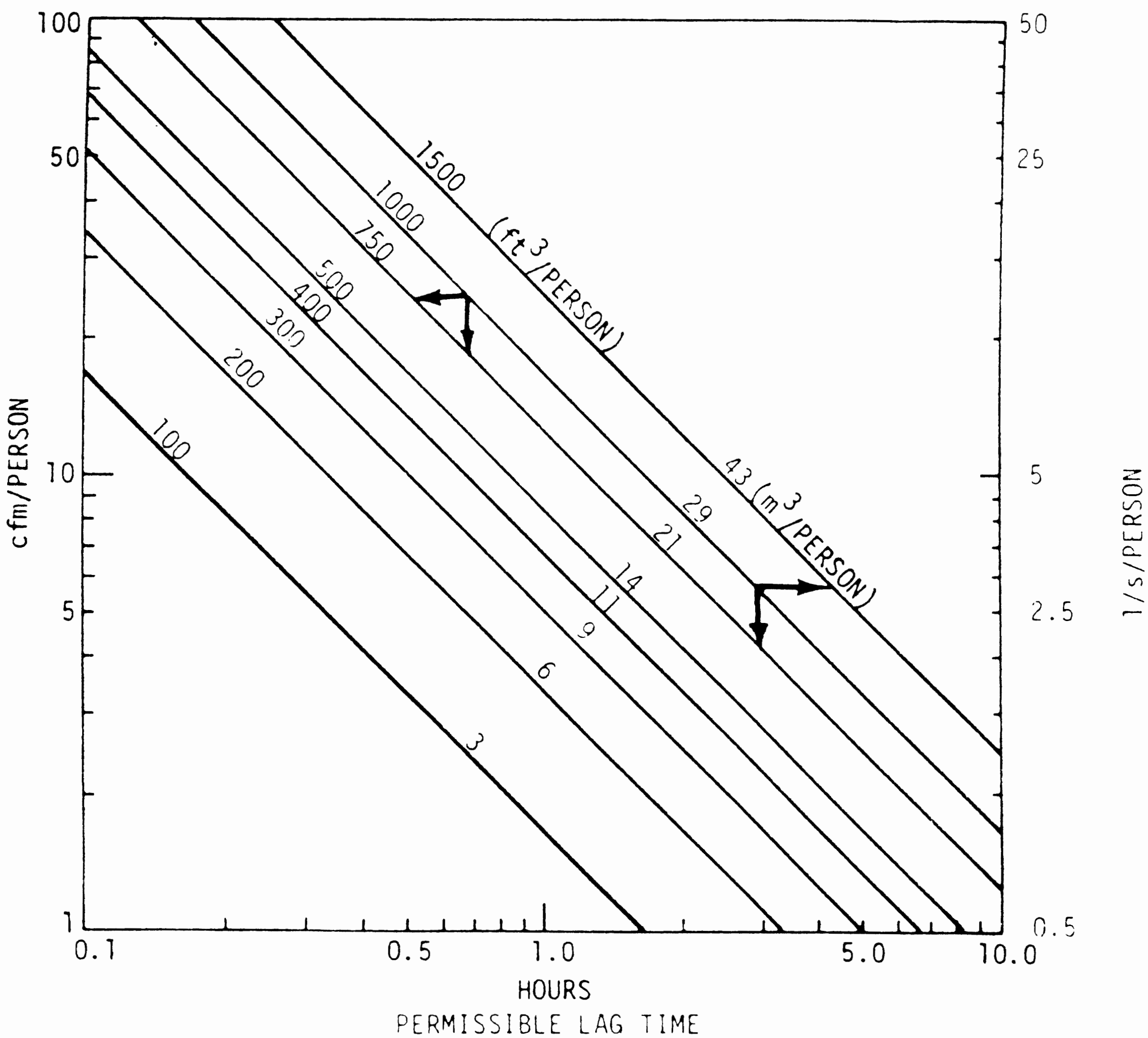

Fig. 4 Maximum Permissible Ventilation Lag Time

TABLE 3
GUIDELINES FOR SELECTED AIR CONTAMINANTS OF INDOOR ORIGIN

Contaminant	Concentration	ppm	Exposure Time	Comments
Carbon Dioxide	1.8 g/m³	1000*	Continuous	See Appendix D
Chlordane	5 ug/m³	0.0003	Continuous	Reference 27
Ozone	100 ug/m³	0.05	Continuous	Reference 28
Radon gas	0.027 WL		Annual Average	Reference 29, Paragraph 12.6 (background 0.002- 0.994WL)

*This level is not considered a health risk but is a surrogate for human comfort (odor). See Section 6.1.3 and Appendix D.

emanations from food preparation. Precise quantitative treatment of these contaminants can be difficult. To some degree, adequacy of control must rest upon subjective evaluation.

In the case of some odorless biologic aerosols, subjective evaluation is irrelevant. Application of generally acceptable technology, and vigilance regarding adverse influences of reduced ventilation, must therefore suffice. Appendix C contains information on standards and guidelines for selected air contaminants. Uniform governmental policies regarding limits on exposure to environmental carcinogens have not yet emerged.

PROCEDURE

a. Compute the air capacity per person in the space in ft³ (m³).
b. Find the required ventilation rate, in cfm (L/s) per person.
c. Enter Figure 3 with these values and read the minimum required ventilation lead time before occupancy from the intersection of a and b.

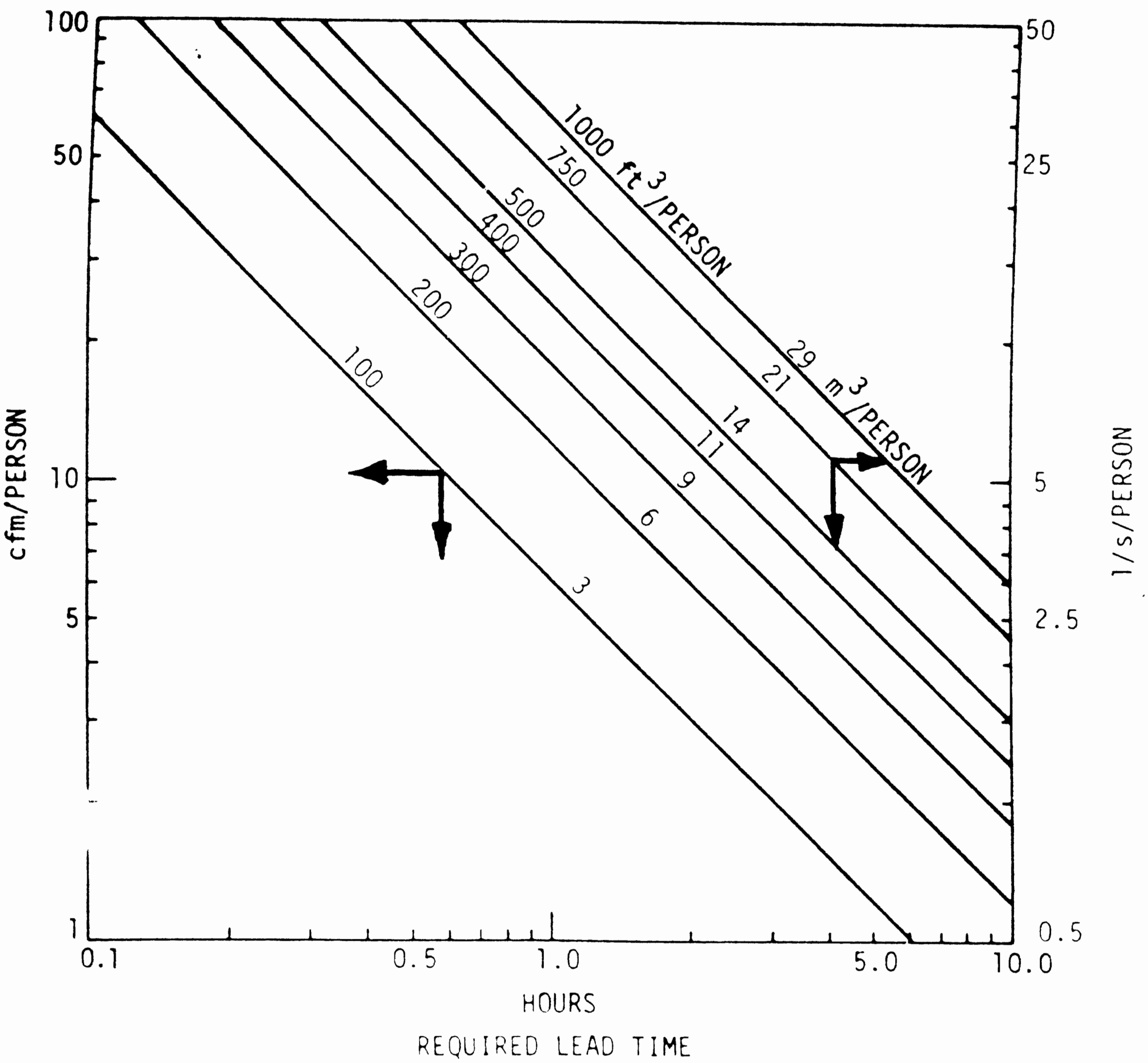

Fig. 5 Minimum Ventilation Time Required Before Occupancy of Space

6.2.2 Subjective Evaluation. Various indoor air contaminants may give rise to odor that is of unacceptable intensity or character or that irritates the eyes, nose, or throat. In the absence of objective means to assess the acceptability of such contaminants, the judgment of acceptability must necessarily derive from subjective evaluations of impartial observers. One method that may be used for measuring subjective response is described in Appendix C. Caution should be used in any subjective evaluation procedure to avoid unacceptable concentrations of other contaminants.

6.2.3 Air Cleaning. Recirculation criteria are defined in 6.1.3.2 for use with the Ventilation Rate Procedure. Recirculation with air-cleaning systems is also an effective means for controlling contaminants when using the Indoor Air Quality Procedure. The allowable contaminant concentration in the occupied zone can be used with the various system models in Appendix E to compute the required outdoor air flow rate. The air-cleaning system efficiency for the troublesome contaminants present, both gaseous and particulate, may be adequate to satisfy the Indoor Air Quality criteria of 6.2.1 and 6.2.2. However, contaminants that are not appreciably reduced by the air-cleaning system may be the controlling factor in design and prohibit the reduction of air below that set by the Ventilation Rate Procedure.

6.3 Design Documentation Procedures. Design criteria and assumptions shall be documented and should be made available for operation of the system within a reasonable time after installation. See Sections 4 and 6 as well as 5.2 and 6.1.3 regarding assumptions that should be detailed in the documentation.

7. REFERENCES

[1] *ANSI/ASHRAE Standard 55-1981, Environmental Conditions For Human Occupancy.* American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., Atlanta, GA. 30329. 1981.

[2] *UL 181, Factory Made Air Ducts and Air Duct Connectors,* March 19, 1984. Underwriters' Laboratories, 333 Pfingsten Rd., Northbrook, IL 60611. 1984.

[3] *NFPA 90A 1978, Standard for the Installation of Air Conditioning and Ventilating Systems.* National Fire Protection Association, Battery March Park, Quincy, MA 02269. 1978.

[4] *NFPA 90B 1980, Standard for the Installation of Warm Air Heating and Air Conditioning Systems.* National Fire Protection Association, Battery March Park, Quincy, MA 02269. 1980

[5] SMACNA Duct Construction Standards: *High-pressure Duct Construction Standards,* third ed., 1975; *Low-pressure Duct Construction Standards,* fifth ed., 1976. Sheet Metal and Air-Conditioning Contractors National Association, Inc., 8224 Old Courthouse Road, Tyson Corners, Vienna, VA 22180. 1975, 1976.

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SECTION 7

ELECTRICAL DESIGN & LIGHTING

Chapter 7

Electrical Design

Introduction

This section describes the designer's responsibility to electrical design issues including, electrical system design, lighting and on-site power generation.

Electrical System Design

The electrical system shall be designed to comply with the requirements of ASHRAE Std. 90.1-1999. The system shall be designed so that the College can independently measure power consumed for lighting, hvac, central plant and other building loads.

The primary power to the building shall be designed to allow central point metering to be installed on the campus in the future.

The College requests that the building be designed to be 480 Volt.

The designer shall include sub-metering pulse capability and monitor kW and kWh through the BAC.

Lighting Design

An appropriately designed lighting system provides both natural and artificial lighting to the desired task in a manner that optimizes efficacy and minimizes electrical and HVAC loads. Controls shall be provided to shut-off or minimize electrical lighting loads when no longer needed. Attachment 7-1, EDG Lighting Design Guidelines provides guidance. The College will review these requirements with the design team and determine specific applicability. The following details apply:

1. ASHRAE Std. 90.1-1999 sets maximum power limits. The designer shall calculate the maximum power limit and design a system that will be 30% less than the allowable limit. The designer should be able to design the system to be less that 1.0 watt/GSF on a building wide basis.

2. Illumination Levels - For normal tasks a design level of 50 footcandle(f.c.) maintained provides adequate lighting. The designer shall provide a list of all of the spaces, their task, and the illumination design level at the schematic design phase.

3. Illumination Sources and Illuminaires - The highest efficacy illumination sources and illuminaires are desired. Normal tasks shall be illuminated with fluorescent lighting sources using high efficiency T-8 tubes and electronic

ballasts. Fluorescent illuminaires shall be 2-tube, parabolic, with deep cell louvers. Other fixtures shall be coordinated with the College's Energy Manager. HID and Metal Halide shall be used for specialty lighting. ASTRALITE LED exit signs shall be specified. Incandescent illumination sources shall not be used without first coordinating their use with the College's Energy Manager.

4. Lighting Layout - The lighting system shall be designed to provide lighting on the task. Fixtures shall be arranged according to the proposed furniture layout in the space. Ceiling grids shall be designed to fit the lighting layout. Hallways shall have 2-tube fixtures on 16 foot centers.

5. Controls and Switching - Motion sensors, daylighting controls, appropriate switching and connections to the BAC shall be included to completely control the building's lighting system. All spaces shall have motion sensor controlled lighting. Rooms with more that two fixtures shall have motion sensors with auxiliary contacts which will be connect to the BAC through spare digital inputs on the local terminal control devices. Exterior lighting shall be controlled by the BAC. An exterior mounted photocell shall be connected to the BAC to signal exterior lighting levels above 1 f.c.

6. Lighting Analysis - The designer shall provide a point-by-point lighting analysis of all IES Category D and above spaces and a zonal cavity analysis of IES Category A,B & C. The exception is hallways where the prescriptive layout applies.

<u>**On-site Power Generation**</u>

1. **Micro-Turbine with Heat Recovery** - The design team shall include a 75-100 kW micro-turbine with exhaust gas heat recovery directed to the outdoor air pre-treatment system. This system shall be mounted on the roof and run on Natural Gas. The College will assist the designer in defining the systems parameters.

2. **Solar Photovoltaics** - The design team shall include a building integrated photovoltaic solar electricity generation system. The system shall be direct connected to the building's electrical grid. The College will assist the designer in defining the systems parmeters.

Attachment 7-1, EDG Lighting Design Guidelines

Lighting Design Guidelines

Contents

Lighting Design Summary Sheet

The Designer should review requirements at the start of each phase and before submitting design for review to ensure completeness and correct procedure.

PreDesign

Phase	Design Element	Synopsis	Method	Section
PD	Coordination	***ENERGY Analyst** must meet with **DESIGN TEAM** for lighting, electrical, HVAC and architecture to review responsibilities by phase listed here.*	Pre-Design Energy Meeting	Design Contract

Schematic Design

Phase	Design Element	Synopsis	Method	Section
SD	Wattage Budget	***LIGHTING Designer**: Your design is limited to 65% of the Wattage Budget calculated by ASHRAE 90.1 Section 6 lighting program. Submit calculation.*	ASHRAE LTGSTD program	A-1 Appendix One
SD	Coordination with HVAC and electrical	***HVAC Designer** must use 65% of wattage budget at SD to calculate cooling load.* ***ELECTRICAL Designer** must use it in transformer calculations.* ***ENERGY Analyst** must make sure the information is transmitted and used.*	W/ft^2 entry into Carrier HAP or DOE2 block load	A-3 B-2
SD	Fixture Selection	*Propose fixtures for "basis of lighting design" meeting Lighting Guidelines:* ■ Parabolic troffers ■ Electronic ballasts/ T8 lamps ■ Compact Fluorescent downlights ■ Exterior Cutoff fixtures ■ No incandescents anywhere	Submit cutsheets of proposed fixtures in SD energy report.	Section B
SD	Light levels	*List <u>proposed</u> illumination levels by task.* ***[Do not perform any calculations or design at this phase.]***	Complete Lotus Spreadsheet for IES light level selections	Section C

Lighting Design Summary Sheet

Design Development

Phase	Design Element	Synopsis	Method	Section
DD	Lighting Layout	Use zonal cavity calculation for IES categories A,B,C (less than 20 fc). Use Localized General Lighting for IES task Categories D and E for non-partitioned desks and individual offices. Use Task-Ambient Lighting for systems furniture, partitioned desks and carrels.	Zonal Cavity Pre-approved layouts. Built in task lighting plus ambient.	D-1 D-2.1 D-2.2
DD	Specifications	You must use available Lighting specifications verbatim for parabolic troffers, ballasts, lamps, occupancy sensors and "EXIT" signs. Other specifications must be provided to meet all guidelines.	Lighting standard specifications and guidelines; hardcopy and diskette provided.	Appendix 2
DD	Wattage Compliance	Demonstrate that actual design lighting wattage for the building falls below the 65% budget set at SD.	Compare actual wattage to budget	A-1
DD	Coordination	**HVAC Designer** must use actual lighting wattage for final cooling loads.	Enter actual W/ft2 room by room	A-3
DD	ON/OFF Controls	All lighting must be subject to automatic ON/OFF control by either: ■ Occupancy sensors (> 300 Watts) ■ Energy Management OFF signal	Show controls in room wiring.	Section F
DD	Daylighting Controls	**Non-Task Daylighting:** Provide Photocell ON/OFF control of fixtures within 8' of windows in non-office areas. Fixture group must exceed 300 Watts per control.	Indicate photocell wiring on plans.	Section G
DD	Manual Switching	Provide wall switches for each room at each entrance. Switches for each task in space. Maximum of 1 kW per switch.	Subdivide spaces	F-1 F-2

Section A - Wattage Budgets

Your design must use 65 % or less of the calculated ASHRAE wattage budgets.

A-1 Wattage Budget at 65% of ASHRAE

Calculate the ASHRAE Standard 90.1 lighting power budget for the total building Interior and Exterior, using the LTGSTD program in Appendix One. Submit printouts with the Schematic Design Energy report. The ASHRAE budgets are typically liberal in that they allow for less efficient fixtures than these Guidelines require. The actual design is permitted to use 65% or less of the ASHRAE wattage budget in each category.

A-2 Limited Decorative Lighting

The use of accent lighting and highlighting is encouraged but must not bring the total design lighting power above 65 % of the appropriate ASHRAE Standard 90.1 level.

A-3 Integration of HVAC and Lighting

The HVAC and electrical load calculations depend directly on the assumed power density of lighting. In order to control first-cost, the correct lighting Watts/ft^2 must be known and used from the earliest stages of design.

3.1 **Communication**. As soon as the 65% Lighting Power Budget has been calculated the **LIGHTING Designer** is directed to send the budget in writing to the designated Energy Analyst on the Consultant's team. The Energy Analyst is responsible for using the 65% lighting power budget at Schematic Design, and the actual lighting wattage at Design Development, in HVAC load, ELECTRICAL and ENERGY calculations.

3.2 **Review**. Energy analysis and HVAC load sizing that is not coordinated with lighting design wattage will be rejected during the Owner's review.

At Schematic Design, all Energy and Load calculations must be based on 65% of ASHRAE Lighting Wattage budgets.

At Design Development, all Energy and Load Calculations must be based on actual lighting wattage.

Failure to coordinate will cause rejection and rework of your submission.

Section B
- Fixtures, Lamps and Ballasts

Responsibilities

The Lighting Designer must:

- **Design**
- **Specify**
- **Verify Installation**

to meet all requirements of Lighting Guidelines.

The Designer must use the Owner's lighting specifications verbatim, starting with Design Development documents.

B-1 Quality Requirement

The standardized lighting selections in this Section have been made on the basis of lowest life-cycle-cost to the Owner. The Owner requires the selected fixtures to be used by the **LIGHTING Designer**. "Cheaper" fixtures are not permitted in design nor as bid alternates.

1.1 Lighting Designer. The **LIGHTING Designer** is responsible for:

(1) designing with approved fixtures, lamps, ballasts and diffusers as described in this section,

(2) providing construction drawings and specifications that require all properties of lamps, ballasts, fixtures and diffusers described in this section verbatim and

(3) verifying all requirements on Contractor's submittals.

1.2 Energy Analyst. The **ENERGY Analyst** on the Consultant's team is responsible for checking drawings and specifications against these fixture requirements prior to submission to the Owner for review.

B-2 Required Specifications.

Appendix Two contains specifications for permitted fixtures, along with approved manufacturers. A WordPerfect copy of the file is included on the enclosed "Required Specifications" diskette, section 16515.

These specifications must appear verbatim in the Design Development documents for the project. These specifications are complete and consistent. Do not modify, add to or delete from these specifications except where directed. Do not try to modify your "standard" lighting specifications to meet these requirements.

Light Fixtures

Required Specifications

"Use these specifications verbatim"

SECTION 16515 - INTERIOR LUMINAIRES

(Note: Provide Part 1 - General **)**

Part 2 - Products

2.01 Parabolic 2x4 Fluorescent Troffers

Fixtures shall be deep-cell true parabolic, including 3" deep specular or semi-specular louver with parabolic cross section. Lamp placement shall correspond with the focal points of the parabolas.

A. Number of Cells:

2x4, 3-lamp fixtures shall have 18 cell louver.
2x4, 2-lamp fixtures shall have 12 cell louver.
1x4, 1-lamp fixtures shall have 6 cell louver.

B. Fixture efficiency, as measured by an independent photometric testing lab, shall be greater than or equal to 70%.

C. Visual Comfort Probability (VCP) shall not be less than 75, either lenghtwise of crosswise at 100 fc in a room 20 feet wide, 40 feet long and 8.5 feet ceiling height, with reflectances of 80/50/20.

D. Contractor shall submit fixture cut sheets showing section through fixture and photometric data from an independent testing laboratory using IES reporting format.

E. Each fixture shall contain a single electronic ballast to fire the required number of lamps.

F. Manufacturer shall be Lightolier, Columbia, Metalux, Lithonia, or Day-Brite.

2.02 Compact Fluorescent Fixtures:

(NOTE: Edit to delete any types not used on this project and/or add additional compact fluorescent fixtures. **)**

A. Recessed Compact Fluorescent Downlight: Lightolier 8055CL-IF 713H or Prescolite CFR813 series downlights with 2, 13W twin tube lamps and specular clear alzak reflector. Minimum photometric efficiency of 70 %. Ballasts: Two 13 W encased and potted ballasts, High Power Factor. Maximum fixture input: 36 Watts.

B. Ceiling Surface Compact Fluorescent: American Scientific Lighting Corp., "DIAMONLITE" catalog number HDI/26. Lens: 0.125" clear non-yellowing acrylic, diamond cut. Metal Housing with bronze finish. Ballast: two PL13 lamp ballasts.

Find complete specifications under FILENAME: 16515.SPC
on the Diskette labelled REQUIRED SPECIFICATIONS.

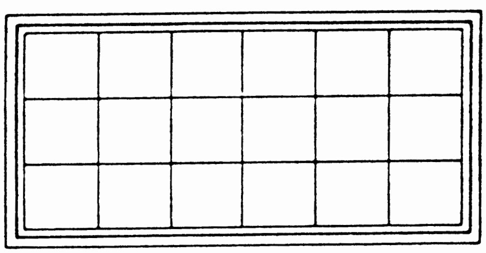
B-2 First-Cost Control

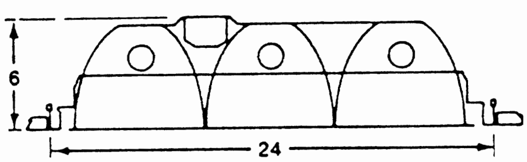
The high-efficiency fixtures specified here need not cost the project more than standard fixtures when project expenses are viewed as a whole. The superior optical control provided by parabolic diffusers and cut-off fixtures allows wider fixture spacing, localized lighting design and fewer total fixtures, typically 25 % less. The combined effect of fewer, lower-wattage fixtures produces significant first-cost reductions in air-conditioning systems and electrical distribution systems. The net effect of high-efficiency lighting fixtures is <u>first-cost reduction for the overall project</u>.

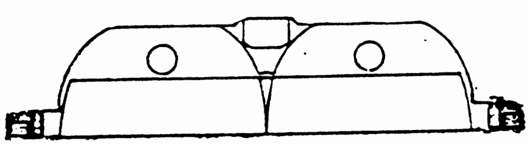
Which Fixture is Really Cheaper?

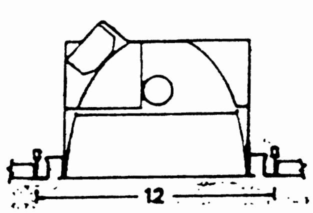
Lamp:	T8	T12
Ballast:	Electronic	Efficient
Diffuser:	<u>Parabolic</u>	<u>Acrylic</u>
Cost per Fixture	$111	$60
# of Fixtures	750	1050
Total Fixture Cost	**$83,250**	**$63,000**
Total Watts	62 kW	173 kW
HVAC First Cost	$442,000	$505,000
Total Project Cost	**$525,250**	**$568,000**

[Based on 100,000 sf office building]









B-3 Fluorescent Troffers

APPLICATIONS: Offices, conference rooms, corridors, general office lighting.

Deep-cell parabolic fixtures using electronic ballasts and 4-foot T8 lamps constitute the office lighting system with the lowest life-cycle cost as well as the lowest power density and excellent potential for reducing peak cooling capacity and project first cost. These conclusions are based on a comprehensive study of lighting alternatives conducted by the Owner, comparing all types of lamps, ballasts and fixtures on the basis of total project first-cost and life-cycle cost in realistic situations. The designer is required to use the selected system for all fluorescent troffer applications.

3.1 **<u>Fixture</u>: The fixture may contain 1, 2 or 3-T8 lamps,** depending on the light level sought. The parabolic louver shall be minimum 3" deep and contain one row for each lamp, with the lamp located at the focus of the parabolic curve. Fixture photometric efficiency must be 70% or higher.

3.2 **<u>Diffuser</u>: Parabolic Louvers** provide high fixture efficiencies with excellent light distribution that assists the "localized" lighting approach required by these Guidelines. Properly positioned, parabolic fixtures can provide high-quality light that is free of glare and veiling reflections. The high

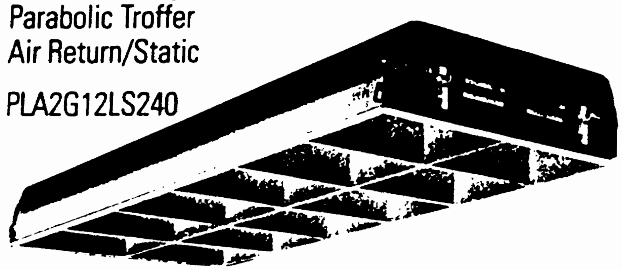
10

[redacted]

Paralyte 2448

2' x 4', 2 Lamp
Parabolic Troffer
Air Return/Static

PLA2G12LS240



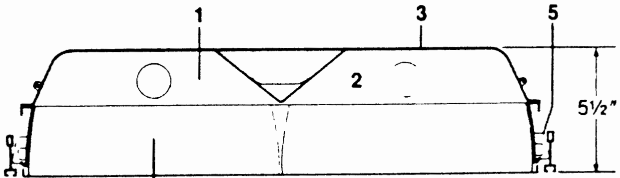
Application

- Areas where the low brightness appearance of a louver versus a lens is desired. Also the appearance of a full size louver versus a floating louver.
- Areas where VCP is important such as accounting, drafting, classrooms and libraries.
- Areas where maintained footcandle levels required are approximately:

62 maintained footcandles	8' x 10' fixture spacing	RCR1
77 maintained footcandles	8' x 8' fixture spacing	RCR1

Features

1. Individual lamp compartments.
2. 81.9% efficient. 82 minimum VCP.
3. 5¹/₂" deep embossed one-piece housing.
4. Precision contoured low iridescence aluminum parabolic louver.
5. Built-in automatic centering system.



Spec Sheet Section 2/G50-62

Specification	Existing 10 Year Old Lens Troffer 2' x 4', 4 Lamp Not Cleaned New Lamps	Paralyte 2448 with Standard Lamps 2' x 4', 2 Lamp PLA2G12LS240LE		Paralyte 2448 with Octron Lamps 2' x 4', 2 Lamp PLA2G12LS240OC	
Ballast Type	Standard	ESB	Electronic	Octic	Electronic
Lamp Type	40 W	40 W	40 W	Octron	Octron
Fixture Efficiency	38	81.9	81.9	78.9	78.9
Spacing to Mounting Ht.	1.4	1.7	1.7	1.7	1.7
Maint. Footcandles	53	62	62	55	55
Average VCP	85	90	90	93	93
Input Watts/Fixture	188	88	72	70	61
Watts/Sq. Ft.	2.35	1.10	0.90	0.88	0.76
S Savings/Fixture/Year	Base	$35.00	$40.60	$41.30	$44.45
Pay Back in Years*	Base	2.0	2.2	1.8	2.1
Utility Rebate					

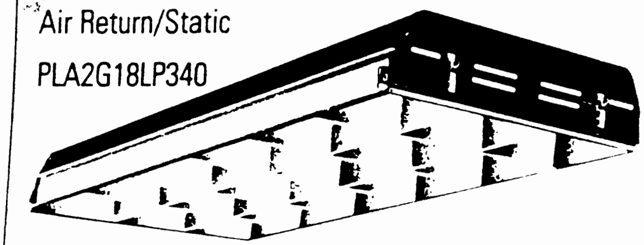
**Does not include utility company rebates or installation costs*

Footcandles based on room size 56' x 56' x 8'6" ceiling.
Fixtures 8' x 10' on centers. For 8' x 8' centers, multiply by 1.25
Savings based on $0.10/KWH, 3,500 hours per year.

Paralyte 2448

2' x 4', 3 Lamp
Parabolic Troffer
Air Return/Static

PLA2G18LP340



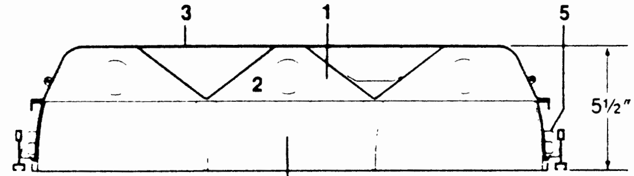
Application

- Areas where the low brightness appearance of a louver versus a lens is desired. Also the appearance of a full size louver versus a floating louver.
- Areas where VCP is important such as accounting, drafting, classrooms and libraries.
- Areas where maintained footcandle levels required are approximately:

74 maintained footcandles	8' x 10' fixture spacing	RCR1
93 maintained footcandles	8' x 8' fixture spacing	RCR1

Features

1. Individual lamp compartments.
2. 74.9% efficient. 86 minimum VCP.
3. 5¹/₂" deep embossed one-piece housing.
4. Precision contoured low iridescence aluminum parabolic louver.
5. Built-in automatic centering system.



Spec Sheet Section 2/G50-63

Specifications	Existing 10 Year Old Lens Troffer 2' x 4', 4 Lamp Cleaned† New Lamps	Paralyte 2448 with Standard Lamps 2' x 4', 3 Lamp PLA2G18LP340LE		Paralyte 2448 with Octron Lamps 2' x 4', 3 Lamp PLA2G18LP340OC	
Ballast Type	Standard	ESB	Electronic	Octic	Electronic
Lamp Type	40 W	34 W	34 W	Octron	Octron
Fixture Efficiency	55.6	74.9	74.9	73.3	73.3
Spacing to Mounting Ht.	1.4	1.5	1.5	1.5	1.5
Maint. Footcandles	77	74	74	76	76
Average VCP	80	92	92	92	92
Input Watts/Fixture	188	111	88	107	86
Watts/Sq. Ft.	2.35	1.39	1.10	1.34	1.08
S Savings/Fixture/Year	Base	$26.95	$35.00	$28.35	$35.70
Pay Back in Years*	Base	2.8	2.7	3	2.8
Utility Rebate					

**Does not include utility company rebates or installation costs.*

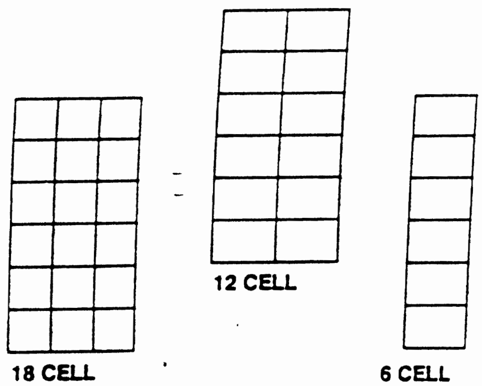
Footcandles based on room size 56' x 56' x 8'6" ceiling.
Fixtures 8' x 10' on centers. For 8' x 8' centers, multiply by 1.25.
Savings based on $0.10/KWH, 3,500 hours per year.

†Lens and interior surface of body cleaned when relamping.

LIGHTOLIER

Spacing Criterion of parabolic louvers permits very wide fixture spacing yielding uniform illumination with a reduced number of fixtures.

Specular vs. Semi-Specular. Specular louvers offer better CRT glare protection than semi-specular louvers, but will appear to be darker in the ceiling plane. Either type is permissible.



Cell Depth and Number. The cell depth of the parabolic louver must a minimum of 3". The 3-lamp fixture shall contain 18 cells, 2-lamp shall contain 12 cells, and 1-lamp fixture shall contain 6 cells.

The following louver types <u>must not be accepted</u> as alternatives: Specular "egg-crate" louvers with less than 3" cells, e.g., "paracube" diffusers (3/4 to 1" grid). These louvers provide an unacceptably low fixture efficiency.

Use of Acrylic Prismatic Lenses. Acrylic prismatic lenses may be used in non-task areas where illumination of walls is specifically desired, e.g. in storage rooms or near bulletin boards.

Thick-Coat T8 Lamps are Superior

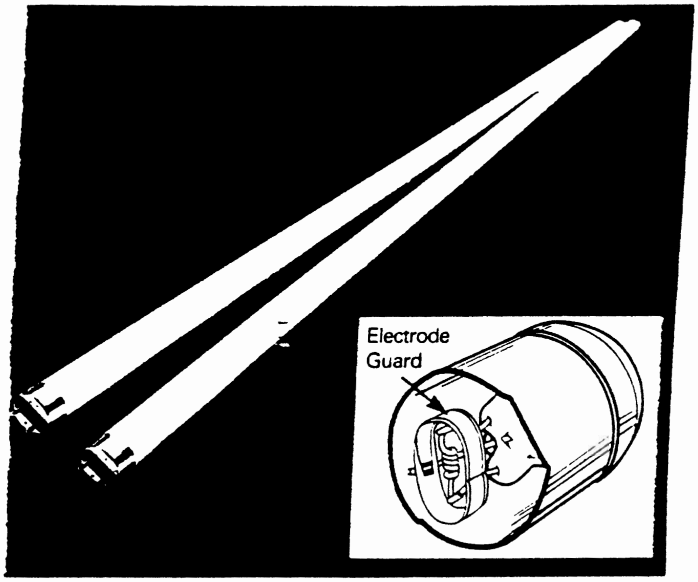
Lamp Type	CRI	Design Lumens	Fixture Watts
F40 T12	60	2650/lamp	92
F40 T12 ES	60	2300/lamp	77
F32T8/TL735	75	2600/lamp	62
F32T8/TL835	**85**	**2850/lamp**	**62**

[Based on 2-lamp fixture with electronic ballast]

3.3 <u>**Lamps**</u>: Thick-Coat **T8 lamps** are economical, high-efficiency lamps with superior maintained light output (2850 lumens). They cost about the same as 34 W, T12 "energy-saving" (ES) lamps, yet produce far more light at less wattage and have a superior Color Rendering Index (CRI). Thick-coat T8 (TL835) lamps are required in all four-foot fluorescent applications.

3.4 <u>**Ballasts**</u>: **Electronic Ballasts** are a proven technology that boosts lighting efficiency 25% over standard ballasts. Discrete T8-ballasts provide a fixed, lower amperage appropriate to T8 lamps. The reduced electrical load is permanent and can be confidently used in electrical and cooling load calculations.

TL 80 Series Fluorescent Lamps



Definition

A blend of rare-earth phosphors combined in a one-inch diameter tube, makes it possible for the Philips TL 80 lamp to produce a light output of 3050 lumens, efficacies of more than 100 LPW* and a color rendering index of 85

Description

The TL 80 is available in four sizes (2', 3', 4' and 5') and in three color temperatures (3000K, 3500K and 4100K

The new TL 80 lamp combines the best features of high lumen output, lumen maintenance, and color rendering, making it the preferred lighting choice for new construction and retrofit applications

Features[1]	Benefits
• Reduced System Wattage	• Reduced operating costs up to 43% savings
• Over 100 LPW* Lamp Efficacy	• More efficient use of energy • Lower energy costs
• Increased Light Output (3050 Lumens)	• Increased light levels to aid visibility • Less fixtures needed - reduces new construction cost
• Trichromatic Phosphors (CRI 85)	• High quality of light • Better merchandise appeal • Increased worker productivity and comfort
• Electrode Guard	• Greater maintained light over lifetime 93% at 5,000 hours • Improved overall lamp appearance due to reduced end darkening
• Reduced Diameter (T-8)	• Increased luminaire efficiencies (2 5% higher) due to optics • Reduced transportation, inventory and storage costs • Ease of handling and installation

Applications

TL 80 lamps are ideal for office buildings, retail stores, hospitals and other applications where energy savings and quality lighting are of importance

The F17T8 and F32T8 TL 80 lamps are ideally suited for use and retrofit in conventional 2' x 2' and 2' x 4' luminaires, respectively. The F40T8 TL 80 lamp is designed for 5 foot construction modules that meet the 1500 mm universal standard length

All lamp sizes are perfect as task lighting for modular office furniture and combinations of the four sizes (2', 3', 4' and 5') can be used in indirect, strip and cove lighting applications and applications where "filling the space" is of importance

TL 80 System Circuitry

TL 80 lamps, because of their 0 265 amp operating current, require special ballasts that are different than conventional T12 ballasts. This is common for any one inch diameter lamp

Magnetic and electronic ballasts for the T8 lamp operation on 120 and 277-volt line inputs are available through several manufacturers. However, the optimum efficacy performance of over 100 LPW is achieved by operating the TL 80 lamp on parallel electronic ballasts. It is this combination (TL 80 lamp-electronic parallel ballast) that constitutes the Philips TL 80 System

[illegible]

[illegible]

PHILIPS

Lamp Type	No. of Lamps	Line Voltage	Catalog Number	Input Watts: Std. Lamps FIXT	Input Watts: Std. Lamps ANSI	Input Watts: E.S. Lamps FIXT	Input Watts: E.S. Lamps ANSI	Line Amps Nom.	Line Amps Max.	Min. Start. Temp.	Wiring Diag. Pages 9 & 10	Notes

OCTIC For use with OCTIC type (265 mA) T8 lamps, 2 to 5 feet in length..

Lamp Type	No. of Lamps	Line Voltage	Catalog Number	Std. FIXT	Std. ANSI	E.S. FIXT	E.S. ANSI	Nom.	Max.	Min. Start. Temp.	Wiring Diag.	Notes
F017T8 (2' or U) (17 watt)	2	120	B2321120	32	34			.30	.34	0°F	8	a,b
		277	B2321277					.13	.15			
	3	120	B3321120	48	50			.45	.50	0°F	9	a,b
		277	B3321277					.19	.21			
	4	120	B4321120	60	62			.56	.63	50°F	10	a,b
		277	B4321277					.24	.27			
F025T8 (3' or U) (25 watt)	1	120	B2321120	29	30			.27	.30	0°F	7	a,b
		277	B2321277					.12	.13			
	2	120	B2321120	46	48			.43	.48	0°F	8	a,b
		277	B2321277					.19	.21			
	3	120	B3321120	66	68			.61	.68	0°F	9	a,b
		277	B3321277					.26	.29			
	4	120	B4321120	87	90			.81	.91	50°F	10	a,b
		277	B4321277					.35	.39			
F032T8 (4' ~~or U~~) (32 watts)	1	120	B2321120	37	39			.34	.38	0°F	7	a,b
		277	B2321277					.15	.17			
	2	120	B2321120	58	62			.54	.60	0°F	8	a,b
		277	B2321277					.24	.27			
	3	120	B3321120	86	89			.78	.87	0°F	9	a,b
		277	B3321277					.34	.38			
	4	120	B4321120	109	114			1.00	1.12	50°F	10	a,b
		277	B4321277					.43	.48			
F040T8 (5') (40 watts)	1	120	B2321120	42	44			.39	.44	0°F	7	a,b
		277	B2321277					.17	.19			
	2	120	B2321120	69	73			.64	.72	0°F	8	a,b
		277	B2321277					.28	.31			
	3	120	B3321120	104	108			.95	1.06	0°F	9	a,b
		277	B3321277					.41	.46			

COMPACT For use with 18 to 40 watt biaxial compact lamps.

Lamp Type	No. of Lamps	Line Voltage	Catalog Number	Std. FIXT	Std. ANSI	E.S. FIXT	E.S. ANSI	Nom.	Max.	Min. Start. Temp.	Wiring Diag.	Notes
F18BX (18 watts)	2	120	B2321120	34	35			.31	.35	50°F	12	a,b,i
		277	B2321277					.14	.16			
	3	120	B3321120	50	51			.46	.52	50°F	13	a,b,i
		277	B3321277					.20	.22			
F27BX (27 watt)	2	120	B2321120	40	41			.36	.40	50°F	12	a,b,i
		277	B2321277					.16	.18			
	3	120	B3321120	60	61			.54	.60	50°F	13	a,b,i
		277	B3321277					.23	.26			
F39BX (39 watt)	2	120	B2321120	51	52			.46	.52	50°F	12	a,b,e,i
		277	B2321277					.20	.22			
	3	120	B3321120	76	77			.68	.76	50°F	13	a,b,e,i
		277	B3321277					.29	.32			
F40BX (39 watt)	1	120	B2321120	41	43			.39	.43	50°F	11	a,b,i
		277	B2321277					.17	.19			
	2	120	B2321120	70	72			.63	.70	50°F	12	a,b,i
		277	B2321277					.27	.30			
	3	120	B3321120	103	105			.92	1.03	50°F	13	a,b,i
		277	B3321277					.40	.45			

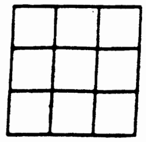
Notes:

a. Parallel lamp connections allow remaining lamps to stay fully lit if companion lamps fail.

b. CSA (Canadian Standard Asociation) certified (120 volt model only).

e. This lamp/ballast combination yields approximately 70% light output due to difference in lamp current rating. All others in this family yield full light output or more.

i. Consult factory for information regarding other compact types (18 to 40 watt).



9 CELL

- Ceiling downlights
- Wall sconces
- Hallway lighting
- Entrance
- Under-counter lighting
- Desktop task lighting
- Post lamps
- Decorative fixtures

B-4 2'x2' BIAX Fixture Option

APPLICATIONS: Use of 2'x2' fixtures is discouraged due to the high replacement cost of non-4-foot lamps. BIAX fixtures may be used only in areas where space does not permit alternatives.

Use 9-cell deep parabolic fixtures with three BIAX lamps. U-tube lamps are <u>not</u> an acceptable alternative to BIAX lamps.
A compatible 3-lamp electronic ballast is required.

B-5 Compact Fluorescent Fixtures

APPLICATIONS: Compact fluorescent lamps and ballasts must be used in all downlights, wall-washers, sconces, and surface-mounted compact fixtures.

5.1 **<u>Downlights</u>**. Downlights shall be compact fluorescent type with 2 PL-13 S twin-tube lamps on separate ballasts. Minimum photometric efficiency shall be 70%. Reflector shall be clear ALZAK aluminum. No tints, baffles or louvers are permitted.

Dimming Substitute. Rooms requiring variable light levels from downlights shall be provided with compact fluorescent downlights with two lamps on separate ballasts and separately switched to provide three light levels [OFF-ON-ON].

5.2 **<u>Surface Rounds</u>**. Surface-mounted round lights shall be compact fluorescent type with 2 PL-13 S twin-tube lamps. Reflector plate shall be white enameled aluminum. Diffuser shall be clear prismatic glass or polycarbonate. No opal or non-transparent diffusers are permitted.

5.3 **<u>Sconces</u>**. Wall-mounted decorative and accent lights shall be compact fluorescent type with 2 PL-13 S twin-tube lamps.

5.4 **<u>Task Lights</u>**. Task lights located under cabinets or shelves on typing stands shall be compact fluorescent type with 1 or 2 PL-13 S twin-tube lamps.

SIMPLUX®/8

recessed compact fluorescent downlight/wallwasher

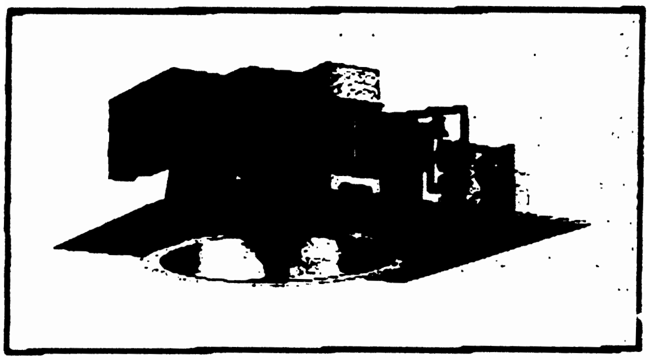
FEATURES

Simplux/8 is a highly efficient 8" aperture low brightness downlight, designed for use with two 13-watt twin-tube compact fluorescent lamps. The fixture provides shielding angles of 35° parallel to and 40° perpendicular to the lamps. Recess depth is only 5 5/8".

One housing allows interchangeably use of downlight and wallwash reflectors, permitting housings to be installed first and reflectors to be installed or changed at any time.

Simplux/8 uses two 13-watt twin-tube lamps providing 1800 lumens (more than a 100-watt incandescent), and it consumes only 34 watts when operated at 120 volts. Twin-tube lamps have a 10,000-hour life, a color rendering index (CRI) of 85, and are available in a range of color temperatures as warm as 2700°K, nearly duplicating the color qualities of incandescent.

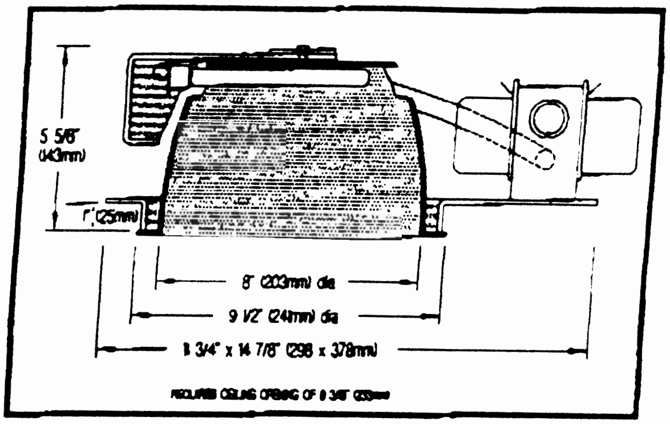
Reflectors are available in clear natural aluminum or champagne gold Alzak® with Color-Chek® anodizing, virtually eliminating iridescence. Wallwash reflectors available are: wallwash (120°) and double wallwash (2x120°) for corridor lighting.



APPLICATIONS

Fixture is suitable for downlighting or wallwashing in offices, stores, lobbies, corridors, restrooms and public areas. The shallow recess depth allows mounting in constricted plenum situations.

Fixture is UL listed for Damp Location (may not be suitable for some outdoor environments). Fixture is union made IBEW and in compliance with the component based efficiency standards of the 1991 New York State Energy Conservation Code. Fixture is prewired with high power factor Class P ballasts and approved for eight #12 wire 75°C branch circuit pull-through wiring. Removal of the reflector allows access to the ballasts and junction box.



PRODUCT CODE

For a complete product code, list the basic unit and select one code item from each of the following boxes.

Basic Unit Simplux/8

Reflector Type
- Wallwash .... WW
- Downlight .... no suffix
- Double Wallwash .... DWW

Voltage
- 120 volt service 120
- 277 volt service 277

Reflector and Flange Color

	Overlap	Flush
Clear	COL	CFL
Champagne Gold	GOL	GFL

Standard reflector flange continues reflector finish. White painted flanges and custom painted flanges are available on special order. Add WF (white flange) or CCF (custom color flange).

Example: Simplux/8 WW 277 COL WF is the complete product code for a wallwash fixture with a clear reflector and white painted overlap flange, suitable for 277 volt operation.

OPTIONS

Specify by adding to the basic unit.

Emergency battery pack operates one lamp in the event of power outage. Not available with DWW reflector. Recess depth increases to 7 5/16" (186mm), plus an additional 2 1/4" (57mm) to remove EM pack through aperture. Not for outdoor application .... – EM

1/8" (3mm) thick **clear acrylic shield**, spring-mounted within reflector .... – PS

EDISON PRICE LIGHTING

409 EAST 60 STREET, NEW YORK NY 10022 TEL 212 838 5212 FAX 212 888 798'

SIMPLUX/8

PHOTOMETRIC REPORT

Independent Testing Laboratories Report No. 38342

Lamps .... two 13-watt compact fluorescent (PL or TT), GX-23 base, 900 lumens each
Efficiency 72.1%
Spacing Criteria .... 0°-1.9, 90°-1.8, 180°-1.7
Axis orientation .... 0° plane is parallel to lamps, opposite sockets

BALLAST INFORMATION

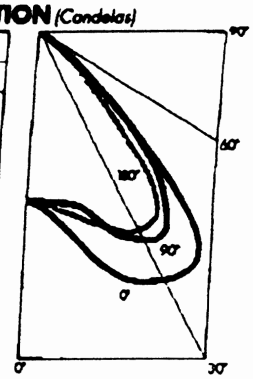
Voltage	120	277
Input Watts	34	44
Line Current (A)	.28	.17
Power Factor (%)	>90	>90
Min. Starting Temp.(°F)	32	32

ZONAL LUMEN SUMMARY

Zone	Lumens	%Lamp	%Fixture
0-30°	516	28.7	39.7
0-40°	948	52.7	73.0
0-60°	1298	72.1	100.0
0-90°	1298	72.1	100.0

CANDLEPOWER DISTRIBUTION *(Candelas)*

Vertical Angle	Horizontal Angle 0.0	90.0	180.0
0	477	477	477
10	548	489	510
20	713	552	578
30	806	676	643
40	768	611	536
50	216	165	85
60	2	2	0
70	0	0	0
80	0	0	0
90	0	0	0



LUMINANCE DATA *(Candelas/m²)*

Vertical Angle	Average 0° Latitude	Average 90° Latitude	Average 180° Latitude
45	21468	19313	10650
55	1980	625	625
65	0	0	0
75	0	0	0
85	0	0	0

To convert cd/m2 to footlamberts multiply by 0.2919.

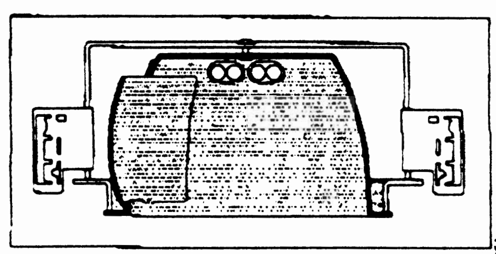
COEFFICIENTS OF UTILIZATION – ZONAL CAVITY METHOD
Effective Floor Cavity Reflectance 20%

Ceiling Reflectance (%)	80				70				50			30			10			0
Wall Reflectance (%)	70	50	30	10	70	50	30	10	50	30	10	50	30	10	50	30	10	0
Room Cavity Ratio																		
0	86	86	86	86	84	84	84	84	80	80	80	77	77	77	74	74	74	72
1	81	79	77	75	79	77	75	74	74	73	71	71	70	69	69	68	67	66
2	76	72	68	65	74	70	67	65	68	65	63	66	64	62	64	62	60	59
3	71	65	61	57	69	64	60	57	62	59	56	60	58	55	59	56	54	53
4	66	59	55	51	65	59	54	51	57	53	50	55	52	49	54	51	49	47
5	62	54	49	45	60	54	49	45	52	48	45	51	47	44	50	46	44	43
6	57	50	44	40	56	49	44	40	48	43	40	47	43	40	46	42	39	38
7	54	45	40	36	52	45	40	36	44	39	36	43	39	36	42	38	36	34
8	50	42	36	33	49	41	36	33	40	36	32	39	35	32	39	35	32	31
9	47	38	33	30	46	38	33	30	37	33	29	36	32	29	36	32	29	28
10	44	35	30	27	43	35	30	27	34	30	27	34	30	27	33	29	27	25

SIMPLUX/8 WW

WALLWASH INFORMATION

Distance From Ceiling (Feet)	2'6" From Wall; 2'6" O.C. Below Fixture	2'6" From Wall; 2'6" O.C. Between Fixtures	3' From Wall; 3' O.C. Below Fixture	3' From Wall; 3' O.C. Between Fixtures	4' From Wall; 3'6" O.C. Below Fixture	4' From Wall; 3'6" O.C. Between Fixture
1	18	17	12	11	6	6
2	19	20	13	13	8	8
3	27	27	17	17	9	9
4	26	25	19	19	11	10
5	21	21	18	17	12	12
6	16	16	15	15	12	12
7	12	12	12	12	11	11
8	9	9	10	10	9	10
9	7	7	8	8	8	8
10			6	6	7	7
11			5	5	6	6
12			4	4	5	5



All vertical footcandles are initial values with no contribution from ceiling or floor reflectances. Computation performed with a total of five wallwashers.

5.5 **PL Lamp Type**. The compact lamp type should be limited to PL 13 twin tube only, for economy of lamp replacements and simplicity of stocking.

5.6 **PL Ballast**. Ballasts for 13 Watt compact fluorescent lamps shall be "High Power Factor" type in all downlights.

B-6 Wall Lighting Fixtures

APPLICATIONS: Lighting vertical surfaces along walls such as bulletin boards, marker boards, directories, merchandise, bookcase, and so on.

Use a recessed fluorescent wall-lighting fixture such as the Lightolier "Wal-Lyter" (see description sheet following) utilizing BIAX lamps. This fixture produces more uniform lighting of wall surfaces more efficiently than either fluorescent or incandescent round "wall-washer" fixtures or spots or floods. Significantly fewer fixtures are required, reducing first cost as well as energy costs.

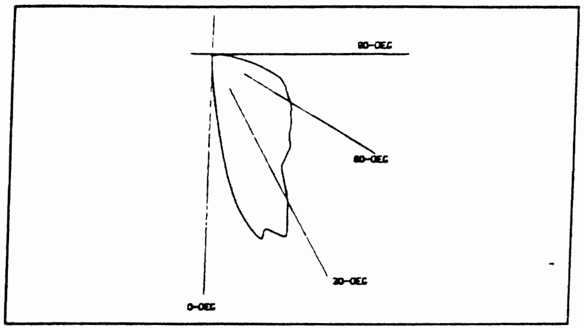
The BIAX lamps also have a 20,000 hour rated life, greatly reducing maintenance over smaller compact fluorescent lamps (10,000 hours) or incandescent bulbs (1,000 to 3,000 hours). Also, far fewer total lamps are needed since each F40BX BIAX lamp produces as much light as three PL-13 Watt lamps or two 100 Watt incandescent lamps.

6.1 **BIAX Lamp Type**. Use a two-foot BIAX lamp with 3500 color temperature, equivalent to Phillips PL-L 40W/35.

6.2 **BIAX Ballast Type**. Use a discrete electronic ballast designated for BIAX lamps. Tandem-wire fixtures using 2- or 3-lamp ballasts where feasible.

WLRN124120BX WAL-LYTER
RECESSED WALLWASHER/ACCENT LIGHT

PHOTOMETRY



MODEL NO. WLRN124120BX

coefficients of utilization—zonal cavity method

	RF	20			20			30		
	RC	80			50			30		
	RW	70	50	30	50	30	10	50	30	10
room cavity ratio	1	74	71	68	66	64	62	64	62	60
	2	67	61	57	58	54	51	55	52	49
	3	61	54	48	51	46	42	49	45	41
	4	56	47	41	45	39	35	43	38	35
	5	51	41	35	39	34	29	38	33	29
	6	46	37	30	35	29	25	33	29	25
	7	42	32	26	31	25	21	30	25	21
	8	39	29	23	27	22	18	26	22	18
	9	35	26	19	24	19	15	24	19	15
	10	33	23	17	22	17	13	21	16	13

FOOTCANDLES ON WALL **Fixtures: 3 feet from wall to outside trim on lamp side of fixture**

Ceiling	INDIVIDUAL WAL-LYTER 0'	1'	2'	3'	4'	5'	6'	7'	8'	MULTIPLE UNITS 4'					MULTIPLE UNITS 6'							CONTINUOUS ROW 0'	1'	2'	3'	4'	5'	6'	7'	8'
8'	76	67	46	25	14	8	5	4	3	107	104	102	104	107	86	79	63	50	63	79	86	204	204	209	208	212	208	209	204	204
7'	64	60	46	29	17	10	7	5	4	102	104	106	104	102	78	75	67	58	67	75	78	201	203	208	208	212	208	208	203	201
6'	47	44	36	24	17	12	8	6	4	85	86	88	86	85	63	62	57	48	57	62	63	165	166	173	172	177	172	173	166	165
5'	33	34	29	24	14	10	8	6	5	66	74	74	74	66	49	50	48	48	48	50	49	132	142	140	148	145	148	140	142	132
4'	26	28	23	20	14	11	8	6	5	59	65	62	65	59	42	45	42	40	42	45	42	113	124	121	130	126	130	121	124	113
3'	19	21	20	17	12	9	8	6	5	48	53	56	53	48	35	36	37	34	37	35	35	96	100	104	106	109	106	104	100	96
2'	15	16	15	13	11	9	8	6	5	42	44	46	44	42	31	31	31	26	31	31	31	80	82	88	88	93	88	88	82	80
1'	13	12	11	11	10	8	7	6	5	38	37	36	37	38	27	26	26	22	26	26	27	67	68	74	74	79	74	74	68	67
Floor																														

ORDERING INFORMATION

Explanation of Catalog Number Example: WLRN124120BXGLR

WL	R	N	1	2	4	120		
WAL-LYTER: Non-iridescent specular wallwash	**RECESSED**	**REFLECTOR:** N = Non-iridescent specular, standard	**LAMPS**	**LENGTH:** 2 = 24"	**WATTS:** 4 = 40 watts	**VOLTAGE:** 120 or 277	**BALLAST/LAMP:** (For 40 Watt Lamp) BX = Biax Type SB = Electronic Biax	**OPTIONS:** Add appropriate suffix to catalog no., ie: (GLR)

OPTIONS/ACCESSORIES

FUSING Internal fast-blow fusing SUFFIX GLR
Internal slow-blow fusing SUFFIX GMF
RADIO INTERFERENCE FILTER 120 or 277 volt 60 or 50 Hz One per fixture standard SUFFIX RF
ELECTRICAL/WIRING Consult factory
FLUORESCENT EMERGENCY LIGHTING SYSTEM Factory-installed emergency power battery pack with charger and inverter SUFFIX EM
DRYWALL FRAME. Catalog Number WL2DF

optional drywall frame (WL2DF)

SPECIFICATIONS

MATERIALS. Chassis parts are die-formed 20 gauge cold rolled steel with integral adjustable hanger clamp Reflectors are Genisal 1 non-iridescent specular aluminum laminate.

FINISH: Chassis exterior—phosphate undercoating, baked white acrylic enamel Reflector—non-iridescent specular is standard

ELECTRICAL. Rapid start HPF thermally protected class "P" ballast (Biax type) If K O s are within 3" of ballast, use wire suitable for at least 90°

LABELS I.B E W Listed by Underwriters Laboratories.

LIGHTOLIER®
a GENLYTE company

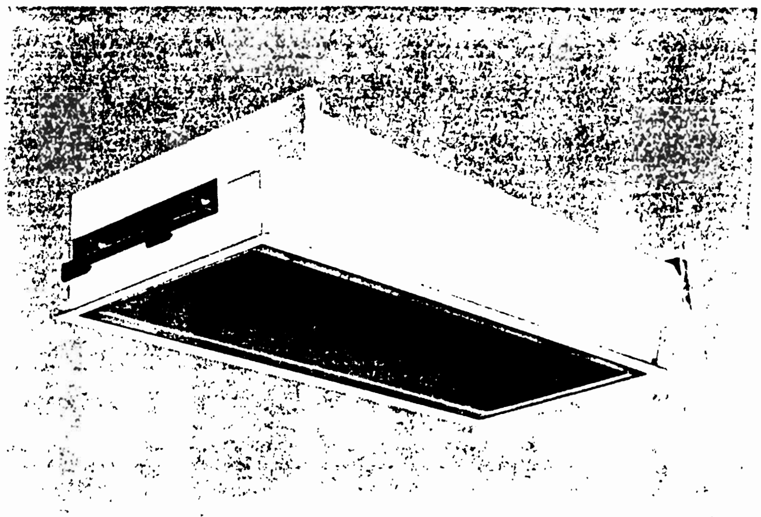
INDUSTRIAL WAY, WILMINGTON, MA 01887 • (508) 657-7600
100 LIGHTING WAY, SECAUCUS, NJ 07094 • (201) 864-3000

Printed in U S A 10M 1/91

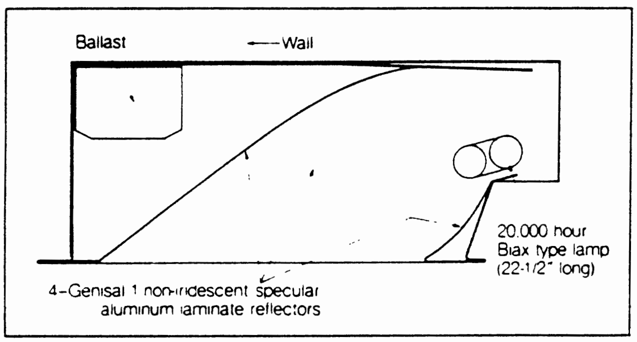
WLRN124120BX

WAL-LYTER
HIGH PERFORMANCE
RECESSED WALLWASHER/ACCENT LIGHT
ONE BIAX TYPE LAMP

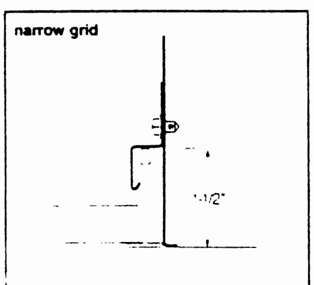
- Non-iridescent specular reflector system for precise controlled light output.
- Evenly lights vertical surfaces or displays
- 87% energy savings vs. incandescent.
- 3,150 lumen Biax type lamp-requires fewer fixtures to provide the same wall illumination as a 150 watt incandescent wallwasher.
- 20,000 hours lamp life requires less maintenance than incandescent.
- Fits all lay-in grid ceiling systems.
- One-piece body and integral hanger for easy, quick installation.
- UL-Listed access plate.
- Meets NYC Code requirements.

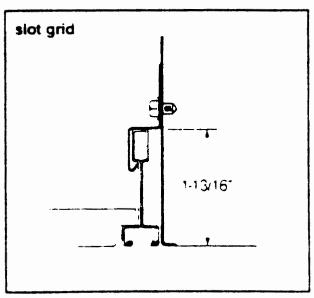


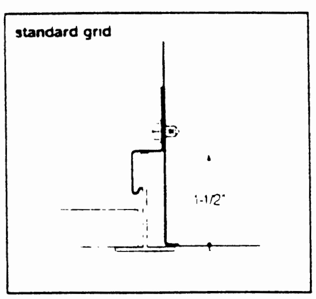
FEATURES

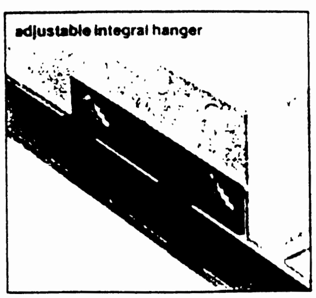


MOUNTING METHODS



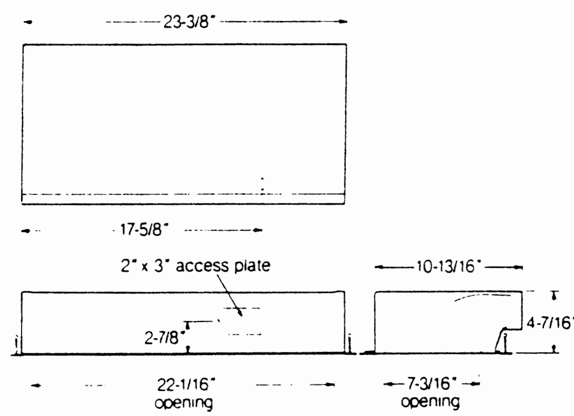






DIMENSIONS

All K.O.s are ⅞" unless otherwise noted.



FIXTURE SCHEDULE		
TYPE	CATALOG NO.	VOLTS

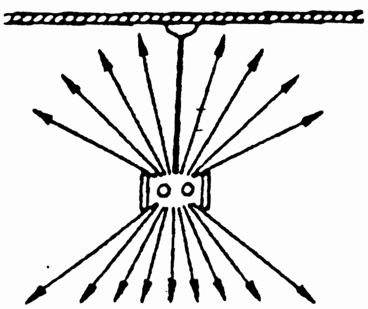
REMARKS

LIGHTOLIER®
a GENLYTE company

B-7 Pendant Direct/Indirect Fixtures

APPLICATIONS: Classrooms, library stacks, partitioned office areas, and areas without a normal drop ceiling due to daylighting, roof monitors, etc.

Parabolic Direct/Indirect Fixtures provide exceptionally high fixture efficiency, high-quality glare-free lighting and very wide fixture spacing. The uniformity of lighting is convenient in large areas with movable task surfaces such as desks and low partitions.



7.1 **Fixtures**: 4-foot pendant-mounted with Parabolic Louver: Lightolier Paralyte S/P PLM/PLJ series UPLIGHT/DOWNLIGHT or approved equal. PERFORMANCE: In an installation with a room cavity ratio of 1, with reflectance of 80% ceiling, 50% wall, and 20% floor, the luminaire shall have a minimum Coefficient of Utilization of 0.83. Minimum Visual Comfort Probability (VCP) shall be 94 at 100 fc.

7.2 **Diffuser**: Semi-specular 8-inch wide parabolic louver, made of Coilzak or equal.

7.3 **Lamps**: Thick-Coat T8, 4-foot 3500 K.

7.4 **Ballast**: Electronic discrete T8 ballast by a manufacturer listed in the Lighting System Specifications, Appendix Two. Tandem wire pendant fixtures to avoid 1-lamp ballasts.

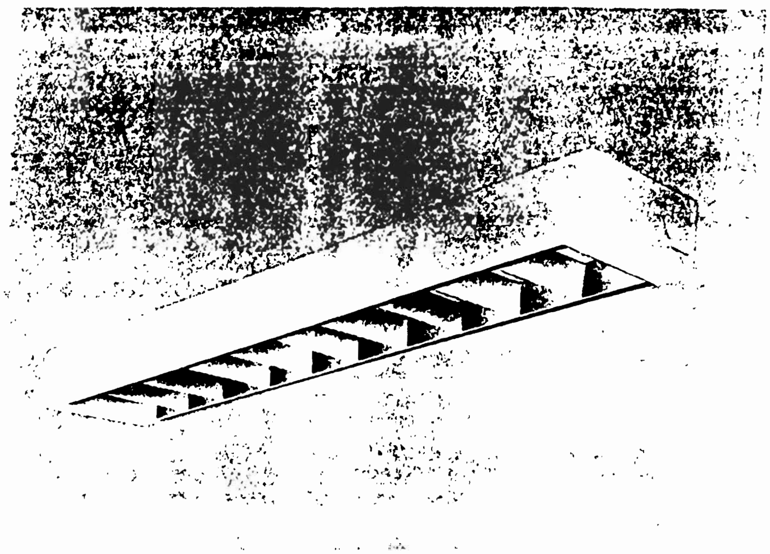
51

PARALYTE S/P

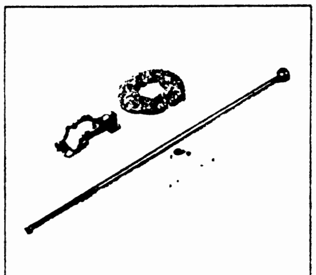
SAME AS 18121
18123
18133

UPLIGHT/DOWNLIGHT PENDANT
4⅝" DEEP, 10" WIDE,
48" OR 96" NOMINAL LENGTHS
1 LAMP RAPID START OR T8

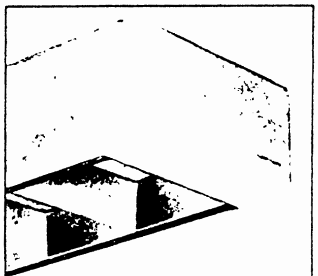
- Uplight/downlight pendant.
- Softly rounded corners and edges create a subtle architectural appearance.
- No visible fasteners.
- Self-aligning ends for hairline joints in continuous row mounting.
- Efficiency 87.3% (48" length).
- Spacing ratio 2.4.
- Transverse mounted ballast (eliminates unbalanced side-to-side linear weight distribution.
- 20 gauge body
- Die-cast aluminum end caps.
- Pre-anodized low iridescence semi-specular aluminum parabolic louver with protective film dust bag (standard).
- Spring-loaded latches.
- Bead safety chain allows louver to be suspended safely for relamping.



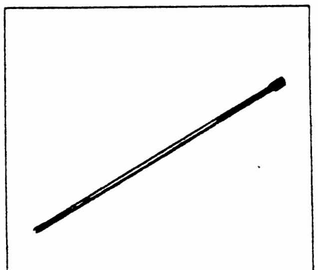
MOUNTING METHODS/FEATURES



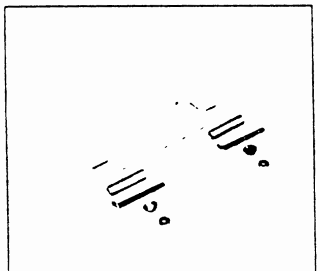
pendant mounting stem sets (optional). Catalog Number: 18048.



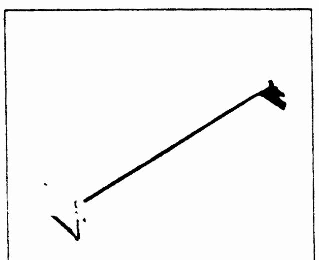
end cap (2 provided with PLM, none provided with PLJ). Catalog Number: 18002.



pendant mounting stem extension (optional). Catalog Number: 18148.

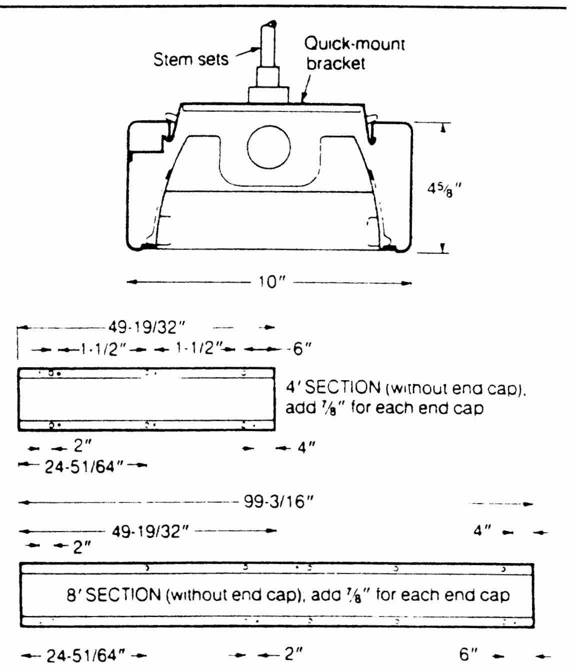


joiner spline (1 provided with PLJ). Catalog Number: 18030.



quick mount bracket (2 provided with PLM, one provided with PLJ). Catalog Number: 18099.

DIMENSIONS



FIXTURE TYPE	VOLTS
JOB INFORMATION	

LIGHTOLIER a GENLYTE company

PLM/PLJ SERIES

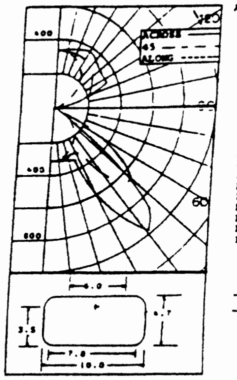
PARALYTE S/P
4⅝" DEEP, 10" WIDE, 48" OR 96" NOMINAL LENGTHS

PHOTOMETRY

ENVIRONMENTAL RESEARCH LABORATORIES
7410 E. HELM DRIVE
SCOTTSDALE, AZ 85260 (602)948-3471

TEST REPORT NO. 7211

LIGHTOLIER PRODUCTS FLUORESCENT FIXTURE
CAT# PLM8P10LX140 WITH 10 CELL SEMISPECULAR LOUVER
1) F40T12CW LAMP, & 1) ADVANCE RM-140-4-TP BALLAST



CANDLEPOWER SUMMARY

ANGLE	ALONG	22.5	45	67.5	ACROSS	TOTAL OUTPUT LUMENS
0	330	330	330	330	330	
5	326	327	327	328	328	31
15	305	308	316	324	328	[illegible]
25	276	284	309	337	360	[illegible]
35	243	264	384	702	815	296
45	192	238	642	873	909	432
55	127	293	494	236	89	272
65	44	123	30	23	14	61
75	2	4	4	5	3	5
85	0	1	1	1	1	[illegible]
90	0	0	0	0	0	
95	8	43	47	46	44	49
105	46	113	197	208	210	169
115	99	162	244	321	350	232
125	157	212	272	325	347	237
135	211	249	314	348	361	230
145	258	284	332	374	384	204
155	289	304	330	353	362	154
165	313	320	331	341	345	94
175	331	332	335	336	337	31
180	335	335	335	335	335	

TABULATION OF LUMENS IN MAJOR ZONES

ZONE	LUMENS	% LAMP	% LUMINAIRE
0-30	275	8.7	10.0
0-40	571	18.2	20.8
0-60	1277	40.6	46.5
0-90	1346	42.8	49.0
90-180	1403	44.6	51.0
0-180	2750	87.3	100.0

** EFFICIENCY = 87.3 % **

CIE CLASSIFICATION: DIRECT-INDIRECT

LAMP LUMEN RATING: 3150

INPUT WATTS: 49.6

PREPARED FOR:
KEENE LIGHTING
WILMINGTON, MA

SC(ALONG)=1.2,SC(ACROSS)=2.4

LUMINANCE SUMMARY - FOOTLAMBERTS

ANGLE	ALONG	45	ACROSS
45	427	1426	2019
55	348	1355	245
65	163	115	52
75	14	24	19
85	14	22	22

DATE: OCT 09, 1986

TESTED IN ACCORDANCE WITH IES PROCEDURES FOR RELATIVE PHOTOMETRY WHERE LAMP IS RATED AT LAMP MANUFACTURERS LUMEN OUTPUT. ABSOLUTE LUMENS MAY BE OF A DIFFERENT VALUE FOR LAMP-BALLAST COMBINATION AND SHOULD BE

MODEL NO. PLM8P10LX140

coefficients of utilization — zonal cavity method

RF	20			20			20		
RC	80			50			30		
RW	70	50	30	50	30	10	50	30	10
room cavity ratio 1	86	83	80	65	63	61	54	53	52
2	79	73	68	58	54	52	48	46	44
3	73	65	59	52	48	45	44	41	38
4	66	58	51	46	42	38	39	36	33
5	61	50	44	41	36	32	34	31	28
6	56	45	38	36	31	28	30	27	24
7	51	40	33	32	27	23	27	23	20
8	46	35	28	28	23	20	24	20	17
9	42	31	25	25	20	17	21	17	14
10	39	28	22	22	18	14	19	15	12

visual comfort probability (VCP) average 100 fc: reflectances 80/50/20

room size W	L	luminaires lengthwise: ceiling height 8.5	10.0	13.0	16.0	luminaires crosswise: ceiling height 8.5	10.0	13.0	16.0
20	20	91	88	83	92	90	89	81	71
20	30	91	91	85	84	91	91	85	77
20	40	92	91	85	86	92	91	88	80
20	60	93	92	86	86	93	92	88	81
30	20	91	91	85	86	90	91	83	71
30	30	91	92	87	79	91	92	86	77
30	40	93	92	87	82	93	92	89	80
30	60	93	93	87	83	93	93	89	80
30	80	93	93	88	83	94	93	80	81
40	20	91	91	86	87	90	91	85	73
40	30	92	92	88	81	91	92	88	78
40	40	93	92	89	84	93	92	90	81
40	60	94	93	89	84	94	93	90	82
40	80	94	93	90	85	94	93	91	82
40	100	94	93	90	85	94	93	91	82
60	30	91	92	89	83	92	92	88	81
60	40	94	92	89	86	93	92	90	84
60	60	94	93	89	86	94	93	90	84
60	80	94	93	91	86	94	93	91	84
60	100	95	93	90	86	94	94	91	85
100	40	94	92	89	86	94	93	90	84
100	60	94	94	90	86	94	94	90	84
100	80	95	94	91	86	94	94	92	84
100	100	95	94	91	87	94	94	92	85

ORDERING INFORMATION Explanation of Catalog Number Example: PLM8P10LX140120LEGLR

PL		8	P	10		X	1				
PARALYTE S/P: Surface/ Pendant with 2" Deep Parabolic Precision Contoured Pre-anodized Aluminum Louver	BODY STYLE: M=Individual Module J=Joiner Module	8" WIDE LOUVER	FIXTURE MOUNTING: P=Pendant	NUMBER OF CELLS: 10 (48" Length)	LOUVER FINISH:* L=Low Indescence Semi-specular (standard) S=Specular P=Low Indescence Specular	TOP REFLECTOR: X=None	LAMP QUANTITY	LAMP/ FIXTURE LENGTH: 40=(Nominal 48") 42=(Nominal 96") 2-48" Lamps in tandem	VOLTAGE: 120 or 277	BALLAST TYPE: LE=Energy Saving OC=Octic SS=Electronic SO=Electronic Octic	OPTIONS: Add appropriate suffix to catalog no., ie: (GLR)

*Consult factory for availability of louver finishes

OPTIONS/ACCESSORIES

STEM SETS: ½" diameter tubing, 18" long, chrome plated finish. CATALOG NUMBER: 18048.
STEM EXTENSION KIT: 18" extension. CATALOG NUMBER: 18148.

ELECTRICAL/WIRING OPTIONS. Consult factory
FUSING.
Internal fast-blow fusing. SUFFIX. GLR.
Internal slow-blow fusing. SUFFIX. GMF

SPECIFICATIONS

PERFORMANCE: In an installation of 1 lamp 40W luminaires with a room cavity ratio of 1, with reflectance 80% ceiling, 50% wall, 20% floor, the C.U. shall be not less than .8[illegible]. To reduce glare the VCP shall be not less than [illegible] either lengthwise or cross-wise (at 100fc level) and the average brightness at 65° shall not exceed 163 footlamberts. To control veiling reflections, luminaire output in the 30°-90° zone shall be not less than 90%.

MATERIALS: Chassis parts are die-formed 20 gauge code cold rolled steel. End caps are die-cast aluminum with soft rounded corners. Louver — pre-anodized aluminum (Coilzak® or equal).

FINISH: Louver — low iridescence semi-specular anodized aluminum (standard). Chassis exterior — semi-gloss off-white baked enamel. Cavity — white baked enamel. Phosphate undercoating.

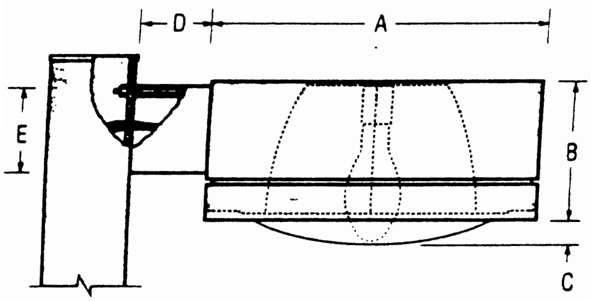
ELECTRICAL. Rapid start HPF, LE (energy saving where applicable) thermally protected class "P" ballast C.B.M. certified by E.T.L. If K.O. is within 3" of ballast, use wire suitable for at least 90°C.

LABELS. I.B.E.W. Listed by Underwriters Laboratories.

LIGHTOLIER®
a GENLYTE company
INDUSTRIAL WAY, WILMINGTON, MA 01887 • (508) 657-7600
100 LIGHTING WAY, SECAUCUS, NJ 07094 • (201) 864-3000

PRINTED IN USA 10M 1/92

B-8 Exterior Lighting



8.1 **<u>Use HPS Lamps</u>**. High Pressure Sodium (HPS) lamps shall be used for all parking lots, walkways and site lighting. Metal Halide lamps may be used for lighting building entrances and facades.

8.2 **<u>Exterior Fixtures</u>**. Use fixtures with high-quality optics to maximize fixture spacing and minimize the number of fixtures. A spacing-to-mounting-height ratio of 5 to 1 should be possible.

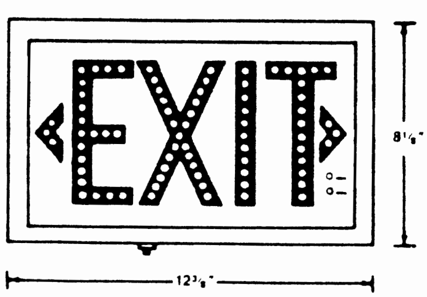
Pole fixtures shall be <u>vertical burn</u> for best optics, *Quality Lighting Design 123* or equal. Mounting height should be 10' to 25'.

Wall Fixtures shall be *Sylvania AlleyKat* for maximum spacing with lowest total cost.

8.2 **<u>Glare Control</u>**. All exterior fixtures shall have a cut off angle of 75 degrees or less to prevent glare and inefficient light distribution.

This criteria <u>eliminates</u> the use of "Wall-pak", globe, ground-mounted and bollard fixtures.

"Tilt up" of any fixture head is <u>prohibited</u> due to glare and "light pollution" liabilities.

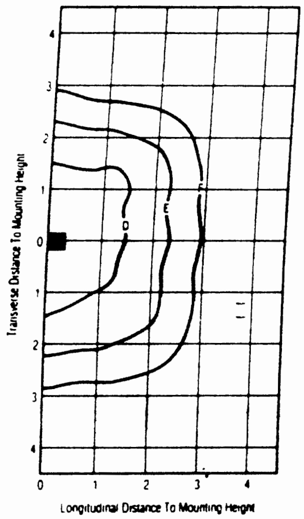


B-9 Exit Signs

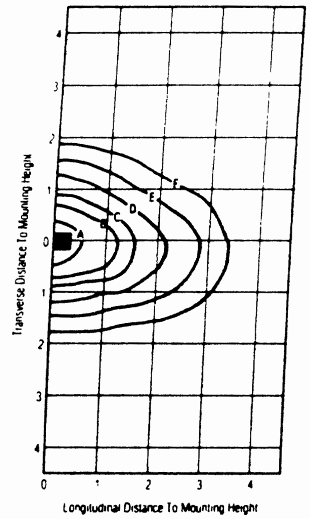
Exit signs shall be of LED type, UL listed, 7 Watts or less power consumption for single-faced signs, 20 year warranty, solid state design. Use Guide specifications verbatim.

Photometric Data

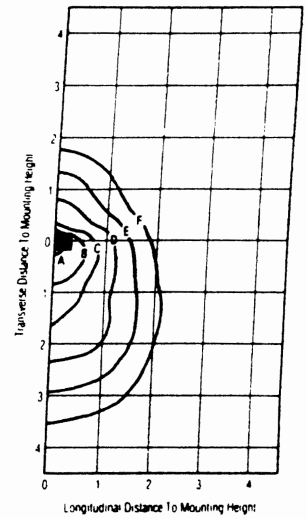
Luminaires: Designs 123,124,125,126
Distribution Pattern: Type VS
Lamp: 400W MH (40,000 lumens)
Bulb/Base: BT-37/Mogul
Report Number: L9433



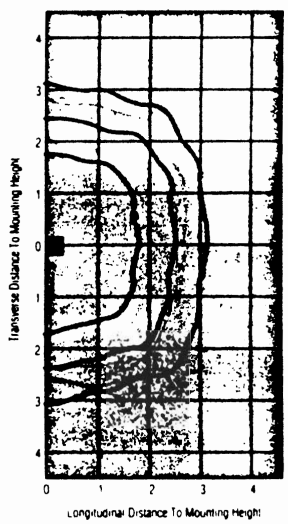
Luminaires: Designs 123,124,125,126
Distribution Pattern: Type 3
Lamp: 400W MH (40,000 lumens)
Bulb/Base: BT-37/Mogul
Report Number: LA3159



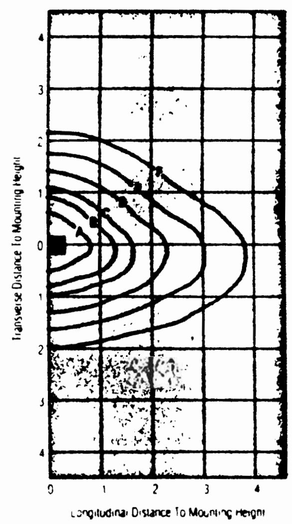
Luminaires: Designs 123,124,125,126
Distribution Pattern: Type F
Lamp: 400W MH (40,000 lumens)
Bulb/Base: BT-37/Mogul
Report Number: I28485A



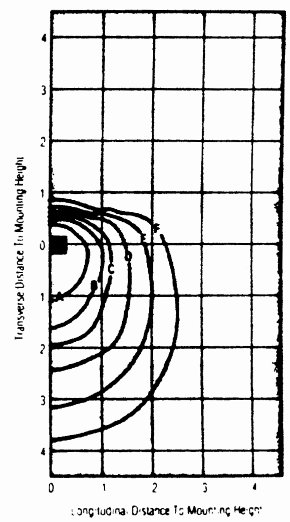
Luminaires: Designs 123,124,125,126
Distribution Pattern: Type VS
Lamp: 400W HPS (50,000 lumens)
Bulb/Base: E-18/Mogul
Report Number: L9488



Luminaires: Designs 123,124,125,126
Distribution Pattern: Type 3
Lamp: 400W HPS (50,000 lumens)
Bulb/Base: E-18/Mogul
Report Number: L3316



Luminaires: Designs 123,124,125,126
Distribution Pattern: Type F
Lamp: 400W HPS (50,000 lumens)
Bulb/Base: E-18/Mogul
Report Number: L5898



Footcandle Conversion Chart – Footcandles are initial

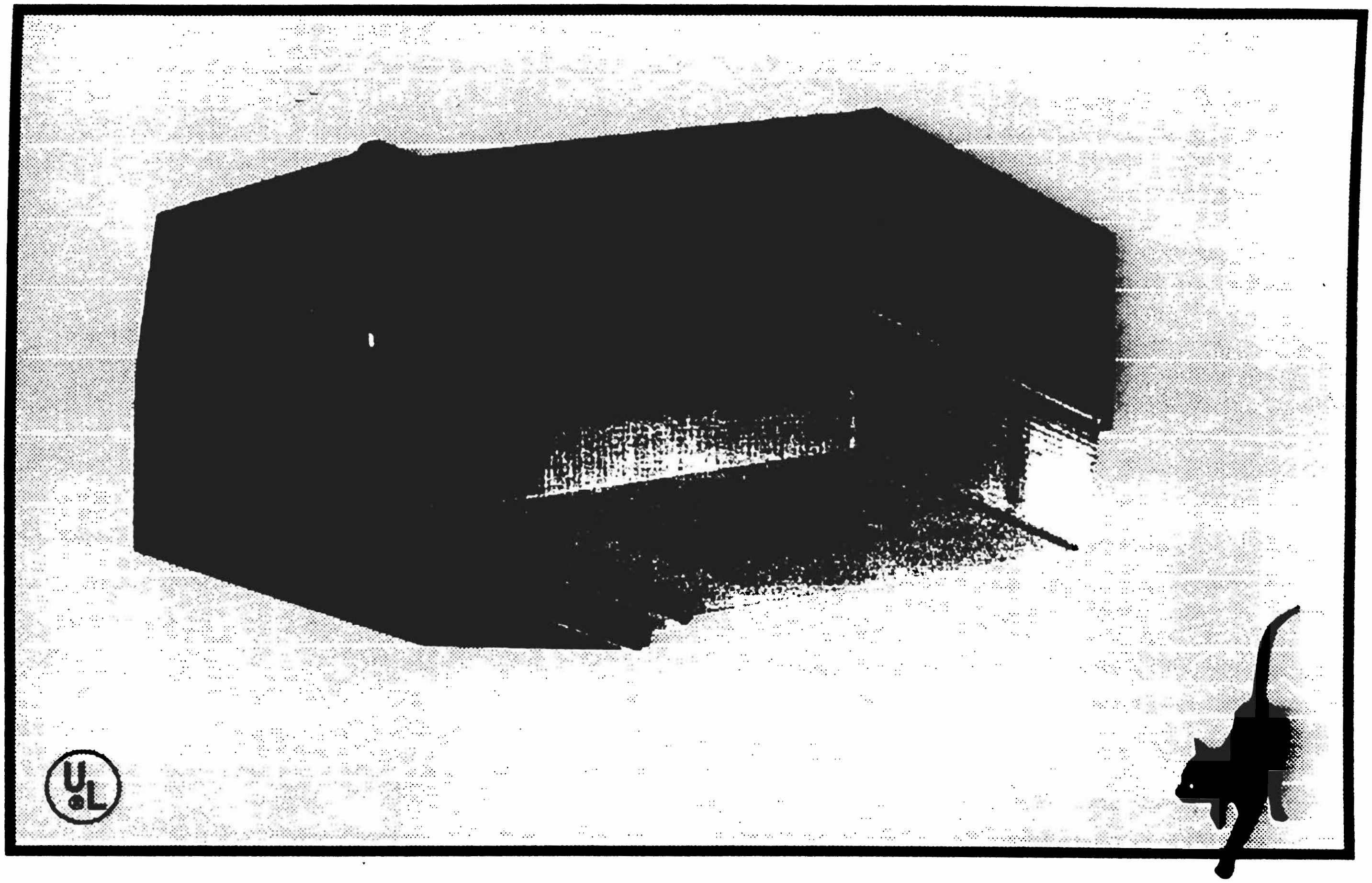
[illegible]	Mounting Heights 20'	25'	30'	35'	40'	45'	50'	60'
A	11 25	7 20	5.00	3.65	2 80	2 20	1.80	1 30
B	6.75	4.32	3.00	2.19	1.68	1.32	1.08	0.80
C	4 50	2 88	2 00	1 46	1 12	0 88	0 72	0 50
D	2.25	1.44	1.00	0.73	0.56	0.44	0.36	0.30
E	1 13	0 72	0 50	0 37	0 28	0 22	0 18	0 10
F	0.56	0.36	0.25	0.19	0 14	0 11	0.09	0 06

Quality Lighting. QL/MWC 11530 Melrose Av. Franklin Park, IL 60131
Phone (708) 451-0040 FAX (708) 451-6768

Powerlite

Member of the Kaufel Group of Companies

AlleyKat



■ More Light, Fewer Fixtures...

Coordinated reflector and refractor system provide a highly efficient, controlled light distribution... Allows spacing of up to **8 times mounting height.**

■ Energy Efficient...

Optics designed to deliver maximum lumens to the task. Pay only for light you use.

■ Prewired and Prelamped for fast installation...

■ All hardware included for 3 versatile mounting positions...

The basic unit comes complete with mounting hardware to accommodate all three mounting positions; vertical, horizontal or pole.

Powerlite Inc.

Emergi Lane • P.O.Box 548 • Westbrook, CT 06498 • Phone (203) 399-7991 • Fax (203) 399-0082

Powerlite

the difference AlleyKat® optics make:

Figures 1 and 2 clearly show the difference AlleyKat® optics make for a typical application. Both fixtures use an efficient 70-watt, 6,300-lumen, medium base high pressure sodium lamp powered by a 12-watt ballast system. Other than appearance and weight, there are three important points of difference:

(1.) Fixture A costs 18% less than the AlleyKat®

(2.) AlleyKat® has a precision optical system which will save the user 30 to 50 percent on electricity.

(3.) Fixture A drops a pool of light under the fixture with little spreading to the right and left. AlleyKat® provides uniform smooth coverage over a much larger area. It covers twice the area at strong illumination levels at half the energy per-square-foot rate.

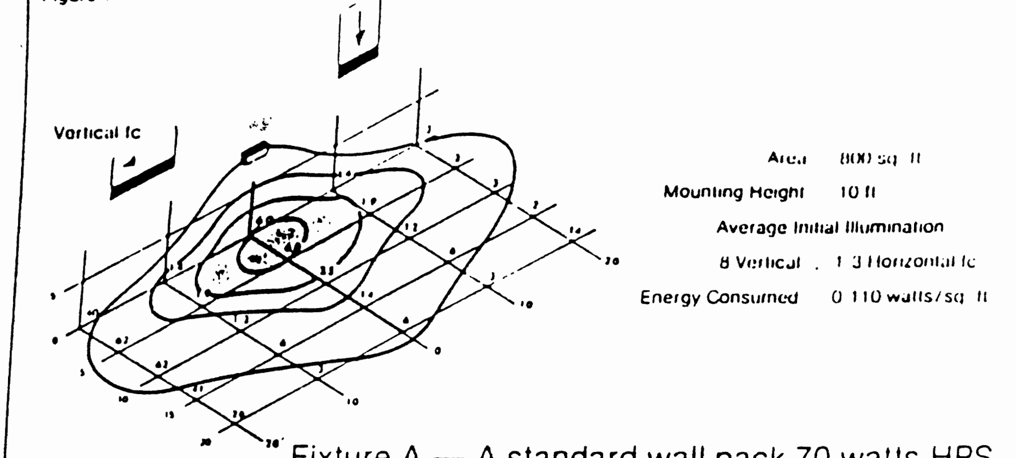
Pay for only the light you need!

Only the Sylvania AlleyKat® lighting system gives you the sophicticated optical performance and lowest energy cost to illuminate your specific task. No waste, no blinding glare, as is found with typical dusk-to-dawn fixtures.

When you make your decision on the basis of reducing your monthly power bill while providing sufficient illumination, you'll choose the Sylvania AlleyKat® lighting system.

There is no other fixture like it. You see the result in uniform light distribution without wasteful glare

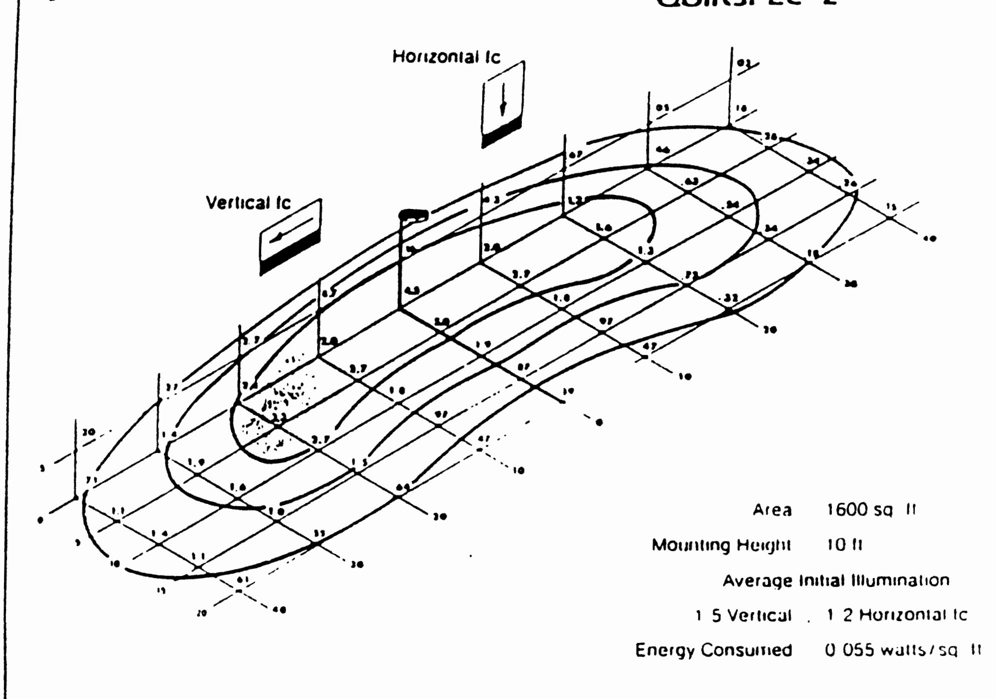
Figure 1



Fixture A — A standard wall pack 70 watts HPS.

Figure 2

QUIKSPEC 2



AlleyKat® — 70 Watt HPS

Use QuikSpec™ for lighting task solutions

QuikSpec™ is an innovative method to lay out task-matched precision HID lighting for lowest possible installation and operating costs. It is a faster way to do a better lighting job reliably

Section C
- Lighting Levels

Lighting energy is directly proportional to the lighting level provided. Too often, designers apply high light levels uniformly to all areas of building. This approach results in a uniform "checkerboard" layout of fixtures with a high power density. Using moderate light levels and layouts tailored to each task in a building results in dramatically lower lighting energy. In fact, of all energy guidelines, the single most important is simply to apply IES footcandle recommendations literally and completely. Total building energy consumption will typically be reduced 20%, and the first cost of construction will actually be reduced.

The Designer must submit the proposed IES Category and Characteristics for each space prior to lighting design.

C-1 Footcandle Requirements

Use the maintained illumination levels recommended in the most recent IES Lighting Handbook. A copy of IES recommendations appears on the following pages for your reference. To demonstrate compliance, the **LIGHTING Designer** must complete the spreadsheet "IES.WK3" on the diskette labelled "Supplemental Software".

1.1 Non-task areas. Areas without work tasks, including lobbies, reception areas, corridors, lounges and rest rooms shall be lit to Category A, B or C general illumination levels, not to exceed 20 fc maintained illuminance.

1.2 Task Surfaces. Office desks and reading-task surfaces should meet Category D requirements, not to exceed 50 fc, maintained point illuminance on the task surface. Category E should only be applied where more exacting tasks, listed by IES as Category E, will frequently occur.

Note that Category D and E (reading) recommendations are for illumination on the work surface, and are not intended to be average illumination levels. Do not use average illumination calculations such as the zonal cavity method for Category D and E.

IES LIGHTING HANDBOOK *VISUAL COMFORT*

The target values of illuminance for Illuminance Categories A to C are *average maintained illuminance*, and the lumen method, using zonal-cavity calculated coefficients of utilization for luminaires, or for daylighting, predicts such average illuminance values. The target values of illuminance obtained for visual displays in the last six categories (D through I) are localized values, that is, *maintained illuminance on the task* and point calculations methods are appropriate. In either case the procedure for determining light loss factors should be used in calculating maintained average or point illuminance.

Chart for Determing Illuminance Values, Maintained, in Lux, for a Combination of Illuminance Categories and User, Room and Task Characteristics (For Illuminance in Footcandles, Divide by 10).

a. General Lighting Throughout Room

Weighting Factors		Illuminance Categories		
Average of Occupants Ages	Average Room Surface Reflectance (percent)	A	B	C
Under 40	Over 70	20	50	100
	30-70	20	50	100
	Under 30	20	50	100
40-55	Over 70	20	50	100
	30-70	30	75	150
	Under 30	50	100	200
Over 55	Over 70	30	75	150
	30-70	50	100	200
	Under 30	50	100	200

b. Illuminance on Task

Weighting Factors			Illuminance Categories					
Average of Workers Ages	Demand for Speed and/or Accuracy*	Task Background Reflectance (percent)	D	E	F	G**	H**	I**
Under 40	NI	Over 70	200	500	1000	2000	5000	10000
		30-70	200	500	1000	2000	5000	10000
		Under 30	300	750	1500	3000	7500	15000
	I	Over 70	200	500	1000	2000	5000	10000
		30-70	300	750	1500	3000	7500	15000
		Under 30	300	750	1500	3000	7500	15000
	C	Over 70	300	750	1500	3000	7500	15000
		30-70	300	750	1500	3000	7500	15000
		Under 30	300	750	1500	3000	7500	15000
40-55	NI	Over 70	200	500	1000	2000	5000	10000
		30-70	300	750	1500	3000	7500	15000
		Under 30	300	750	1500	3000	7500	15000
	I	Over 70	300	750	1500	3000	7500	15000
		30-70	300	750	1500	3000	7500	15000
		Under 30	300	750	1500	3000	7500	15000
	C	Over 70	300	750	1500	3000	7500	15000
		30-70	300	750	1500	3000	7500	15000
		Under 30	500	1000	2000	5000	10000	20000
Over 55	NI	Over 70	300	750	1500	3000	7500	15000
		30-70	300	750	1500	3000	7500	15000
		Under 30	300	750	1500	3000	7500	15000
	I	Over 70	300	750	1500	3000	7500	15000
		30-70	300	750	1500	3000	7500	15000
		Under 30	500	1000	2000	5000	10000	20000
	C	Over 70	300	750	1500	3000	7500	15000
		30-70	500	1000	2000	5000	10000	20000
		Under 30	500	1000	2000	5000	10000	20000

* NI = not important, I = important, and C = critical
** Obtained by a combination of general and supplementary lighting.

Fig. 2-1. Currently Recommended Illuminance Categories and Illuminance Values for Lighting Design—Targeted Maintained Levels

The tabulation that follows is a consolidated listing of the Society's current illuminance recommendations. This listing is intended to guide the lighting designer in selecting an appropriate illuminance for design and evaluation of lighting systems.

Guidance is provided in two forms: (1), in Parts I, II and III as an *Illuminance Category*, representing a range of illuminances (see page 2-3 for a method of selecting a value within each illuminance range); and (2), in parts IV, V and VI as an *Illuminance Value*. Illuminance Categories are represented by letter designations A through I. Illuminance Values are given in *lux* with an approximate equivalence in *footcandles* and as such are intended as *target* (nominal) values with deviations expected. These target values also represent *maintained* values (see page 2-23).

This table has been divided into the six parts for ease of use. Part I provides a listing of both Illuminance Categories and Illuminance Values for generic types of interior activities and normally is to be used when Illuminance Categories for a specific Area/Activity cannot be found in parts II and III. Parts IV, V and VI provide target maintained Illuminance Values for outdoor facilities, sports and recreational areas, and transportation vehicles where special considerations apply as discussed on page 2-4.

In all cases the recommendations in this table are based on the assumption that the lighting will be properly designed to take into account the visual characteristics of the task. See the design information in the particular application sections in this Application Handbook for further recommendations.

I. Illuminance Categories and Illuminance Values for Generic Types of Activities in Interiors

Type of Activity	Illuminance Category	Ranges of Illuminances: Lux	Ranges of Illuminances: Footcandles	Reference Work-Plane
Public spaces with dark surroundings	A	20-30-50	2-3-5	General lighting throughout spaces
Simple orientation for short temporary visits	B	50-75-100	5-7.5-10	
Working spaces where visual tasks are only occasionally performed	C	100-150-200	10-15-20	
Performance of visual tasks of high contrast or large size	D	200-300-500	20-30-50	Illuminance on task
Performance of visual tasks of medium contrast or small size	E	500-750-1000	50-75-100	
Performance of visual tasks of low contrast or very small size	F	1000-1500-2000	100-150-200	
Performance of visual tasks of low contrast and very small size over a prolonged period	G	2000-3000-5000	200-300-500	Illuminance on task, obtained by a combination of general and local (supplementary lighting)
Performance of very prolonged and exacting visual task	H	5000-7500-10000	500-750-1000	
Performance of very special visual tasks of extremely low contrast and small size	I	10000-15000-20000	1000-1500-2000	

II. Commercial, Institutional, Residential and Public Assembly Interiors

Area/Activity	Illuminance Category
Accounting (see **Reading**)	
Air terminals (see **Transportation terminals**)	
Armories	C[1]
Art galleries (see **Museums**)	
Auditoriums	
Assembly	C[1]
Social activity	B
Banks (also see **Reading**)	
Lobby	
General	C
Writing area	D
Tellers' stations	E[3]
Barber shops and beauty parlors	E
Churches and synagogues . . (see page 7-2)[4]	
Club and lodge rooms	
Lounge and reading	D
Conference rooms	
Conferring	D
Critical seeing (refer to individual task)	
Court rooms	
Seating area	C
Court activity area	E[3]
Dance halls and discotheques	B
Depots, terminals and stations (see **Transportation terminals**)	

For footnotes, see page 2-20.

Fig. 2-1. *Continued*

II. *Continued*

Area/Activity	Illuminance Category
Drafting	
Mylar	
High contrast media; India ink, plastic leads, soft graphite leads	E[3]
Low contrast media; hard graphite leads	F[3]
Vellum	
High contrast	E[3]
Low contrast	F[3]
Tracing paper	
High contrast	E[3]
Low contrast	F[3]
Overlays[5]	
Light table	C
Prints	
Blue line	E
Blueprints	E
Sepia prints	F
Educational facilities	
Classrooms	
General (see **Reading**)	
Drafting (see **Drafting**)	
Home economics (see **Residences**)	
Science laboratories	E
Lecture rooms	
Audience (see **Reading**)	
Demonstration	F
Music rooms (see **Reading**)	
Shops (see Part III, Industrial Group)	
Sight saving rooms	F
Study halls (see **Reading**)	
Typing (see **Reading**)	
Sports facilities (see Part V, Sports and Recreational Areas)	
Cafeterias (see **Food service facilities**)	
Dormitories (see **Residences**)	
Elevators, freight and passenger	C
Exhibition halls	C[1]
Filing (refer to individual task)	
Financial facilities (see **Banks**)	
Fire halls (see **Municipal buildings**)	
Food service facilities	
Dining areas	
Cashier	D
Cleaning	C
Dining	B[6]
Food displays (see **Merchandising spaces**)	
Kitchen	E
Garages—parking	(see page 14-28)
Gasoline stations (see **Service stations**)	
Graphic design and material	
Color selection	F[11]
Charting and mapping	F
Graphs	E
Keylining	F
Layout and artwork	F
Photographs, moderate detail	E[13]

Area/Activity	Illuminance Category
Health care facilities	
Ambulance (local)	E
Anesthetizing	E
Autopsy and morgue[17, 18]	
Autopsy, general	E
Autopsy table	G
Morgue, general	D
Museum	E
Cardiac function lab	E
Central sterile supply	
Inspection, general	E
Inspection	F
At sinks	E
Work areas, general	D
Processed storage	D
Corridors[17]	
Nursing areas—day	C
Nursing areas—night	B
Operating areas, delivery, recovery, and laboratory suites and service	E
Critical care areas[17]	
General	C
Examination	E
Surgical task lighting	H
Handwashing	F
Cystoscopy room[17, 18]	E
Dental suite[17]	
General	D
Instrument tray	E
Oral cavity	H
Prosthetic laboratory, general	D
Prosthetic laboratory, work bench	E
Prosthetic laboratory, local	F
Recovery room, general	C
Recovery room, emergency examination	E
Dialysis unit, medical[17]	F
Elevators	C
EKG and specimen room[17]	
General	B
On equipment	C
Emergency outpatient[17]	
General	E
Local	F
Endoscopy rooms[17, 18]	
General	E
Peritoneoscopy	D
Culdoscopy	D
Examination and treatment rooms[17]	
General	D
Local	E
Eye surgery[17, 18]	F
Fracture room[17]	
General	E
Local	F
Inhalation therapy	D
Laboratories[17]	
Specimen collecting	E
Tissue laboratories	F
Microscopic reading room	D
Gross specimen review	F

For footnotes, see page 2-20. For illuminance ranges for each Illuminance Category, see page 2-5 or inside of back cover.

Fig. 2-1. *Continued*

II *Continued*

Area/Activity	Illuminance Category
Chemistry rooms	E
Bacteriology rooms	
General	E
Reading culture plates	F
Hematology	E
Linens	
Sorting soiled linen	D
Central (clean) linen room	D
Sewing room, general	D
Sewing room, work area	E
Linen closet	B
Lobby	C
Locker rooms	C
Medical illustration studio[17, 18]	F
Medical records	E
Nurseries[17]	
General[18]	C
Observation and treatment	E
Nursing stations[17]	
General	D
Desk	E
Corridors, day	C
Corridors, night	A
Medication station	E
Obstetric delivery suite[17]	
Labor rooms	
General	C
Local	E
Birthing room	F[7]
Delivery area	
Scrub, general	F
General	G
Delivery table	(see page 7-19)
Resuscitation	G
Postdelivery recovery area	E
Substerilizing room	B
Occupational therapy[17]	
Work area, general	D
Work tables or benches	E
Patients' rooms[17]	
General[18]	B
Observation	A
Critical examination	E
Reading	D
Toilets	D
Pharmacy[17]	
General	E
Alcohol vault	D
Laminar flow bench	F
Night light	A
Parenteral solution room	D
Physical therapy departments	
Gymnasiums	D
Tank rooms	D
Treatment cubicles	D
Postanesthetic recovery room[17]	
General[18]	E
Local	H
Pulmonary function laboratories[17]	E
Radiological suite[17]	
Diagnostic section	
General[18]	A
Waiting area	A
Radiographic/fluoroscopic room	A
Film sorting	F
Barium kitchen	E
Radiation therapy section	
General[18]	B
Waiting area	B
Isotope kitchen, general	E
Isotope kitchen, benches	E
Computerized radiotomography section	
Scanning room	B
Equipment maintenance room	E
Solarium	
General	C
Local for reading	D
Stairways	C
Surgical suite[17]	
Operating room, general[18]	F
Operating table	(see page 7-15)
Scrub room[18]	F
Instruments and sterile supply room	D
Clean up room, instruments	E
Anesthesia storage	C
Substerilizing room	C
Surgical induction room[17, 18]	E
Surgical holding area[17, 18]	E
Toilets	C
Utility room	D
Waiting areas[17]	
General	C
Local for reading	D
Homes (see Residences)	
Hospitality facilities (see Hotels, Food service facilities)	
Hospitals (see Health care facilities)	
Hotels	
Bathrooms, for grooming	D
Bedrooms, for reading	D
Corridors, elevators and stairs	C
Front desk	E[3]
Linen room	
Sewing	F
General	C
Lobby	
General lighting	C
Reading and working areas	D
Canopy (see Part IV, Outdoor Facilities)	
Houses of worship	(see page 7-5)
Kitchens (see Food service facilities or Residences)	
Libraries	
Reading areas (see **Reading**)	
Book stacks (vertical 760 millimeters (30 inches) above floor)	
Active stacks	D
Inactive stacks	B

For footnotes, see page 2-20. For illuminance ranges for each Illuminance Category, see page 2-5 or inside of back cover.

Fig. 2-1. *Continued*

II. *Continued*

Area/Activity	Illuminance Category
Book repair and binding	D
Cataloging	D[3]
Card files	E
Carrels, individual study areas (see **Reading**)	
Circulation desks	D
Map, picture and print rooms (see **Graphic design and material**)	
Audiovisual areas	D
Audio listening areas	D
Microform areas (see **Reading**)	
Locker rooms	C
Merchandising spaces	
Alteration room	F
Fitting room	
Dressing areas	D
Fitting areas	F
Locker rooms	C
Stock rooms, wrapping and packaging	D
Sales transaction area (see **Reading**)	
Circulation	(see page 8-7)[8]
Merchandise	(see page 8-7)[8]
Feature display	(see page 8-7)[8]
Show windows	(see page 8-7)[8]
Motels (see **Hotels**)	
Minicipal buildings—fire and police	
Police	
Identification records	F
Jail cells and interrogation rooms	D
Fire hall	D
Museums	
Displays of non-sensitive materials	D
Displays of sensitive materials	(see page 7-34)[2]
Lobbies, general gallery areas, corridors	C
Restoration or conservation shops and laboratories	E
Nursing homes (see **Health care facilities**)	
Offices	
Accounting (see **Reading**)	
Audio-visual areas	D
Conference areas (see **Conference rooms**)	
Drafting (see **Drafting**)	
General and private offices (see **Reading**)	
Libraries (see **Libraries**)	
Lobbies, lounges and reception areas	C
Mail sorting	E
Off-set printing and duplicating area	D
Spaces with VDTs	(see page 5-13)
Parking facilities	(see page 14-28)
Post offices (see **Offices**)	
Reading	
Copied tasks	
Ditto copy	E[3]
Micro-fiche reader	B[12, 13]
Mimeograph	D
Photograph, moderate detail	E[13]

Area/Activity	Illuminance Category
Thermal copy, poor copy	F[3]
Xerograph	D
Xerography, 3rd generation and greater	E
Electronic data processing tasks	
CRT screens	B[12, 13]
Impact printer	
good ribbon	D
poor ribbon	E
2nd carbon and greater	E
Ink jet printer	D
Keyboard reading	D
Machine rooms	
Active operations	D
Tape storage	D
Machine area	C
Equipment service	E[10]
Thermal print	E
Handwritten tasks	
#2 pencil and softer leads	D[3]
#3 pencil	E[3]
#4 pencil and harder leads	F[3]
Ball-point pen	D[3]
Felt-tip pen	D
Handwritten carbon copies	E
Non photographically reproducible colors	F
Chalkboards	E[3]
Printed tasks	
6 point type	E[3]
8 and 10 point type	D[3]
Glossy magazines	D[13]
Maps	E
Newsprint	D
Typed originals	D
Typed 2nd carbon and later	E
Telephone books	E
Residences	
General lighting	
Conversation, relaxation and entertainment	B
Passage areas	B
Specific visual tasks [20]	
Dining	C
Grooming	
Makeup and shaving	D
Full-length mirror	D
Handcrafts and hobbies	
Workbench hobbies	
Ordinary tasks	D
Difficult tasks	E
Critical tasks	F
Easel hobbies	E
Ironing	D
Kitchen duties	
Kitchen counter	
Critical seeing	E
Noncritical	D
Kitchen range	
Difficult seeing	E
Noncritical	D

For footnotes, see page 2-20. For illuminance ranges for each Illuminance Category, see page 2-5 or inside of back cover.

Fig. 2-1. *Continued*

II. Continued

Area/Activity	Illuminance Category
Kitchen sink	
Difficult seeing	E
Noncritical	D
Laundry	
Preparation and tubs	D
Washer and dryer	D
Music study (piano or organ)	
Simple scores	D
Advanced scores	E
Substand size scores	F
Reading	
In a chair	
Books, magazines and newspapers	D
Handwriting, reproductions and poor copies	E
In bed	
Normal	D
Prolonged serious or critical	E
Desk	
Primary task plane, casual	D
Primary task plane, study	E
Sewing	
Hand sewing	
Dark fabrics, low contrast	F
Light to medium fabrics	E
Occasional, high contrast	D
Machine sewing	
Dark fabrics, low contrast	F
Light to medium fabrics	E
Occasional, high contrast	D
Table games	D
Restaurants (see **Food service facilities**)	
Safety	(see page 2-45)
Schools (see **Educational facilities**)	
Service spaces (see also **Storage rooms**)	
Stairways, corridors	C
Elevators, freight and passenger	C
Toilets and washrooms	C
Service stations	
Service bays (see Part III, Industrial Group)	
Sales room (see **Merchandising spaces**)	
Show windows	(see page 8-7)
Stairways (see **Service spaces**)	
Storage rooms (see Part III, Industrial Group)	
Stores (see **Merchandising spaces** and **Show windows**)	
Television	(see Section 11)
Theatre and motion picture houses	(see Section 11)
Toilets and washrooms	C
Transportation terminals	
Waiting room and lounge	C
Ticket counters	E
Baggage checking	D
Rest rooms	C
Concourse	B
Boarding area	C

III. Industrial Group

Area/Activity	Illuminance Category
Aircraft maintenance	(see page 9-13)[21]
Aircraft manufacturing	(see page 9-13)[21]
Assembly	
Simple	D
Moderately difficult	E
Difficult	F
Very difficult	G
Exacting	H
Automobile manufacturing	(see page 9-17)[21]
Bakeries	
Mixing room	D
Face of shelves	D
Inside of mixing bowl	D
Fermentation room	D
Make-up room	
Bread	D
Sweet yeast-raised products	D
Proofing room	D
Oven room	D
Fillings and other ingredients	D
Decorating and icing	
Mechanical	D
Hand	E
Scales and thermometers	D
Wrapping	D
Book binding	
Folding, assembling, pasting	D
Cutting, punching, stitching	E
Embossing and inspection	F
Breweries	
Brew house	D
Boiling and keg washing	D
Filling (bottles, cans, kegs)	D
Building construction (see Part IV, Outdoor Facilities)	
Building exteriors (see Part IV, Outdoor Facilities)	
Candy making	
Box department	D
Chocolate department	
Husking, winnowing, fat extraction, crushing and refining, feeding	D

For footnotes, see page 2-20. For illuminance ranges for each Illuminance Category, see page 2-5 or inside of back cover.

Fig. 11-1. *Continued*

IV. *Continued*

Area/Activity	Lux	Footcandles
Sawmills (see also **Logging**)		
Cut-off saw	100	10
Log haul	20	2
Log hoist (side lift)	20	2
Primary log deck	100	10
Barker in-feed	300	30
Green chain[26]	200 to 300	20 to 30
Lumber strapping[26]	150 to 200	15 to 20
Lumber handling areas	20	2
Lumber loading areas	50	5
Wood chip storage piles	5	0.5
Service station (at grade)		
Dark surrounding		
Approach	15	1.5
Driveway	15	1.5
Pump island area	200	20
Building faces (exclusive of glass)[14]	100	10
Service areas	30	3
Landscape highlights	20	2
Light surrounding		
Approach	30	3
Driveway	50	5
Pump island area	300	30
Building faces (exclusive of glass)[14]	300	30
Service areas	70	7
Landscape highlights	50	5
Ship yards		
General	50	5
Ways	100	10
Fabrication areas	300	30
Signs		
Advertising (see **Bulletin and poster boards**)		
Externally lighted roadway (see chapter 24)		
Smokestacks with advertising messages (see **Bulletin and poster boards**)		
Storage yards		
Active	200	20
Inactive	10	1
Streets (see chapter 24)		
Walkways (see chapter 24)		
Water tanks with advertising messages (see **Bulletin and poster boards**)		

V. Sports and Recreational Areas

Area/Activity	Lux	Footcandles
Archery (indoor)		
Target, tournament[14]	500	50
Target, recreational[14]	300	30
Shooting line, tournament	200	20
Shooting line, recrational	100	10
Archery (outdoor)		
Target, tournament[14]	100	10
Target, recreational[14]	50	5
Shooting line, tournament	100	10
Shooting line, recreational	50	5
Badminton		
Tournament	300	30
Club	200	20
Recreational	100	10
Baseball		
Major league		
Infield	1500	150
Outfield	1000	100
AA and AAA league		
Infield	700	70
Outfield	500	50
A and B league		
Infield	500	50
Outfield	300	30
C and D league		
Infield	300	30
Outfield	200	20
Semi-pro and municipal league		
Infield	200	20
Outfield	150	15
Recreational		
Infield	150	15
Outfield	100	10
Junior league (Class I and Class II)		
Infield	300	30
Outfield	200	20
On seat during game	20	2
On seats before & after game	50	5
Basketball		
College and professional	500	50
College intramural and high school	300	30
Recreational (outdoor)	100	10
Bathing beaches		
On land	10	1
150 feet from shore[14]	30	3
Billiards (on table)		
Tournament	500	50
Recreational	300	30
Bowling		
Tournament		
Approaches	100	10
Lanes	200	20
Pins[14]	500	50
Recreational		
Approaches	100	10
Lanes	100	10
Pins[14]	300	30
Bowling on the green		
Tournament	100	10
Recreational	50	5
Boxing or wrestling (ring)		
Championship	5000	500

For footnotes, see end of table.

Fig. 11-1. *Continued*

V. *Continued*

Area/Activity	Lux	Footcandles
Professional	2000	200
Amateur	1000	100
Seats during bout	20	2
Seats before and after bout	50	5
Casting—bait, dry-fly, wet-fly		
Pier or dock	100	10
Target (at 24 meters [80 feet] for bait casting and 15 meters [50 feet] for wet or dry-fly casting)[14]	50	5
Combination (outdoor)		
Baseball/football		
Infield	200	20
Outfield and football	150	15
Industrial softball/football		
Infield	200	20
Outfield and football	150	15
Industrial softball/6-man football		
Infield	200	20
Outfield and football	150	15
Croquet or Roque		
Tournament	100	10
Recreational	50	5
Curling		
Tournament		
Tees	500	50
Rink	300	30
Recreational		
Tees	200	20
Rink	100	10
Fencing		
Exhibitions	500	50
Recreational	300	30
Football		
Distance from nearest sideline to the farthest row of spectators		
Class I Over 30 meters [100 feet]	1000	100
Class II 15 to 30 meters [50 to 100 feet]	500	50
Class III 9 to 15 meters [30 to 50 feet	300	30
Class IV Under 9 meters [30 feet]	200	20
Class V No fixed seating facilities	100	10

It is generally conceded that the distance between the spectators and the play is the first consideration in determining the class and lighting requirements. However, the potential seating capacity of the stands should also be considered and the following ratio is suggested: Class I for over 30,000 spectators;Class II for 10,000 to 30,000; Class III for 5000 to 10,000; andClass IV for under 5000 spectators.

Area/Activity	Lux	Footcandles
Football, Canadian—rugby (see Football)		
Football, six-man		
High school or college	200	20
Jr. high and recreational	100	10
Golf		
Tee	50	5
Fairway[14]	10–30	1–3
Green	50	5
Driving range		
At 180 meters [200 yards][14]	50	5
Over tee area	100	10
Miniature	100	10
Practice putting green	100	10
Gymnasiums (refer to individual sports listed)		
General exercising and recreation	300	30
Handball		
Tournament	500	50
Club		
Indoor—four-wall or squash	300	30
Outdoor—two-court	200	20
Recreational		
Indoor—four-wall or squash	200	20
Outdoor—two-court	100	10
Hockey, field	200	20
Hockey, ice (indoor)		
College or professional	1000	100
Amateur	500	50
Recreational	200	20
Hockey, ice (outdoor)		
College or professional	500	50
Amateur	200	20
Recreational	100	10
Horse shoes		
Tournament	100	10
Recreational	50	5
Horse shows	200	20
Jai-alai		
Professional	1000	100
Amateur	700	70
Lacrosse	200	20
Playgrounds	50	5
Quoits	50	5
Racing (outdoor)		
Auto	200	20
Bicycle		
Tournament	300	30
Competitive	200	20
Recreational	100	10
Dog	300	30
Dragstrip		
Staging area	100	10
Acceleration, 400 meters [1320 feet]	200	20
Deceleration, first 200 meters [660 feet]	150	15
Deceleration, second 200 meters [660 feet]	100	10
Shutdown, 250 meters [820 feet]	50	5
Horse	200	20
Motor (midget of motorcycle)	200	20

For footnotes, see end of table.

Fig. 11-1. *Continued*

V. *Continued*

Area/Activity	Lux	Footcandles
Racquetball (see Handball)		
Rifle 45 meters [50 yards]—outdoor)		
On targets[14]	500	50
Firing point	100	10
Range	50	5
Rifle and pistol range (indoor)		
On targets[14]	1000	100
Firing point	200	20
Range	100	10
Rodeo		
Arena		
Professional	500	50
Amateur	300	30
Recreational	100	10
Pens and chutes	50	5
Roque (see Croquet)		
Shuffleboard (indoor)		
Tournament	300	30
Recreational	200	20
Shuffleboard (outdoor)		
Tournament	100	10
Recreational	50	5
Skating		
Roller rink	100	10
Ice rink, indoor	100	10
Ice rink, outdoor	50	5
Lagoon, pond, or flooded area	10	1
Skeet		
Targets at 18 meters [60 feet][14]	300	30
Firing points	50	5
Skeet and trap (combination)		
Targets at 30 meters [100 feet] for trap, 18 meters [60 feet] for skeet[14]	300	30
Firing points	50	5
Ski slope	10	1
Soccer (see Football)		
Softball		
Professional and championship		
Infield	500	50
Outfield	300	30
Semi-professional		

Area/Activity	Lux	Footcandles
Infield	300	30
Outfield	2000	20
Industrial league		
Infield	200	20
Outfield	150	15
Recreational (6-pole)		
Infield	100	10
Outfield	70	7
Slow pitch, tournament—see industrial league		
Slow pitch, recreational (6-pole)—see recreational (6-pole)		
Squash (see Handball)		
Swimming (indoor)		
Exhibitions	500	50
Recreational	300	30
Underwater—1000 [100] lamp lumens per square meter [foot] of surface area		
Swimming (outdoor)		
Exhibitions	200	20
Recreational	100	10
Underwater—600 [60] lamp lumens per square meter [foot] of surface area		
Tennis (indoor)		
Tournament	1000	100
Club	750	75
Recreational	500	50
Tennis (outdoor)		
Tournament	300	30
Club	200	20
Recreational	100	10
Tennis, platform	500	50
Tennis, table		
Tournament	500	50
Club	300	30
Recreational	200	20
Trap		
Targets at 30 meters [100 feet][14]	300	30
Firing points	50	5
Volley ball		
Tournaments	200	20
Recreational	100	10

VI. Transportation Vehicles

Area/Activity	Lux	Footcandles
Aircraft		
Passenger compartment		
General	50	5
Reading (at seat)	200	20
Airports		
Hangar apron	10	1
Terminal building apron		
Parking area	5	0.5
Loading area[14]	20	2
Rail conveyances		
Boarding or exiting	100	10

Area/Activity	Lux	Footcandles
Fare box (rapid transit train)	150	15
Vestibule (commuter and intercity trains)	100	10
Aisles	100	10
Advertising cards (rapid transit and commuter trains)	300	30
Back-lighted advertising cards (rapid transit and commuter trains)—860 cd/m^2 (80 cd/ft^2) average maximum.		
Reading[3]	300	30

For footnotes, see end of table.

VI. *Continued*

Area/Activity	Lux	Footcandles
Cargo handling (weather deck)	50[16]	5[16]
Control stations (except navigating areas)		
General		
Control consoles	200	20
Gauge and control boards	300	30
Switchboards	300	30
Engine rooms	200[16]	20[16]
Generator and switchboard rooms	200[16]	20[16]
Fan rooms (ventilation & air conditioning)	100	10
Motor rooms	200	20
Motor generator rooms (cargo handling)	100	10
Pump room	100	10
Shaft alley	100	10
Shaft alley escape	30	3
Steering gear room	200	20
Windlass rooms	100	10
Workshops		
General	300[16]	30[16]
On top of work bench	500[16]	50[16]
Tailor shop	500[16]	50[16]
Cargo holds		
Permanent luminaires	30[16]	3[16]
Passageways and trunks	100	10

[1]Include provisions for higher levels for exhibitions.

[2]Specific limits are provided to minimize deterioration effects.

[3]Task subject to veiling reflections. Illuminance listed is not an ESI value. Currently, insufficient experience in the use of ESI target values precludes the direct use of Equivalent Sphere Illumination in the present consensus approach to recommend illuminance values. Equivalent Sphere Illumination may be used as a tool in determining the effectiveness of controlling veiling reflections and as a part of the evaluation of lighting systems.

[4]Illuminance values are listed based on experience and consensus. Values relate to needs during various religious ceremonies.

[5]Degradation factors: Overlays—add 1 weighting factor for each overlay; Used material—estimate additional factors.

[6]Provide higher level over food service or selection areas.

[7]Supplementary illumination as in delivery room must be available.

[8]Illuminance values developed for various degrees of store area activity.

[9]Or not less than 1/5 the level in the adjacent areas.

[10]Only when actual equipment service is in process. May be achieved by a general lighting system or by localized or portable equipment.

[11]For color matching, the spectral quality of the color of the light source is important.

[12]Veiling reflections may be produced on glass surfaces. It may be necessary to treat plus weighting factors as minus in order to obtain proper illuminance.

[13]Especially subject to veiling reflections. It may be necessary to shield the task or to reorient it.

[14]Vertical

[15]Illuminance values may vary widely, depending upon the effect desired, the decorative scheme, and the use made of the room.

[16]Supplementary lighting should be provided in this space to produce the higher levels required for specific seeing tasks involved.

[17]Good to high color rendering capability should be considered in these areas. As lamps of higher luminous efficacy and higher color rendering capability become available and economically feasible, they should be applied in all areas of health care facilities.

[18]Variable (dimming or switching).

[19]Values based on a 25 percent reflectance, which is average for vegetation and typical outdoor surfaces. These figures must be adjusted to specific reflectances of materials lighted for equivalent brightness. Levels give satisfactory brightness patterns when viewed from dimly lighted terraces or interiors. When viewed from dark areas they may be reduced by at least 1/2; or they may be doubled when a high key is desired.

[20]General lighting should not be less than 1/3 of visual task illuminance nor less than 200 lux [20 footcandles].

[21]Industry representatives have established a table of single illuminance values which, in their opinion, can be used in preference to employing reference 6. Illuminance values for specific operations can also be determined using illuminance categories of similar tasks and activities found in this table and the application of the appropriate weighting factors in Fig. 2-3.

[22]Special lighting such that (1) the luminous area is large enough to cover the surface which is being inspected and (2) the luminance is within the limits necessary to obtain comfortable contrast conditions. This involves the use of sources of large area and relatively low luminance in which the source luminance is the principal factor rather than the illuminance produced at a given point.

[23]Maximum levels—controlled system.

[24]Additional lighting needs to be provided for maintenance only.

[25]Color temperature of the light source is important for color matching.

[26]Select upper level for high speed conveyor systems. For grading redwood lumber 3000 lux [300 footcandles] is required.

[27]Higher levels from local lighting may be required for manually operated cutting machines.

[28]If color matching is critical, use illuminance category G.

low. These levels reflect both traffic and pedestrian activity and are illustrated by, but not limited to, the following examples:

High activity:

- Major league athletic events
- Major cultural or civic events
- Regional shopping centers
- Fast food facilities

Medium activity:

- Community shopping centers
- Office parks
- Hospital parking areas
- Transportation parking (airports, commuter lots, etc.)
- Cultural, civic or recreational events
- Residential complex parking

Low activity:

- Neighborhood shopping
- Industrial employee parking
- Educational facility parking
- Church parking

If the level of nighttime activity involves a large number of vehicles, then the examples above for low and medium activity properly belong in the next higher level.

Covered Parking Facilities. Four critical areas can be identified within covered parking facilities: general parking and pedestrian areas; ramps and corners; entrance areas; and stairways. These critical areas can require lighting both day and night. The first of these areas is considered to be the same as for an open parking facility. The second area is self-explanatory. The third area (entrance) is defined as the entryway into the covered portion of the parking structure from the portal to a point 15 m (50 ft) beyond the edge of covering on the structure. The fourth area again is self-explanatory.

Illuminance Recommendations. Recommendations have been established for both open parking facilities (outdoor) and covered parking facilities (structures), as shown in figure 24-23. These recommendations are given to provide for the safe movement of traffic, for satisfactory vision for pedestrians and for the guidance of both vehicles and pedestrians. They are the lowest acceptable levels consistent with the seeing task involved and the need to deter vandalism while at the same time meeting energy constraints. Customer convenience, closed circuit television surveillance and customer attraction may require a higher level of lighting in some circumstances.

In open parking facilities, a *general parking and pedestrian area* is defined as one where pedestrian conflicts with vehicles are likely to occur. A *vehicular use area (only)* is defined as one where conflicts with pedestrians are not likely to occur. These are areas such as service areas or access roads.

It should be noted that, whereas figure 24-23 specifies *average* levels for the vehicular area in open park-

Fig. 24-23. Recommended Maintained Horizontal Illuminances for Parking Facilities

(a) Open Parking Facilities

	General Parking and Pedestrian Area			Vehicle Use Area (only)		
Level of Activity	Lux (Minimum on Pavement)	Footcandles (Minimum on Pavement)	Uniformity Ratio (Average:Minimum)	Lux (Average on Pavement)	Footcandles (Average on Pavement)	Uniformity Ratio (Average:Minimum)
High	10	0.9	4:1	22	2	3:1
Medium	6	0.6	4:1	11	1	3:1
Low*	2	0.2	4:1	5	0.5	4:1

(b) Covered Parking Facilities

	Day		Night		
Areas	Lux (Average on Pavement)†	Footcandles (Average on Pavement)†	Lux (Average on Pavement)	Footcandles (Average (Average:Minimum)	Uniformity Ratio
General parking and Pedestrian areas	54	5	54	5	4:1
Ramps and corners	110	10	54	5	4:1
Entrance areas	540	50	54	5	4:1
Stairways					

* This recommendation is based on the requirement to maintain security at any time in areas where there is a low level of nighttime activity.
† Sum of electric lighting and daylight.
See chapter 11, Illuminance Selection.

Section D
- DESIGN APPROACH

A combination of design approaches is required to meet lighting requirements under different circumstances.

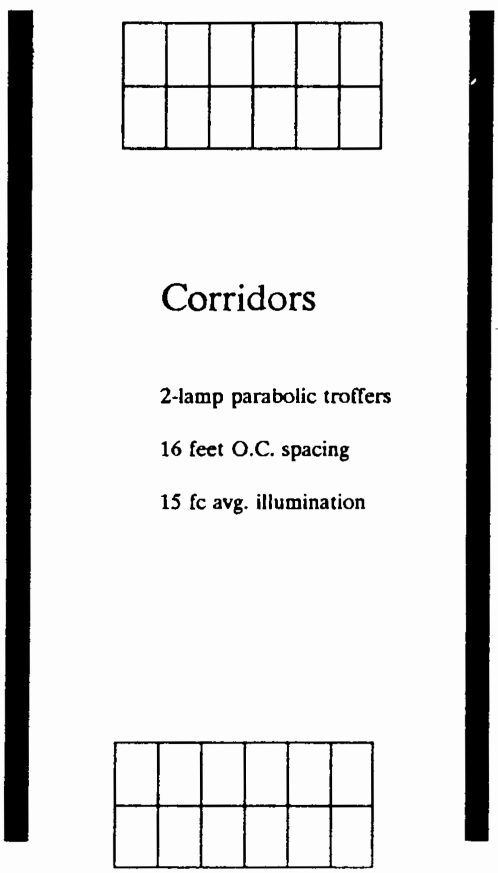
> A combination of design approaches are needed to achieve excellent lighting at low power densities.

The Owner requires uniform, average illumination at low light levels for ambient lighting in IES Categories A, B and C. Zonal cavity calculations are appropriate.

For task light levels, IES categories D and E, we require a "Localized General" lighting approach with careful attention to fixture positioning. Point illuminance calculations may be required.

Where partitions or systems furniture interferes with overhead lighting, we require a task-ambient lighting approach utilizing task lighting mounted in furniture.

This overlay of design approaches permits excellent lighting design meeting all IES illuminance recommendations with very low power densities. This Section provides specific guidance to the designer in application of each method to meet Owner approval.



D-1 General Illumination - IES Categories A, B, C

Zonal-cavity calculations shall be used to select the number of fixtures needed for general illumination of activities in IES Categories A, B, and C, including:

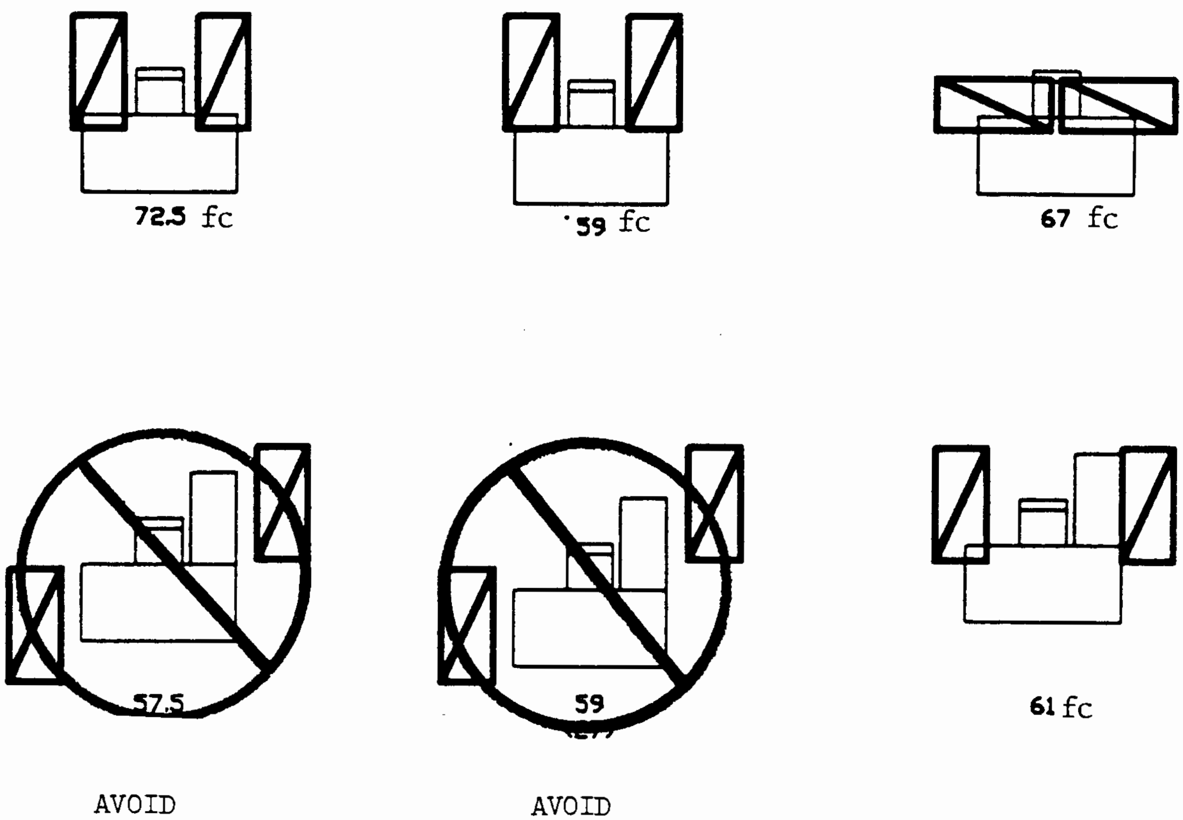
- Corridors
- Stairways
- Lobbies
- Rest Rooms
- Lounges
- Cafeterias

1.1 <u>Corridors</u>: Corridors shall generally be lit by 2-lamp parabolic troffers with the long axis perpendicular to the length of the corridor. The Spacing Criteria of 1.6 for this fixture permits a spacing of fixtures at 16 feet on center with uniform illumination of the corridor floor at 15 fc.

FIGURE ONE -

Localized-General Lighting

Fixtures are Localized to the task to provide high light levels while avoiding veiling reflections. The same fixtures also provide the General lighting of the room. Hence the name Localized-General Lighting.



Footcandles are measured on the desk (task) surface. IES recommended light levels above 20 fc need only be met at the task surfaces.

Fixtures shown are parabolic, 2-lamp, T8 fluorescent in the ceiling grid.

Using 1-lamp parabolic fixtures instead would provide 30 footcandles (IES Category D) and also meet IES recommended practice for maximum luminaire luminances in areas with computer screens.

1.2 **Dormitories**: Dormitory areas with multiple bunks such as fire stations shall provide a compact fluorescent task light on flexible "gooseneck" fixture at each bunk for reading. Ambient light shall be provided at 15 fc by compact fluorescent downlights to light common areas and walkways. No 2x4 troffers shall be used since they produce excess illumination that is blinding to people being woken for emergency calls.

D-2 Lighting for Tasks - IES Categories D, E, F

> IES *LIGHTING SYSTEM DESIGN CONSIDERATIONS*
>
> ***Localized General Lighting.*** A localized general lighting system consists of a functional arrangement of luminaires with respect to the visual task or work areas. It also provides illumination for the entire room area. Such a lighting system requires special coordination in installation and careful consideration to ensure adequate general lighting for the room.
>
> This system has the advantage of better utilization of the light on the work area and the opportunity to locate the luminaires so that annoying shadows, direct glare and veiling reflections are prevented or minimized.

2.1 **Individual Office**: A large portion of office space rests in individual offices in the range of 100 to 150 square feet. A localized general lighting approach is appropriate in these spaces. Such offices will have one primary work plane and should generally not require more than two fixtures for combined task and general lighting. Figure One shows sample layouts using 2-lamp fixtures that will produce 50 to 75 fc (IES category E tasks) on the work plane without unnecessarily high average illumination throughout the space.

Use of two 1-lamp fixtures (tandem-wired to one ballast) in the same locations will produce 30 fc on the work plane, meeting IES category D. Category D covers most common office tasks, including reading print from impact or inkjet printers, pencil tasks, and

reading 8-point type or newspaper print as shown here.

The 1-lamp parabolic fixture also provides superior glare control for VDT applications, meeting IES Recommended Practice 24 direct luminance limits above 55 degrees.

2.2 **Areas without Partitions**: The designer shall use a **Localized General Lighting** approach to meeting illuminance requirements in Categories D and E, as recommended by IES in open offices and multi-use areas without partitions. The designer must tailor the lighting layout to task locations and types within the space. The Architect must provide the lighting designer with furniture layouts and task function descriptions prior to performance of lighting layouts at Design Development. Localized General Lighting will generally be accomplished by three steps in each room to be designed as follows:

Initial Layout: Locate the task surfaces in the room. Select one of the acceptable luminaire layouts and locate fixtures correctly to the task. Select the number of lamps per fixture (1, 2 or 3) to meet approved IES footcandle levels on the task. Then combine all the individual layouts into an initial layout for the complete room.

Eliminate Overlap: After initial layout of the complete room, some fixtures may overlap or fall adjacent to one another due to close proximity of different task surfaces. At this time, eliminate one in each pair of duplicate fixtures and allow the other to do "double duty" serving both task areas. In some cases, a point illuminance printout may be required for the room to minimize the number of fixtures and optimize locations.

Review General Illumination: Review the room design or point illuminance printout to ensure that illuminance ratios do not exceed 5:1 between task and non-task areas. Provide the minimum necessary supplemental light in the form of a 2-lamp troffer, compact fluorescent downlight or wall sconce.

> **5-10** *OFFICE LIGHTING* IES 1987 Applications
>
> If "systems" furniture is used, having vertical screens partly surrounding the work area or cabinets over the work which may cause shadows, local task lighting may be necessary to eliminate shadows on the task area.
>
> If local task lighting is used, the general lighting does not have to provide the required illuminance for the task. It may be designed with a lower illuminance appropriate for circulation, for casual viewing of tasks and to provide the recommended luminance ratios between the task and other areas within the field of view.

2.3 **Areas with System Furniture and Partitions**:

The designer shall use a task-ambient lighting approach where overhead lighting is limited by partitions or system furniture.

Built-in task lighting to meet IES recommended illumination levels should be provided in open offices with systems furniture designs, study carrels or half-height partitions between desks. Ambient lighting shall be limited to Category C (15 fc) average maintained illumination in rooms where the furniture is located. Task lights must be of a quality to eliminate direct glare, avoid excessive luminance ratios and must use lamps and ballasts allowed by *Guidelines*.

2.4 **Vertical Surfaces and Book Stacks:**

Provide point illuminance calculations of vertical surface footcandles to meet IES recommended light levels on book stacks or shelves.

D-3 Light Loss Factor

For all Illuminance Categories, the Light Loss Factor (LLF) is a necessary component of IES methods. For parabolic luminaires with T8 lamps, **use a minimum LLF of 0.75.**

Exterior Don'ts

Do Not Use:

- Bollards
- Fluorescent Fixtures
- Wall-Packs
- Globe Fixtures
- Dark Louvers
- Step Lights
- Incandescent Sources

Interior Don'ts

Do Not Use

- Incandescent Fixtures
- U-lamp Fixtures
- Opal Diffusers

Section E - Don'ts

E-1 Bollard and Ground Mounted Fixtures. Don't use pedestrian accessible bollard light fixtures and ground mounted or recessed fixtures (e.g. step lights). These fixtures have poor light control, limited durability, and are frequently damage by pedestrians, lawn mowers, weather and vandals. Pole or building-mounted fixtures shall be used for all exterior illumination.

E-2 Fluorescent Fixtures in Cold Areas. Fluorescent sources are not permitted in unheated areas and exterior applications, including parking garages, due to inefficiency and low light output at reduced temperatures.

E-3 Exterior Fixture Wall-Packs and Globes. Do not use exterior fixtures with a cut off angle greater than 75 degrees. Such fixtures cause severe problems with direct glare and much of the light output is wasted. Eliminate all globe fixtures, "wall-pak" and bollard-type fixtures.

E-4 Incandescent Lamps are not permitted in any application. Use fluorescent or compact fluorescent or HID sources as appropriate. This restriction applies to lobbies, hallways and closets, conference rooms, storage rooms, etc. Conference rooms which would normally be provided with incandescent downlights for dimming, shall be provided with tri-level compact fluorescent downlights.

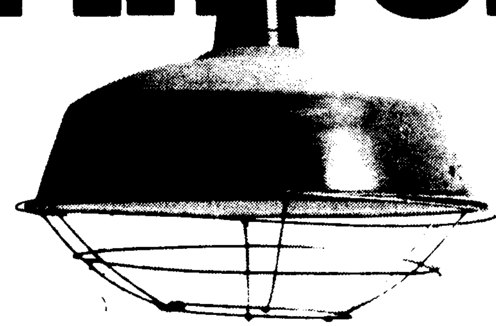
E-5 Quartz or Halogen Sources are also incandescent sources and shall not be used.

E-6 U-tubes U-tube fluorescent lamps are not permitted due to low efficiency, high lamp cost and breakage problems.

E-7 Opal Diffusers are not permitted in any application, including fluorescent, incandescent and HID fixtures, due to inherent inefficiency.

E-8 Dark Painted Louvers are not permitted for use as diffusers in any application, due to inherent inefficiency.

DON'T LET INEFFICIENCY BECOME A FIXTURE.



Section F
- ON/OFF Controls

Switching must be convenient and flexible enough to follow the functions in the room.

F-1 Standard Switching

Standard occupant switching must be within the room containing the switched lighting circuits, near each point of egress, and within view of the lights controlled. Multiple switching shall be used for large spaces with more than one point of egress.

F-2 Large Spaces to be Subdivided

Large (multi-purpose) spaces must be switched to accommodate a variety of simultaneous activities within the space and the use of appropriate lights during partial use of space. In no case shall more than 1 kW of lighting be on a single switch.

Interior lighting must be controlled by the Energy Management System for ON/OFF scheduling.

F-3 Interior Time Controls

Automatic timed switching must be provided through the Energy Management System for all spaces without occupancy sensors. Automatically turn off interior building lighting off on night and weekends.

3.1 Schedule. The following schedule will be nominal but must be adjusted to the actual building occupancy pattern on a zone by zone basis:

Lights OFF at 11:00 PM on weekdays

Lights ENABLED at 6:00 AM on weekdays

3.2 Zoning. Separate control and schedules must be provided for each group of spaces that will typically be used together. Minimum separation includes:

(i) each wing of each floor of the building and

(ii) each agency or department within each floor.

Light Fixtures

Required Specifications

"Use these specifications verbatim"

SECTION 16915 - OCCUPANCY SENSORS

PART 1 - GENERAL

1.01 GENERAL PROVISIONS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division-1 Specifications sections, apply to the work of this section.

B. The sensors shall be installed in rooms according to the Contract drawings, and shall be compatible with all features of the balance of the lighting system.

1.02 WORK INCLUDED:

A. Occupancy sensors to control lighting in rooms specified by the Contract documents.

B. Survey to determine appropriate type, number and location of sensors to achieve performance requirements. Documentation of survey using the Occupancy Sensor Commissioning form provided in these specifications.

C. Associated wiring, power packs, relays, switch-packs and all labor and accessories as may be needed to provide a complete and fully functioning occupancy sensor system in conformance with all performance requirements.

D. Signage at switches to notify personnel of the presence of an occupancy sensor.

E. Sensor Commissioning to obtain specified performance.

F. Provide One-year service on the installed sensors, including reinspection and on-call services as described in this section. Provide 3-year warranty on parts. Provide 3% warranty stock of each part to the Owner for the warranty period.

1.03 QUALITY CONTROL:

A. Time Delay Test: Sensor shall deactivate lighting after a time interval within the range specified for the type of space. Sensor will be tested by leaving the room and timing the interval to deactivate lights. Test shall be conducted with HVAC systems in operation.

B. Entry Test: Sensors shall activate lighting within 2 seconds of entrance by a person beyond 3 feet into the space at each door to the space covered. Sensor shall not activate when person passes room with door open but does not enter.

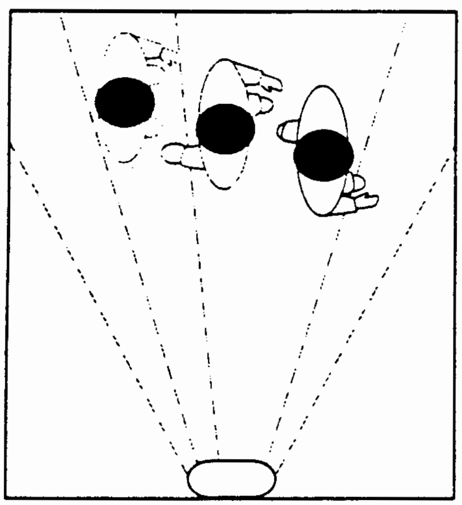
C. Hand Motion Test: Sensor shall provide 100% coverage and maintain lighting at all times that a fixed work station or desk or stationary task is occupied. Sensor must pick up hand motion of one foot distance back and forth, either parallel or perpendicular to the work surfaces. Test may be conducted by observing red LED indicating sensor triggering.

Find complete specifications under FILENAME: 16915.SPC
on the Diskette labelled REQUIRED SPECIFICATIONS.

Parking Lot lights must be controlled by Energy Management to be turned off at Midnight.

Passive Infrared Sensors

All objects give off heat, also known as infrared radiation. Passive infrared sensors (PIRs) sense the difference in temperature between objects and the background. Because



humans are warmer than surrounding surfaces, passive infrared devices sense the presence of people in the room.

3.3 **Switching Over-ride.** Automatic timed switching controls must include over-ride switching using two- hour twist timers. Constant-burn lighting must be placed to illuminate over-ride controls.

3.4 **Warning Sequence**. Five minutes prior to turning off the lights, the EMS shall blink the lights off for 1 second to warn any occupants. Occupants then may engage the over-ride timer before lights are turned off.

F-4 Exterior Lighting Control

Exterior lighting shall be placed under control of the Energy Management System. Separate timers or photocells shall not be used. The Energy Management System shall compute sunrise and sunset times each day. The following schedule will be nominal, but should be adjusted to the actual occupancy of the building:

	ON	OFF
Parking	Sunset	Midnight
Security	Sunset	Sunrise

F-5 Occupancy Sensors

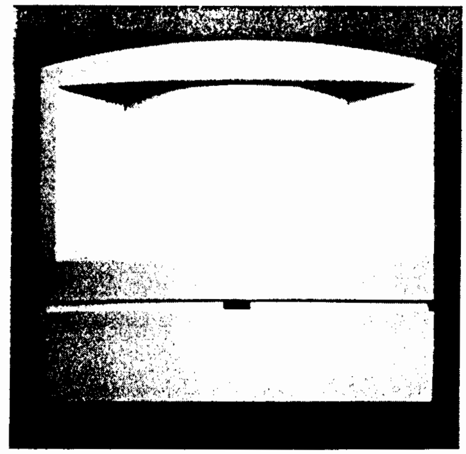
Automatic Occupant-Sensing Switching shall be used for all rooms with variable occupancy, including individual offices, with **at least 300 Watts** combined on the switched circuits. Use the attached Guide Specification Section 16915 for sensing units.

Mounting and Location. Do not use **Wall-mounted** occupancy sensors designed to replace wall switches, due to susceptibility to damage and inadequate field of view around furnishings.

Ceiling or corner-mounted sensors should be used in all applications of occupancy sensors.

TheWatt Stopper®

CI Passive Infrared Sensor



- ♦ Fresnel lens with a choice of 3 patterns for coverage of large areas
- ♦ Part of a complete integrated system of lighting control
- ♦ Built-in light-level sensor
- ♦ Adjustable sensitivity & digital time delay
- ♦ Contains an isolated relay contact for use with HVAC or other control systems
- ♦ 5 year warranty

System Information

The Watt Stopper's new CI occupancy sensor (CI-100) utilizes advanced passive infrared technology to control lighting in a wide variety of applications. It can be used as part of an integrated system of Watt Stopper lighting control or as a stand-alone product. The CI-100's superior coverage and high degree of accuracy provide users with flawless lighting control and huge energy savings.

Operation

The CI-100 is a 24 VDC occupancy sensor which controls lighting systems through a Watt Stopper Power Pack. The unit operates by turning lighting (or HVAC) on when it detects a change in infrared heat radiated within the controlled area. After the area is vacated and after a user-adjustable time delay, lighting automatically turns off.

Features

The CI-100 features adjustable time delay and unit sensitivity . The time delay functions through a highly accurate digital timer with a tolerance of ± 2%. With a 6 position dip switch, the time delay can be programmed from 15 seconds to 30 minutes with 2 minute increments (see chart). The CI-100 also features a unique light-level sensor output which can be used to prevent sections of lights from turning on if natural light levels are above a user specified level (adjustable from 2.5 to 430 footcandles). Adjustable controls are accessible beneath a swing cover. Also with the CI-100, a choice of three different lens patterns is provided. This enables you to customize the sensing pattern for each room to achieve the best possible coverage. The CI-100 contains an isolated relay contact that can be used to interface with HVAC, EMS systems, monitoring systems, or with an additional light circuit. It has normally open and normally closed contacts.

Applications

The CI-100 is the ideal sensor for larger areas and can cover up to 1500 square feet. By choosing the proper lens patterns for each application the sensor can effectively cover large offices, utility areas, computer rooms, open office spaces, classrooms, aisleways, and warehouses. By customizing the coverage pattern to each use, occupancy detection can be extremely accurate and energy savings will therefore increase. The additional amount of savings you receive from the built-in daylighting and from interfacing with HVAC or other building systems gives paybacks well within 2 years.

Specifications

- ♦ Dual-element pyroelectric sensor
- ♦ 3.38" x 3.35" x 2.05" (86mm x 85mm x 52 mm
- ♦ Red LED indicates motion detection
- ♦ Digital Time-delay – adjustable from 15 seconds to 30 minutes; ± 2% tolerance
- ♦ Integrated light level sensor – works from 2.5 to 430 footcandles
- ♦ Available in White

The Watt Stopper, Inc.
Santa Clara, CA 95050
TEL: (408) 988-5331
FAX: (408) 988-5373
Plano, TX 75023
1-800-879-8585

CI-100 Technical Information

Ordering Information & Time-delay Chart

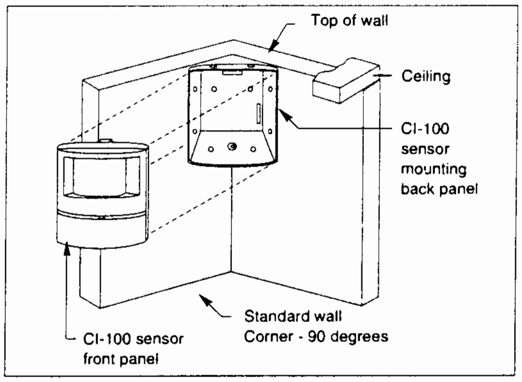
Catalog No.	Description
CI-100	Passive Infrared Sensor
CM-100	Ceiling Mounting Attachment Bracket
WM-100	Swivel Wall Mounting Bracket

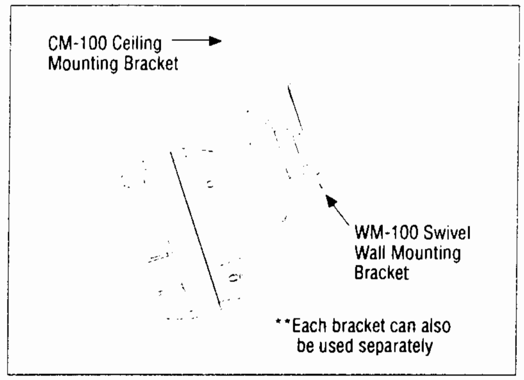
Notes: Dense Wide Angle lens is standard
(see Coverage Patterns below)
Add -1 after Catalog No. for Long Range lens
Add -2 after Catalog No. for Extra Wide Angle lens
All Units are white and use Watt Stopper Power Packs

Time Delay	1	2	3	4	5	6
15 sec	1	0	0	0	0	0
2 min	0	1	0	0	0	0
4 min	0	0	1	0	0	0
6 min	0	1	1	0	0	0
8 min	0	0	0	1	0	0
10 min	0	1	0	1	0	0
12 min	0	0	1	1	0	0
14 min	0	1	1	1	0	0
16 min	0	0	0	0	1	0
18 min	0	1	0	0	1	0
20 min	0	0	1	0	1	0
22 min	0	1	1	0	1	0
24 min	0	0	0	1	1	0
26 min	0	1	0	1	1	0
28 min	0	0	1	1	1	0
30 min	0	1	1	1	1	0
O/R	X	X	X	X	X	1

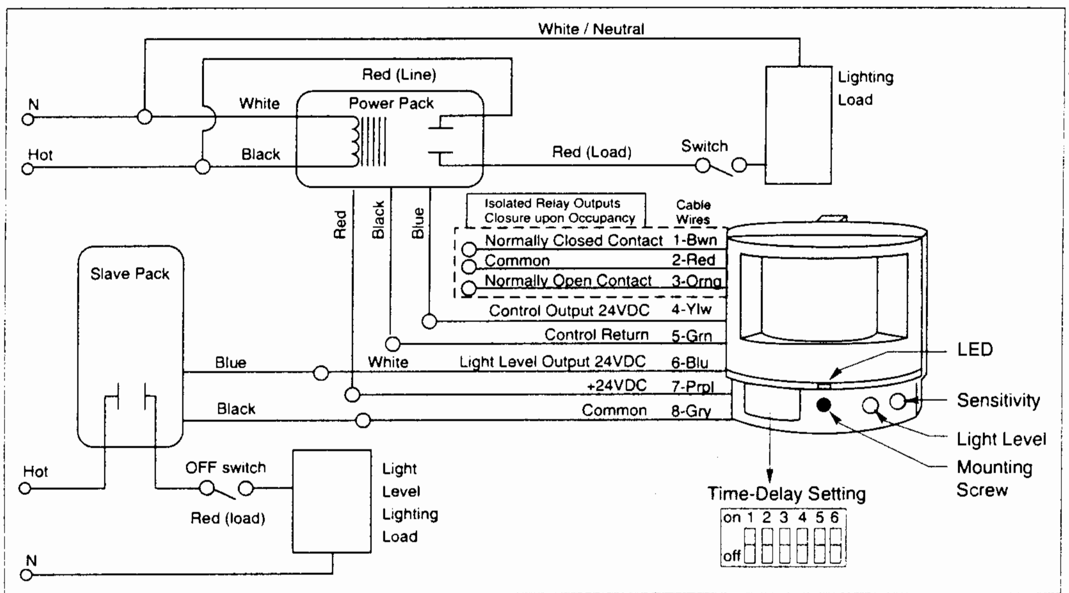
1 = ON 0 = OFF X = Not Applicable

Installation

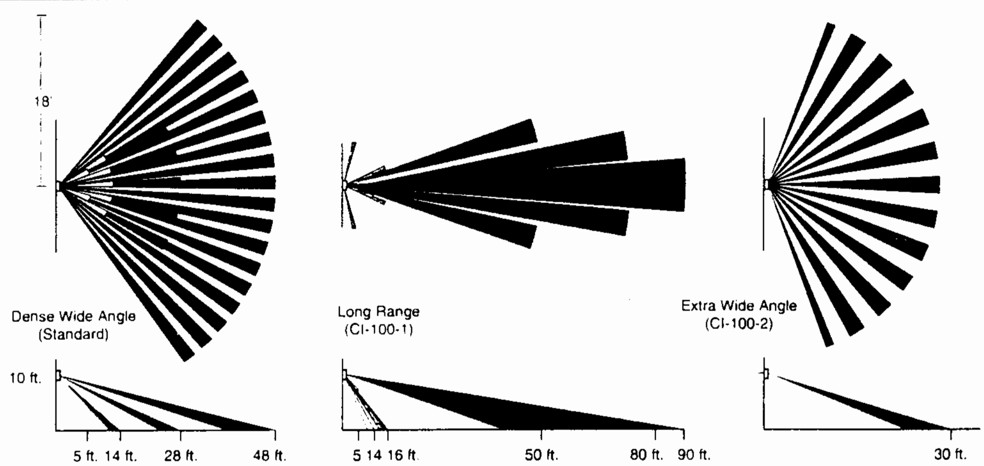




Wiring Schematic & Product Controls



Coverages



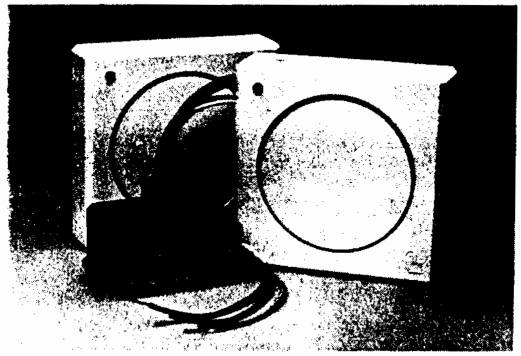
Note: Coverages shown are maximum coverages and represent half-step walking motion.

The Watt Stopper, Inc.
Santa Clara, CA 95050
Pub. No. 3301

The Watt Stopper®

Ultrasonic Sensors

- Proven 30% to 60% savings; Turn lights on only when needed
- 500, 1000 and 2000 sq. ft. coverages available
- Adjustable sensitivity & time delay
- Fully-integrated product line
- UL & CSA Listed; Five-year warranty



System Information

Watt Stopper Ultrasonic Sensors are part of an integrated system of lighting control products. Sensors are available to control almost any application, and can work as stand-alone products or as part of a larger lighting control system.

Operation

Watt Stopper Ultrasonic Sensors utilize advanced omni-directional ultrasonic doppler technology to sense occupancy. When ceiling mount sensors detect movement in controlled areas, they switch lighting systems on through a Watt Stopper Power Pack. The sensor controls the power pack through low-voltage wiring. As long as movement is sensed, the lights remain on. Lighting systems are switched off when no movement is detected after a user-adjustable period of time (from 15 seconds to 15 minutes).

Features

Watt Stopper Ultrasonic Sensors are designed to work across a wide variety of applications, both individually and as part of a larger system. All Watt Stopper Ultrasonic sensors feature adjustable time delay, adjustable sensitivity, logic key/ON bypass and omni-directional ultrasonic technology. An LED indicator makes sensitivity adjustments easier. In addition, Watt Stopper Ultrasonic sensors are UL and CSA Listed and have a five-year warranty.

Applications & Economics

Ultrasonic sensors come in coverages of 500 sq. ft., 1000 sq. ft. and 2000 sq. ft. They're designed to work together to effectively control small offices, utility areas, open office spaces and even warehouses. The W-500A is perfect for offices, conference rooms, bathrooms and other areas up to 500 sq. ft. The W-1000A is ideal for larger spaces like classrooms and storage areas. The W-2000H is ideal for hallways, while the W-2000A is ideal for large open areas such as warehouses and can control partitioned open office spaces when configured in highly-versatile zone patterns. The W-120C and W-277C are wall switch replacement units that are ideal for small storage areas, bathrooms and enclosed rooms. All the units are designed to pick up people writing, reaching for phones, typing, etc. They slash utility costs by turning lights off when they're not needed. And, unlike sweep systems, they don't impair the work environment in any way. Also, easy installation and low initial cost provide fast paybacks.

Specifications

- Solid State, crystal-controlled (25 kHz± 0.005%)
- Omni-directional transmission (360° coverage)
- Temperature and humidity-resistant 25 kHz Microphone Receivers
- Logic Key/ON bypass
- 4.5" x 4.5" x 1.25" (115mm x 115mm x 32mm) (W x L x D)
- Time delay adjustable from 15 seconds to 15 minutes
- Available in White or Ivory

The Watt Stopper, Inc.
Santa Clara, CA 95050
TEL: (408) 988-5331
FAX: (408) 988-5373
Plano, TX 75023
1-800-879-8585

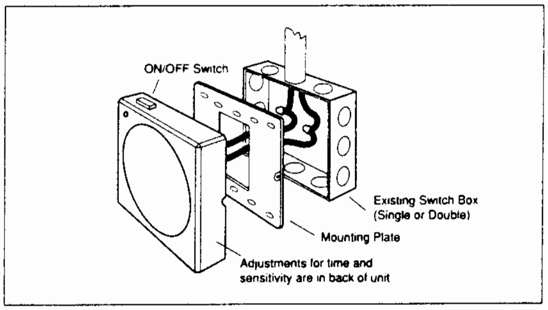
Ultrasonic Sensor Technical Information

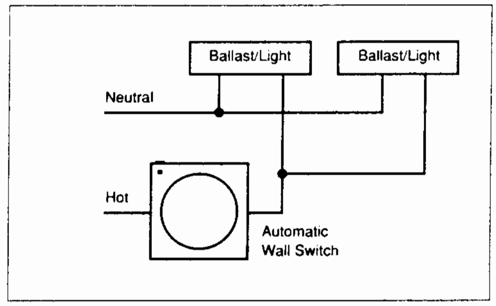
Ordering Information

Catalog No.	Description/Type	Voltage	Current/Load	Coverage	Notes
W-500A	Ceiling Sensor	24 VDC	20 mA	500 sq ft – 360°	1,2
W-1000A	Ceiling Sensor	24 VDC	20 mA	1000 sq ft – 360°	1,2
W-2000A	Ceiling Sensor	24 VDC	20 mA	2000 sq ft – 360°	1,2
W-2000H	Hallway Sensor	24 VDC	20 mA	900 sq ft **	1,2
W-120C	Wall Switch	120 VAC	150-800 Watts	500 sq ft – 180°	
W-277C	Wall Switch	277 VAC	150-1000 Watts	500 sq ft – 180°	

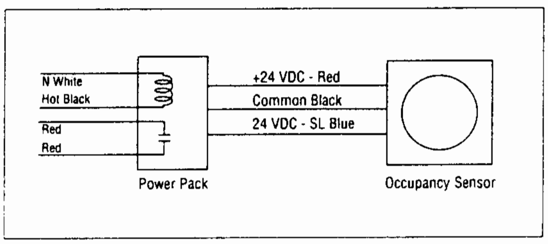
Notes: **1** – Used with Watt Stopper Power Pack
2 – Available for half-wave pulse, low-voltage lighting systems, add **-24** to Catalog No.
All models are White, add an **-I** to Catalog No. for Ivory.

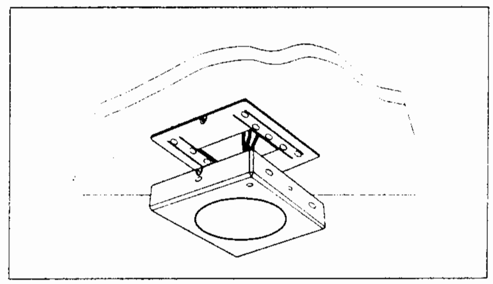
Wall Switch Installation & Schematic



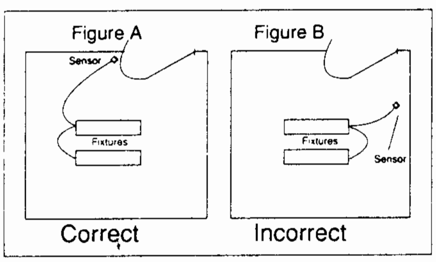


Ceiling Sensor Placement and Schematic

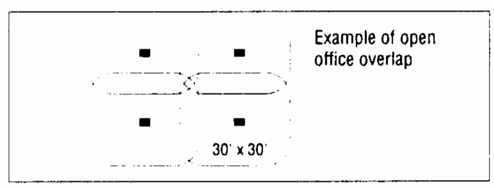




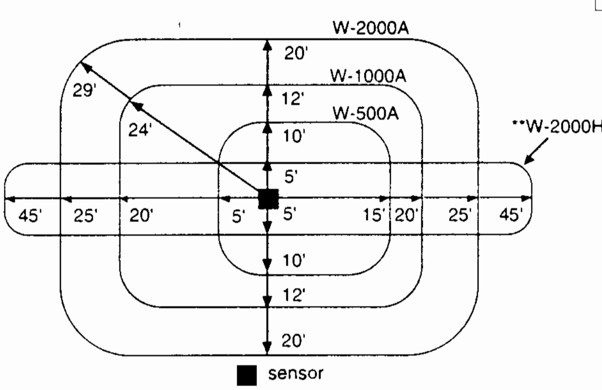
For standard installation use toggle bolts attaching mounting plate to ceiling tile. Always try to attach sensor to a vibration free surface.



For enclosed spaces sensors should be placed as in Figure A. Sensors placed as in Figure B would see out the door, resulting in false triggering.



Ceiling Sensor Coverage



For open office space the W-2000A is the most often used because of its true 360° coverage and capability to bounce off of partitions, walls, floors and other reflecting objects to sense motion. A typical layout for open office space is for the ultrasonic sensors to control the office area in zones that overlap. The coverage can be for a 20' x 20' zone and up to a maximum of 40' x 40'. A typical zone is about 25' x 25' for the lighting fixtures and an overlap on the sensor coverage that picks up to 30' x 30'.

Coverages shown represent half-step walking motion. Actual coverages can vary for each application depending on shape and use of space and obstacles present.

**The W-2000H drawing is not drawn to scale. Coverage is 10' x 90' in a hallway, walls are necessary for this coverage pattern.

The Watt Stopper, Inc.
Santa Clara, CA 95050
Pub. No. 0104

Section G - Daylighting Controls

G-1 Non-task areas

In all buildings, provide photometric ON/OFF controls to turn off lights in response to natural light availability for fixtures meeting the following criteria:

(1) Spaces without assigned work areas, and 20 fc or less maintained illumination, IES categories A, B and C, including:

Corridors
Stairways
Lobbies
Vestibules
Lounges
Multipurpose rooms
Cafeterias

(2) Fixtures within daylighting zone defined by rectangle 8 feet deep from a window and 3 feet to either side.

(3) Minimum of 300 Watts connected lighting per photocell. Combine spaces where feasible to meet this wattage.

2.1 <u>Control Sequence</u>. Photocell shall measure interior light level at a representative point in the daylit space, generally 4 feet away from the window/wall. Photocell shall have an adjustable dead band, with initial settings OFF at 50 fc and ON at 15 fc.

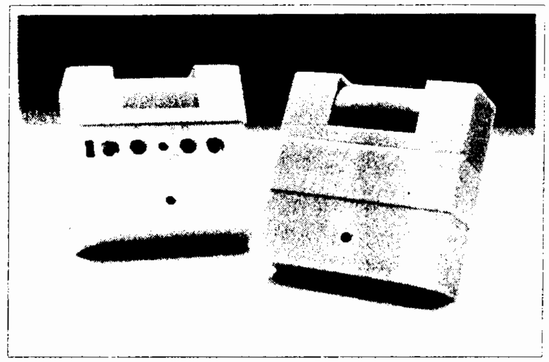
G-1 Task areas

Do not use ON/OFF photocell controls in task areas characterized as IES categories D, E or higher.

The Watt Stopper

LightSaver Controller

- Turns lighting systems on and off according to natural light levels
- Part of a fully-integrated system
- User-adjustable settings: 10 to 1000 footcandles
- User-adjustable Deadband feature prevents lighting system cycling
- Easy installation; Five year warranty



System Information

The LightSaver is part of a fully integrated lighting control system. It automatically switches lighting systems off when enough natural light is available and turns them back on again when lights are needed. The LightSaver sensor also works with other lighting control systems or as part of a larger lighting control system.

Operation

The LightSaver is a self-contained 24 VDC light level sensor which controls lighting systems through Watt Stopper Power Packs. The LightSaver uses an internal photo conductive cell to measure light levels. The sensor turns lighting systems off when natural light levels reach from 10 to 1000 footcandles (setting adjustable by user). Lighting systems come back on when natural light levels have fallen far enough to warrant it. A deadband feature prevents lighting system from cycling on partly cloudy days. The LightSaver also has an adjustable time delay of three seconds to five minutes which helps prevent cycling.

Features

The LightSaver is available in two models—the LS-100XA and the LS-100XB. The LS-100XA operates at light levels from 10 to 200 footcandles, while the LS-100XB works from 50 to 1000 footcandles. The time delay and adjustable deadband features prevent cycling during partly cloudy days. A dual color LED displays the LightSaver's current triggering status. All units have a user logic key ON/bypass.

Applications

LightSavers can be used to control virtually any area through the use of Watt Stopper power and slave packs. Any type of lighting can be controlled: fluorescent, HID and incandescent. LightSaver sensors work in peripheral offices, areas with skylights, cafeterias, warehouses and any other area with natural light access. Other applications include turning off lighting in outdoor parking facilities, car lots, repair and storage facilities, service stations, food establishments, billboard systems, outside signs, and security lighting applications. The LightSaver can be integrated into a system with Watt Stopper occupancy sensors so lighting systems are on only when areas are occupied and artificial light is necessary. Sensors are also an ideal supplement to existing security systems.

Economics

LightSaver sensors slash utility costs by turning lights off when they're not needed. Easy installation and advanced design keep unit costs down and paybacks fast.

The Watt Stopper, Inc.
Santa Clara, CA 95050
TEL: (408) 988-5331
FAX: (408) 988-5373
Plano, TX 75023
1-800-879-8585

LightSaver Technical Information

LightSaver Specifications

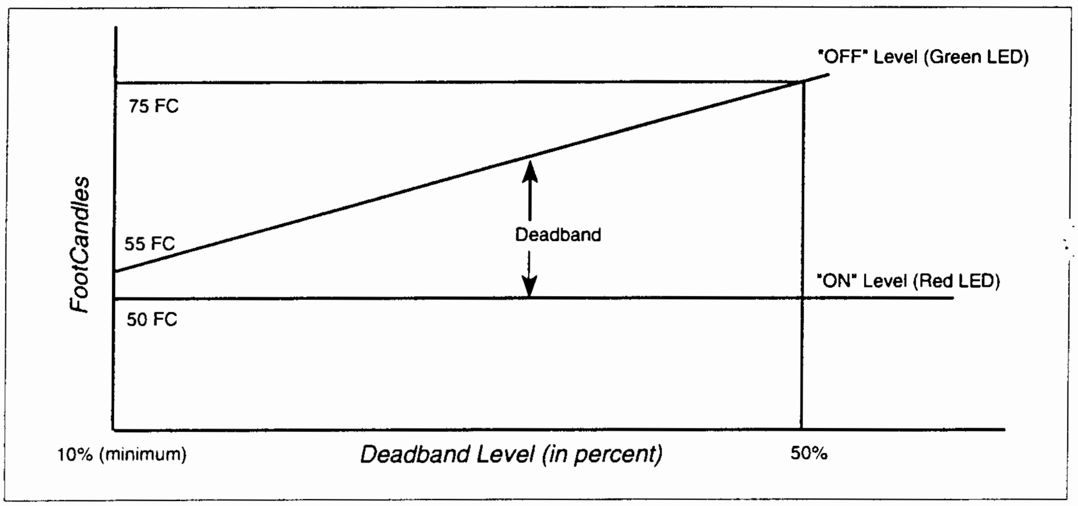
- Completely integrated with the rest of the Watt Stopper line of lighting control
- Solid state system
- Adjustable "ON" light level setting and adjustable "OFF" deadband feature
- Adjustable time delay (three seconds to five minutes)
- Dimensions: 2.5" x 2.5" x .75" (64mm x 64mm x 21mm) (Length x Width x Depth)
- Control output: 120 mA current maximum
- Logic key/ ON bypass; Dual color LED displays unit status
- Five-year Warranty

Ordering Information

Catalog No.	Voltage	Footcandle Range	Deadband Range
LS-100XA	24 VDC	10-200	10 to 300 %
LS-100XB	24 VDC	50-1000	10 to 300 %

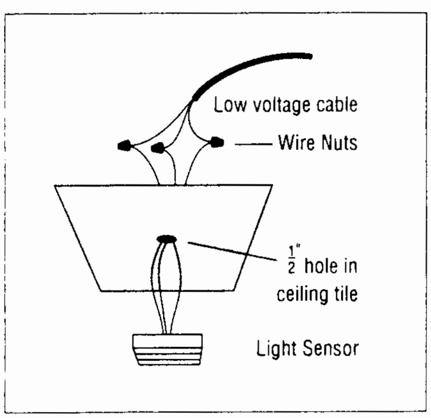
Used with Watt Stopper Power Packs.

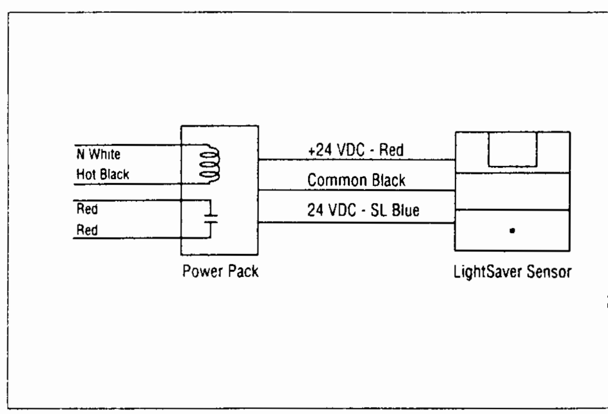
Deadband Feature Information



If lighting levels drop below the ON level (here set to 50 Footcandles), the LED will turn red and the lights will go on after the user-adjustable time delay has expired. Light levels will increase after the lights are turned on, but the lights will remain ON until the OFF level is reached. Should light levels climb above the OFF level, the signal LED will turn green, and the lights will turn off when the time delay has expired. This deadband feature prevents lighting systems from cycling.

Installation and Electrical Schematics





The Watt Stopper, Inc.
Santa Clara, CA 95050

Pub. No. 0203

Appendix One

Lighting Compliance Program

(ASHRAE 90.1-1989 Appendix B)

B.1 Introduction

The microcomputer Lighting Prescriptive and System Performance Compliance Calculation Program calculates requirements in ASHRAE/IES Standard 90.1-1989, "Energy Efficient Design of New Buildings except Low-Rise Residential Buildings". The program may be used for performing the calculations required for the lighting requirements and compliance calculations in 6.4, 6.5, and 6.6 of the standard. The calculations performed by the lighting program are an exact duplicate of the requirements and the compliance calculations contained in 6.4, 6.5, and 6.6 of the standard.

The lighting program does not calculate power adjustment factors for automatic control devices, as described in 6.4. ~~Users must consider these adjustment factors separately.~~

The microcomputer program is provided as a convenience in determining lighting requirements and calculating if a building design is in compliance with those requirements. The program will perform calculations for a maximum of 500 spaces in a building and 100 exterior illumination areas.

This appendix contains instructions for using the program and a list of building type, space type, and exterior area codes incorporated into the program. A diskette containing the program is included with this standard. If you requested a 3.5 in., 720-kybte format diskette, you will receive a single diskette with two directories—ENVELOPE and LIGHTING. The lighting program is under the LIGHTING subdirectory. If you requested 5-1/4 in., 360-kbyte format diskettes, you will receive two diskettes, one containing the lighting program and one containing the envelope program.

B.2 Using The Program

The lighting program has been written in the C computer language. The compiled version of the program provided on the diskette will run on virtually any MS-DOS compatible microcomputer, requiring only the MS-DOS 2.0 or later operating system.

In order to run this program, you will need the following equipment:

* an IBM-DOS or other MS-DOS compatible microcomputer with:
  —at least 384K RAM memory, and
  —a double sided, double density disk drive or a double sided, double density disk drive and a hard disk.
* a monochrome or color monitor
* a math coprocessor (optional)
* MS-DOS operating system; 2.0 or later version

B.2.1 Users with Two Diskette Drives. To run the program, insert the operating system (DOS) diskette in Drive A and turn on the computer. After providing the time and date information requested on the screen, the screen will show an **A>** prompt; at this point replace the operating system diskette in Drive A with the lighting program diskette. Type **Dir** and then press the **Enter** key. A list of the files on the diskette will appear on the screen. The diskette includes the following files:

LTGSTD21.EXE	Compiled Lighting Program
LIGHTING.DOC	Users' guide documentation

Three additional files are included on the diskette as example data files:

BANK.LTG	Example branch bank building, 2,250 ft², single story.
CHURCH.LTG	Example church building, 12,920 ft², single story.
MEDOFFIC.LTG	Example medium office building, 48,664 ft², three stories.

To start the lighting program, type **LTGSTD21** and press **Enter**. After the title screen appears, press any key to continue and the Main Input Screen shown in Fig. B-1 will appear. Before using the lighting program, first make a copy of the original diskette. See your DOS Reference Manual for instructions on formatting and copying diskettes.

B.2.2 Users with Hard Disk Drives. If you have a hard disk drive, it is recommended that the lighting program be copied onto the hard disk. The instructions given below assume that the **DOS** is already on the hard disk and the hard disk is designated as Drive C.

The first step in copying the lighting program files to your hard disk is to create a directory for those files. Directories allow the user to organize files into related groups. You should put all the files from the lighting program diskette into the same directory. The following instructions assume the directory name is **LIGHTING**, but the user can name the directory anything.

* Make sure the **C>** prompt is on the screen. (Type **C:** and press **Enter**).
* Type **MKDIR \LIGHTING** and press **Enter**. This DOS command creates a directory on the hard disk called **LIGHTING** under the main root directory.
* Type **CHDIR \LIGHTING** and press **Enter**. This DOS command makes **LIGHTING** the current directory. Your **DOS** manual contains more information about creating and using directories.

Now copy the files from the lighting program diskette to the hard disk.

* Make sure the **C>** prompt is on the screen. (Type **C:** and press **Enter**).
* Place the **Lighting Program** diskette in Drive **A** and close the door.
* Type **COPY A:*.*** and press **Enter**. This DOS command copies every file from the diskette in Drive **A** to the current directory on the hard disk Drive **C**.

To start the lighting program, type **LTGSTD21** and press **Enter**. After the title screen appears, press any key to continue and the Main Input Screen shown in Fig. B-1 will appear.

B.3 Main Input Screen

The cursor control keys, special function keys, and data required for the Main Input Screen are described below. The Main Input Screen is shown in Fig. B-1. The user enters information about the building types, the gross area of the building, interior and exterior lighting power design watts, and an optional description

```
BUILDING TYPE                AREA          BUILDING
 NA                             0 ft2          DATE
 NA                             0 ft2
 NA                             0 ft2
                                0 Gross ft2
BUILDING DESIGN
  Interior Lighting Power              0 W              0 W/Gross ft2
  Exterior Lighting Power              0 W
______________________________________________________________________

 PRESCRIPTIVE CRITERIA
   Unit Lighting Power Allowance                 NA W/Gross ft2
   Interior Lighting Power Allowance             NA W

 SYSTEM PERFORMANCE CRITERIA
   Unit Power Density                             0 W/Gross ft2
   Interior Lighting Power Allowance              0 W

 EXTERIOR LIGHTING CRITERIA
   Exterior Lighting Power Allowance              0 W
______________________________________________________________________
 F1 Load | F3 Clear     | F5 Space Screen     | F7 Help        | F9 Calculate
 F2 Save | F4 Directory | F6 Bldg Type Codes  | F8 Ext. Screen | Esc Exit to Dos
```

Fig. B-1 Main Input Screen

and date. The program automatically calculates the compliance values for Interior Lighting Power Allowance (ILPA) and Exterior Lighting Power Allowance. (ELPA) If the design lighting power is less than the compliance values, the building design complies.

B.3.1 Cursor Control Keys. The following keys allow the user to move the cursor around the Main Input Screen.

<BACKSPACE>	Delete the last character of a column.
<LEFT ARROW>	Move the cursor one column to the left, or, if at the left-most column, move the cursor to the last column of the previous entry.
<RIGHT ARROW>	Move the cursor one column to the right, or if at the right-most column, move the cursor to the first column of the next entry.
<UP ARROW>	Move the cursor up one row to the start of entry above it, or if on the top row, move the cursor to the bottom row.
<DOWN ARROW>	Move the cursor down one row to the start of the entry below, or if on the bottom row, move the cursor to the top row.

B.3.2 Special Function Keys. Special function keys allow the user to calculate compliance, save and recall lighting compliance calculations, and other features.

<F1>	List all LTGSTD data files in the current default directory (all files with .LTG extension). The user is then prompted for a filename to load into the LTGSTD program. Any filename acceptable to DOS can be used (up to eight characters in length with a three character extension). The program will read up to twenty characters to allow the use of disk drive and directory designations. Enter the disk drive, directory path, and filename without the .LTG extension.
<F2>	Save a LTGSTD data file to disk. The files are saved as ASCII files, allowing the user to print them later. Enter the disk drive, directory path, and filename without the .LTG extension.
<F3>	Clear all data from the Main Input Screen, the Space Data Input Screen, the Controls Data Input Screen, and the Exterior Data Input Screen. Initialize all values to zero.
<F4>	List all LTGSTD data files in the current default directory with an .LTG extension.
<F5>	Move from the Main Input Screen to the Space Data Input Screen.
<F6>	Display the building type descriptions and codes in a window. The user selects a space type by pressing the **Enter** key when the cursor is moved over the desired building type. To return to the Main Input Screen, press **Esc** or the space bar.
<F7>	Display a help context-sensitive message for the information required at the current cursor position. Press any key to return to the Main Input Screen.
<F8>	Move from the Main Input Screen to the Exterior Data Input Screen.
<F9>	Calculate the interior lighting power allowance for both the Prescriptive and System Performance compliance path, and the exterior lighting power allowance. The program also shows if the design values comply with these requirements.
<Esc>	Exit from the program.

B.3.3 Input Requirements for Main Input Screen. The Main Input Screen has two required entries: Building Type Code or Codes and the gross area or areas of the buildings. The other two entries, building description and date, are optional.

BUILDING TYPE	If the Prescriptive Compliance Path in 6.5 will be used, enter a character from A to K to designate the appropriate building occupancy. Alternatively, press F6, move the cursor to the appropriate building type/area code and press **Enter**. The Prescriptive Path is available only for the building type/area codes listed. This option is intended primarily for use with core and shell buildings or during the preliminary design phase. The building type codes are also listed in Table B-1.
AREA	Enter either the gross area of the entire building or if significant amounts of different building/occupancy types are present, the gross area of each. The program and the standard require that different building/occupancy types must be at least 10% of the gross building area to be considered. The units are ft² and the allowable range is 0 to 99,999,999.
BUILDING	Use this space to identify the project being evaluated. The name or description of the building is limited to 30 characters.
DATE	Use this space to record the date and other information such as the initials

Table B-1
Building Type Codes

Building Type Code	Building Type
A	Fast Food/Cafeteria
B	Leisure Dining/Bar
C	Offices
D	Retail
E	Mall Concourse
F	Service Establishment
G	Garage
H	Pre/Elementary School
I	High School
J	Technical/Voc. School
K	Warehouse/Storage

of the individual conducting the evaluation. A maximum of 30 characters may be entered.

INTERIOR LIGHTING POWER Enter the total interior lighting power for the building as it has been designed. Include the power required for supplemental and task related lighting provided by plug-in luminaires as well as permanently installed lighting. Allowable values are 0 to 999,999,999 W.

EXTERIOR LIGHTING POWER Enter the total exterior lighting power for the building as it has been designed. Include all power used for illumination of roads, grounds, and building exteriors that is energized through the building electrical service. Allowable values are 0 to 999,999,999 W.

B.4 Space Data Input Screen

The cursor control keys, special function keys, and input requirements for the Space Data Input Screen are described below. The Space Data Input Screen is shown in Fig. B-2. The user enters information about the space -space number designation (optional), space type code, ceiling height, area or dimensions, and number of spaces. The space type description shown at the top is for the line where the cursor is currently pointing. The program automatically calculates the Area Factor (AF), Unit Power Density (UPD), Base Unit Lighting Power Allowance (Pb), Lighting Power Budget (LPB) based on the space data, and Total Lighting Power Budget (TOTAL LPB).

B.4.1 Cursor Control Keys. The following keys allow the user to move the cursor around the Space Data Input Screen.

<BACKSPACE> Delete the last character of a column.

<LEFT ARROW> Move the cursor one column to the left or if at the left most column, move the cursor to the first column of the same row.

<RIGHT ARROW> Move the cursor one column to the right or if at the right most column, move the cursor to the last column of the same row.

<UP ARROW> Move the cursor up one row in the same column, and if on the top row of the Space Data Input Screen, scroll records up one row.

<DOWN ARROW> Move the cursor down one row in the same column, and if on the bottom row of the Space Data Input Screen, scroll the records down one row.

<Ins> Insert a blank record line at the current position of the cursor. This function can be used at any record line of the space data.

<Del> Delete a record line at the current position of the cursor. This function can be used to delete any record line of the space data.

<PgUp> Move the cursor up 17 record lines or if near the beginning of the space input data, advance the cursor to the first record line.

<PgDn> Move the cursor down 17 record lines.

<Home> Move the cursor to the first record line.

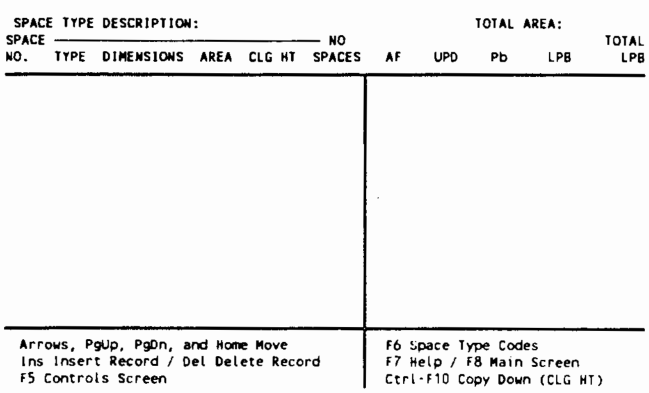


Fig. B-2 Space Data Input Screen

B.4.2 Special Function Keys. The special function keys allow the user to move from the Space Data Input Screen to the Controls Data Input Screen or Main Input Screen, view and select space type codes, and get help on the required data.

<F5> Move from the Space Data Input Screen to the Controls Data Input Screen.

<F6> Display the space types and their descriptions in a window when the cursor is in the space type entry column. Allows the user to cursor through the types and select one by pressing the **Enter** key. If no space type is desired, press the space bar or **Esc** key to return to the Space Data Input Screen.

When in the space type code window, the user can search for a specific space type by pressing the **F1** key, entering a character string and then pressing **Enter**. By pressing **F1** and **Enter** again, the program will search for the next occurrence of the character string.

<F7> Display a help context sensitive message for the information required at the current cursor position. Press any key to return to the Space Data Input Screen.

<F8> Move from the Space Data Input Screen to the Main Input Screen.

<Ctrl> <F10> Copy the Ceiling Height on the line where the cursor is currently located down to all lines where data has been entered.

B.4.3 Input Requirements for Space Data Input Screen. The Space Data Input Screen allows the user to enter information about the building spaces: space type, dimensions or area, ceiling height, and number of spaces. Up to 500 spaces can be entered for a single building. Records do not have to be completely entered before moving to a new record, but incomplete records are not included in the compliance calculations.

SPACE NO.	Enter space numbers to identify individual spaces within the building. Combinations of up to four characters and numbers are allowed.
SPACE TYPE	Enter an integer from 1 to 131 to designate the appropriate space type code. Alternatively, press F6, move the cursor to the appropriate space type code, and press **Enter**. If the space type or activity is not represented by the list, select the code with the most similar space type or activity. The space type codes are also listed in Table B-2.
DIMENSIONS	Enter the length and width of the space, in ft. The program will automatically calculate the floor area. Alternatively, the length and width of the space can be left blank, and the area entered directly. Allowable values are 0 to 999 ft.
AREA	Enter the floor area of the space, in ft^2. Alternatively, the length and width of the space, in ft, can be entered under the Dimensions column and the floor area will be calculated automatically. Allowable values are 0 to 999,999 ft^2.
CLG HT	Enter the height of the ceiling, in ft. The program uses the ceiling height to calculate the Area Factor (AF) for each space. Allowable values are 0 to 500 ft. Alternately, enter all other data, then return to the first data line and enter the typical ceiling height. Then, press <**Ctrl**><**F10**>. The program will automatically copy the ceiling height to all lines with data.
NO. SPACES	Enter the number of spaces in the building that are like the one described. This value serves as a multiplier, allowing the user to enter multiple similar spaces in a single entry. The allowable range is 0 to 99.

B.5 Controls Data Input Screen

The cursor control keys, special function keys, and input requirements for the Controls Data Input Screen are described below. The Controls Data Input Screen is shown in Fig. B-3. The user enters information about the number of tasks or groups of tasks, and the type of controls installed in the space. The requirements for minimum number of equivalent control points and the credits for various control types are in 6.3.2 of the standard. The program automatically calculates the total controls points required for each space based on the data entered. The Space No., Description, and Area are brought forward by the program from the Space Data Input Screen.

B.5.1 Cursor Control Keys. The following keys allow the user to move the cursor around the Controls Data Input Screen.

<**BACKSPACE**>	Delete the last character of a column.
<**LEFT ARROW**>	Move the cursor one column to the left or if at the left most column, move the cursor to the first column of the same row.
<**RIGHT ARROW**>	Move the cursor one column to the right or if at the right most column, move the cursor to the last column of the same row.
<**UP ARROW**>	Move the cursor up one row in the same column, and if on the top row of the Controls Data Input Screen, scroll records up one row.
<**DOWN ARROW**>	Move the cursor down one row in the same column, and if on the bottom row of the Controls Data Input Screen, scroll the records down one row.
<**PgUp**>	Move the cursor up 17 record lines or if near the beginning of the space input data, advance the cursor to the first record line.
<**PgDn**>	Move the cursor down 17 record lines.
<**Home**>	Move the cursor to the first record line.

B.5.2 Special Function Keys. The special function keys allow the user to move from the Controls Input

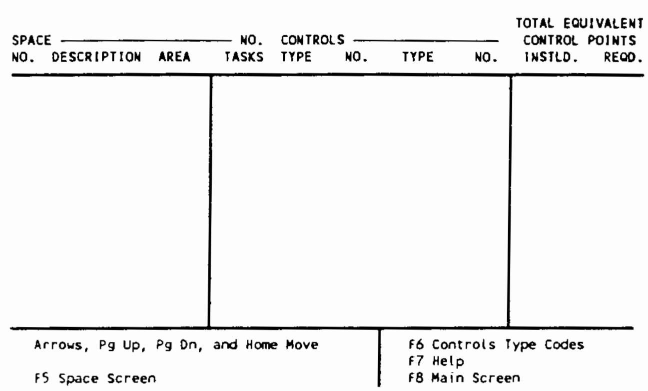


Fig. B-3 Controls Data Input Screen

Table B-2
Space Type Codes

Space Type Code	Description	UPD
	Auditorium	
1	Auditorium	1.6
	Corridor	
2	Corridor	0.8
	Classroom/Lecture Hall	
3	Classroom/Lecture Hall	2.0
	Electrical/Mechanical Equipment Room	
4	General	0.7
5	Control Room	1.5
	Food Service	
6	Fast Food/Cafeteria	1.3
7	Leisure Dining	2.5
8	Bar/Lounge	2.5
9	Kitchen	1.4
	Recreation/Lounge	
10	Recreation/Lounge	0.7
	Stair	
11	Active Traffic	0.6
12	Emergency Exit	0.4
	Toilet and Washroom	
13	Toilet and Washroom	0.8
	Garage	
14	Auto and Pedestrian Circulation	0.3
15	Parking Area	0.2
	Laboratory	
16	Laboratory	2.3
	Library	
17	Audio Visual	1.1
18	Stack Area	1.5
19	Card Filing & Cataloging	1.6
20	Reading Area	1.9
	Lobby (General)	
21	Reception and Waiting	1.0
22	Elevator Lobbies	0.8
	Atrium (Multi-Story)	
23	First 3 Floors	0.7
24	Each Additional Floor	0.2
	Locker Room and Shower	
25	Locker Room and Shower	0.8
	Offices (Partitions > 4.5 ft below ceiling) Enclosed offices, all open plan offices without partitions or with partitions lower than 4.5 ft below the ceiling.	
26	Reading, Typing & Filing	1.8
27	Drafting	2.6
28	Accounting	2.1
	Offices (Partitions 3.5–4.5 ft below ceiling) Open plan offices 900 ft² or larger with partitions 3.5 to 4.5 ft below the ceiling.	
29	Reading, Typing & Filing	1.9
30	Drafting	2.9
31	Accounting	2.4
	Offices (Partitions < 3.5 ft below ceiling) Open plan offices 900 ft² or larger with partitions higher than 3.5 ft below the ceiling. Offices less than 900 ft² shall use types 26, 27, or 28.	
32	Reading, Typing & Filing	2.2
33	Drafting	3.4
34	Accounting	2.7

Table B-2
Space Type Codes

Space Type Code	Description	UPD
	Common Activity Areas	
35	Conference/Meeting Room	1.8
36	Computer/Office Equipment	2.1
37	Inactive Filing	1.0
38	Mail Room	1.8
	Shop (Non-Industrial)	
39	Machinery	2.5
40	Electrical/Electronic	2.5
41	Painting	1.6
42	Carpentry	2.3
43	Welding	1.2
	Storage & Warehouse	
44	Inactive Storage	0.3
45	Bulky Active Storage	0.3
46	Fine Active Storage	1.0
47	Material Handling	1.0
	Unlisted Space	
48	Unlisted Space	0.2
	Airport, Bus & Rail Station	
49	Baggage Area	1.0
50	Concourse/Main Thruway	0.9
51	Ticket Counter	2.5
52	Waiting & Lounge Area	1.2
	Bank	
53	Customer Area	1.1
54	Banking Activity Area	2.8
	Barber & Beauty Parlor	
55	Barber & Beauty Parlor	2.0
	Church, Synagogue, Chapel	
56	Worship/Congregational	2.5
57	Preaching & Sermon/Choir	2.7
	Dormitory	
58	Bedroom	1.1
59	Bedroom with Study	1.4
60	Study Hall	1.8
	Fire & Police Department	
61	Fire Engine Room	0.7
62	Jail Cell	0.8
	Hospital/Nursing Home	
63	Corridor	1.3
64	Dental Suite/Exam/Treatment	1.6
65	Emergency	2.3
66	Laboratory	1.9
67	Lounge/Waiting Room	0.9
68	Medical Supplies	2.4
69	Nursery	2.0
70	Nurse Station	2.1
71	Occu./Physical Therapy	1.6
72	Patient Room	1.4
73	Pharmacy	1.7
74	Radiology	2.1
	Surgery & O.B. Suites	
75	General Area	2.1
76	Operating Room	7.0
77	Recovery	2.3
	Hotel/Conference Center	
78	Banquet/Multipurpose Room	2.4
79	Bathroom/Powder Room	1.2
80	Guest Room	1.4
81	Public Area	1.2
82	Exhibition Hall	2.6
83	Conference/Meeting	1.8
84	Lobby	1.9
85	Reception Desk	2.4

Table B-2
Space Type Codes

Space Type Code	Description	UPD
	Laundry	
86	Washing	0.9
87	Ironing & Sorting	1.3
	Museum & Gallery	
88	General Exhibition	1.9
89	Inspection/Restoration	3.9
90	Inactive Artifacts Storage	0.6
91	Active Artifacts Storage	0.7
	Post Office	
92	Lobby	1.1
93	Sorting & Mailing	2.1
	Service Station/Auto Repair	
94	Service Station	1.0
	Theater	
95	Performance Arts	1.5
96	Motion Picture	1.0
97	Lobby	1.5
	Retail Establishments (Merchandising & Circulation Area) Applicable to all lighting, including accent and display lighting, installed in merchandising and circulation areas.	
98	Type A (Mass Merchandising)	5.6
99	Type B (Service Retail)	3.2
100	Type C (Mixed Use Retail)	3.3
101	Type D (Specialty Shop)	3.1
102	Type E (Fine Merchandise)	2.8
103	Type F (Service Establishment)	2.7
104	Mall Concourse	1.4
	Retail Support	
105	Tailoring	2.1
106	Dressing/Fitting Rooms	1.4
	All Sports	
107	Seating Area	0.4
	Badminton	
108	Club	0.5
109	Tournament	0.8

Table B-2
Space Type Codes

Space Type Code	Description	UPD
	Basketball/Volleyball	
110	Intramural	0.8
111	College	1.3
112	Professional	1.9
	Bowling	
113	Approach Area	0.5
114	Lanes	1.1
	Boxing/Wrestling (Platform)	
115	Amateur	2.4
116	Professional	4.8
	Gymnasium	
117	General Exercise & Recreation	1.0
	Handball/Racquetball/Squash	
118	Club	1.3
119	Tournament	2.6
	Ice Hockey	
120	Amateur	1.3
121	College/Professional	2.6
	Skating Rink	
122	Recreational	0.6
123	Exhibition/Professional	2.6
	Swimming	
124	Recreational	0.9
125	Exhibition	1.5
126	Underwater	1.0
	Tennis	
127	Recreational (Class III)	1.3
128	Club/College (Class II)	1.9
129	Professional (Class I)	2.6
	Table Tennis	
130	Club	1.0
131	Tournament	1.6

Data Screen to the Space Data Input Screen and Main Input Screen, view and select controls codes and get help on the input data.

<F5> Move from the Controls Data Input Screen to the Space Data Input Screen.

<F6> Display the lighting controls types and their descriptions in a window when the cursor is sitting in the controls type columns. The user can cursor through the controls types and choose one by pressing **Enter** or return to the Controls Data Input Screen by pressing **Esc** or the space bar.

<F7> Display a help context sensitive message for the information required at the current cursor position. Press any key to return to the Controls Data Input Screen.

<F8> Move from the Controls Data Input Screen to the Main Input Screen.

B.5.3 Input Requirements for Controls Data Input Screen. The Controls Data Input Screen allows the user to enter information about the types and number of lighting controls installed in each of the spaces entered on the Space Data Input Screen.

NO. TASKS Enter the number of separate tasks or groups of tasks in the space. The program uses the number of tasks to calculate the number of control points required for the space.

CONTROL TYPE Enter one of the lighting system control types codes:
0 None
1 Manual
3 Three-Level
O Occupancy Sensor
T Timer
4 Four Level
A Automatic or continuous dimming
The program defaults to no controls

NO. CONTROLS Enter the number of controls installed in the space for the controls type entered in the column to the left. The allowable range is 0 to 99.

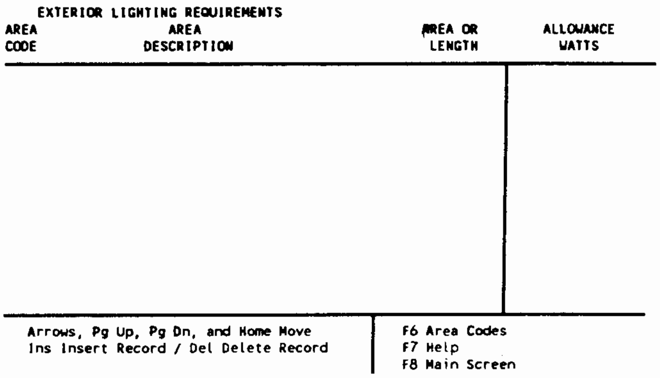


Fig. B-4 Exterior Data Input Screen

B.6 Exterior Data Input Screen

The cursor control keys, special function keys, and input requirements for the Exterior Data Input Screen are described below. The Exterior Data Input Screen is shown in Fig. B-4. The user enters an area code from Table B-3, and an area or length. The program automatically calculates the total watts allowed for each exterior illumination area based on the data entered.

B.6.1 Cursor Control Keys. The following keys allow the user to move the cursor around the Exterior Data Input Screen.

Table B-3
Exterior Area Codes

Area Type Code	Area Type
1	Exit (with or without canopy)
2	Entrance (without canopy)
3	Entrance (with canopy) High Traffic
4	Entrance (with canopy) Light Traffic
5	Entrance (with canopy) Loading Area
6	Entrance (with canopy) Loading Door
7	Building Exterior Surface Facade
8	Storage and non-manufacturing work area
9	Other activity areas for casual use
10	Private driveway/walkways
11	Public driveways/walkways
12	Private parking lots
13	Public parking lots

<BACKSPACE> Delete the last character of a column.

<LEFT ARROW> Move the cursor one column to the left or if at the left most column, move the cursor to the first column of the same row.

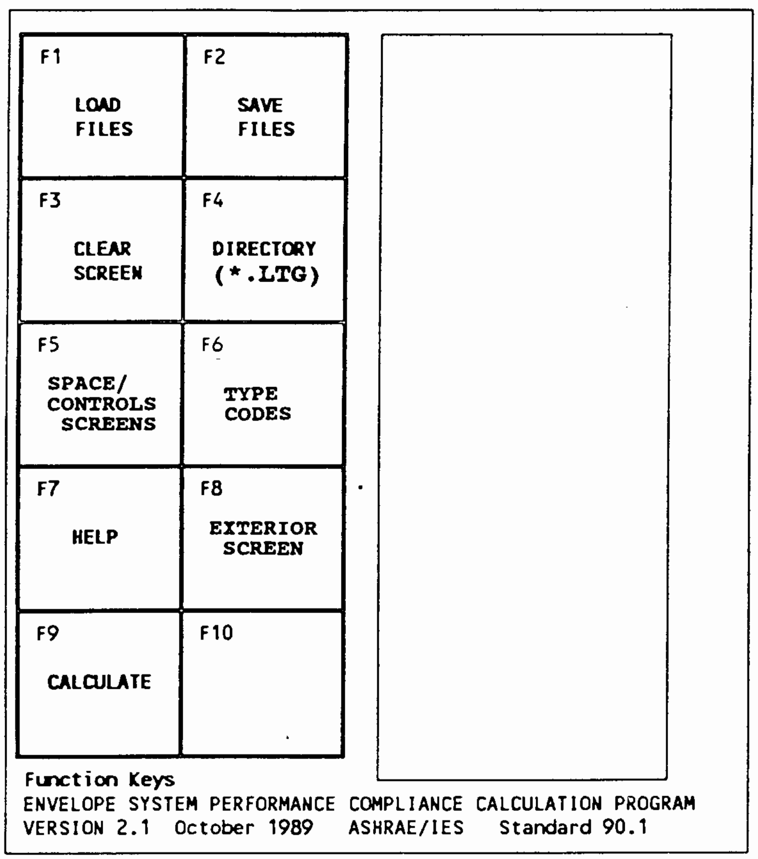


Fig. B-5 Template for 10-Function-Key Computers

<RIGHT ARROW>	Move the cursor one column to the right or if at the right most column, move the cursor to the last column of the same row.
<UP ARROW>	Move the cursor up one row in the same column, and if on the top row of the Exterior Data Input Screen, scroll records up one row.
<DOWN ARROW>	Move the cursor down one row in the same column, and if on the bottom row of the Exterior Data Input Screen, scroll the records down one row.
<Ins>	Insert a blank record line at the current position of the cursor. This function can be used at any record line of the exterior data.
<Del>	Delete a record line at the current position of the cursor. This function can be used at any record line of the exterior data.
<PgUp>	Move the cursor up 17 record lines or if near the beginning of the space input data, advance the cursor to the first record line.
<PgDn>	Move the cursor down 17 record lines.
<Home>	Move the cursor to the first record line.

B.6.2 Special Function Keys. The special function keys allow the user to view and select exterior area codes, get help information for the required data, and move from the Exterior Data Input Screen to the Main Input Screen.

<F6>	Display a window with exterior area type codes and descriptions. The user can cursor through the codes and select a code by pressing the **Enter** key. Pressing any other key brings the user back to the Exterior Data Input Screen.
<F7>	Display a window on the screen with help information on the input data where the cursor is currently located. When any key is pressed, the Exterior Data Input Screen will reappear.
<F8>	Move from the Exterior Data Input Screen to the Main Input Screen.

B.6.3 Input Requirements for Exterior Data Input Screen. The Exterior Data Input Screen allows the user to enter information about exterior illumination of the building. Up to 100 exterior illumination areas can be entered for each building. Records do not have to be completely entered before moving to a new record, but incomplete records are not included in the exterior calculations.

AREA CODE	Enter an integer from 1 to 13 indicating the appropriate code for each illuminated exterior area. Alternatively, press F6, move the cursor to the appropriate area code, and press **Enter**. If the exterior area or activity is not represented by the list, select the code with the most similar area or activity. The exterior area codes are also listed in Table B-3.
AREA OR LENGTH	Enter either the area or the length corresponding with the illuminated exterior area or surface. For exterior area codes 1, 2 and 6, the values are in linear ft; for other area codes, the values are in ft^2. The allowable range for this input is 0 to 999,999,999. The program uses the area or length in calculating the allowance wattage for each exterior illumination area.

B.7 Function Key Templates

A template that can be copied and cut out for use with 10-function-key computers is shown in Fig. B-5 and a template for use with 12-function-key computers is shown in Fig. B-6.

B.8 Example Input Files

Example input and calculations are shown for a branch bank (file **BANK.LTG** on diskette) in Fig. B-7. To review the example with the program, press the **<F1>** key, then type the name of the file (**BANK**) and press the **Enter** key. The data contained in the file will then be loaded by the program.

B.9 Building, Space, and Exterior Type Codes

Building type codes are based on the list of building occupancies/types in Table 6-6 and have been incorporated directly into the program. Table B-1 lists the Building Type Codes for use in the lighting program. The space type codes are based on the list of spaces/functions in Table 6-7. The UPD values for each space type have also been incorporated directly into the program. In Table B-2, the Space Type Codes are listed for the lighting program. The exterior type codes are based on the list of roads, grounds, and other exterior illumination areas in Table 6-5. Table B-3 lists the Exterior Type Codes for use in the lighting program.

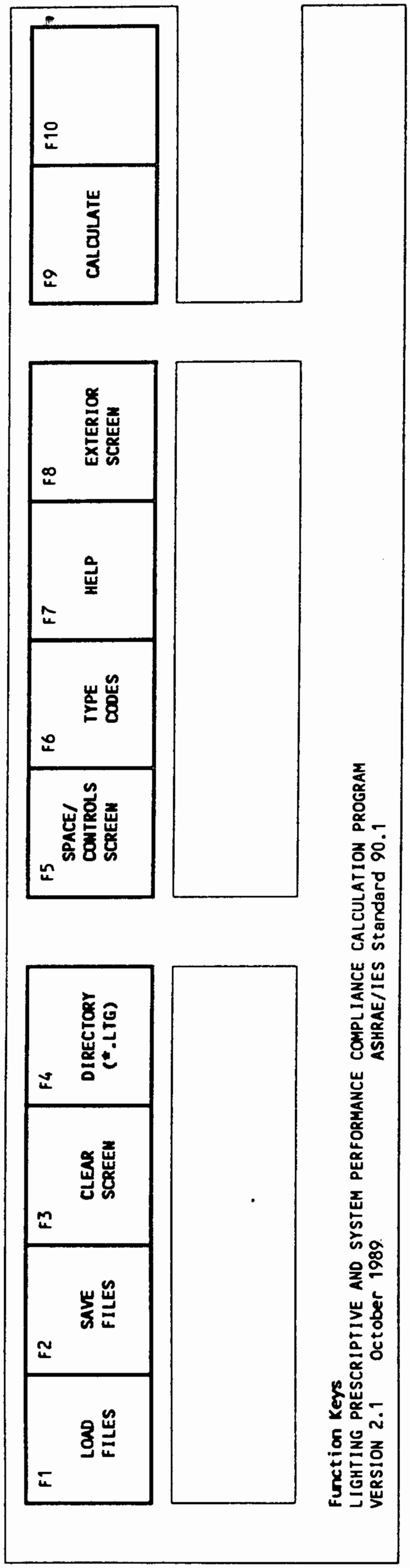


Fig. B-6 Template for 12-Function-Key Computers

Appendix Two

Lighting System Specifications

SECTION 16515 - INTERIOR LUMINAIRES

(Note: Provide Part 1 - General **)**

Part 2 - Products

2.01 Parabolic 2x4 Fluorescent Troffers

Fixtures shall be deep-cell true parabolic, including 3" deep specular or semi-specular louver with parabolic cross section. Lamp placement shall correspond with the focal points of the parabolas.

A. Number of Cells:

2x4, 3-lamp fixtures shall have 18 cell louver.
2x4, 2-lamp fixtures shall have 12 cell louver.
1x4, 1-lamp fixtures shall have 6 cell louver.

B. Fixture efficiency, as measured by an independent photometric testing lab, shall be greater than or equal to 70%.

C. Visual Comfort Probability (VCP) shall not be less than 75 either lengthwise or crosswise at 100 fc in room 20 feet wide, 40 feet long and 8.5 feet ceiling height, with reflectances of 80/50/20.

D. Contractor shall submit fixture cut sheets showing section through fixture and photometric data from an independent testing laboratory using IES reporting format.

E. Each 2- or 3-lamp fixture shall contain a single electronic ballast to fire the required number of lamps. 1-lamp fixtures shall be tandem wired to avoid single lamp ballasts where indicated on drawings.

F. Manufacturer shall be Lightolier, Columbia, Metalux, Lithonia, or Day-Brite.

2.02 Compact Fluorescent Fixtures:

(NOTE: Edit to delete any types not used on this project and/or add additional compact fluorescent fixtures **)**

A. Recessed Compact Fluorescent Downlight: Lightolier 8055CL-IF 713H or Prescolite CFR813 series downlights with 2, 13W twin tube lamps and specular clear alzak reflector. Minimum photometric efficiency of 70 %. Ballasts: Two 13 W encased and potted ballasts, High Power Factor. Maximum input wattage 36 Watts.

B. Ceiling Surface Compact Fluorescent: American Scientific Lighting Corp., "DIAMONLITE" catalog number HDI/26. Lens: 0.125" clear non-yellowing acrylic, diamond cut. Metal Housing with bronze finish. Ballast: two PL13 lamp ballasts.

C. Pendant Compact Fluorescent Swag: KAMRO ES 7 Catalogue No. 10350, Grey finish.

D. Wall Surface Compact Fluorescent Sconce: Lightolier wall mounted compact fluorescent, 40998, Polished Brass finish.

E. Pendant Compact Fluorescent Downlight: Lightolier Calculite premium downlighting, Catalogue No. 8018. Specular clear ALZAK reflector. Housing seamless aluminum with no visible hardware. Matte white finish.

2.03 Fluorescent Wallwashers

High performance recessed wallwasher/accent light using one BIAX type lamp. Lightolier WLRN 124 120/277 BX SB. Ballast: MagneTek electronic BIAX ballast. REFLECTOR: Low-iridescence specular aluminum.

2.04 Pendant Indirect/Direct Fluorescent

4-foot pendant-mounted with Parabolic Louver: Lightolier Paralyte S/P PLM/PLJ series UPLIGHT/DOWNLIGHT or approved equal. Provide new pendant mounting stems and accessories by the fixture manufacturer as needed to achieve proper support and leveling. BALLAST: MagneTek Triad electronic ballast and T8 lamps meeting applicable specifications. DIFFUSER: Semi-specular 8-inch wide parabolic louver, made of Coilzak or equal. PERFORMANCE: In an installation with a room cavity ratio of 1, with reflectance of 80% ceiling, 50% wall, and 20% floor, the luminaire shall have a minimum C.U. of 0.83. Minimum VCP shall be 94 at 100 fc.

2.05 BIAX Fluorescent 2x2 parabolic fixture

Fixtures shall be deep-cell true parabolic, including fixture housing and 3" deep specular or semi-specular louver that together form a parabola. Lamps shall have individual compartments defined by white reflectors. Lightolier Paralyte 2424 PLA2G9LP3U4BX 120/277 X3. BALLAST: MagneTek Triad electronic ballast and BIAX lamps meeting applicable specifications. DIFFUSER: Low-iridescence, 3-inch deep parabolic louver, made of pre-anodized aluminum.

A. Number of Cells: 3-lamp BIAX fixtures shall have 9 cell louver.

B. PERFORMANCE: In an installation with a room cavity ratio of 1, with reflectance of 80% ceiling, 50% wall, and 20% floor, the luminaire shall have a minimum C.U. of 0.76. Minimum VCP shall be 74 at 100 fc. Fixture efficiency, as measured by an independent photometric testing lab, shall be greater than or equal to 70%.

C. Contractor shall submit fixture cut sheets showing section through fixture and photometric data from an independent testing laboratory using IES reporting format.

D. Each fixture shall contain a single electronic ballast to fire all lamps.

E. Manufacturer shall be Lightolier.

2.06 Fluorescent Lamps

All new fluorescent lamps used in fixtures shall meet the following specifications according to lamp length and output type.

A. FO32 4-foot Lamp type: Lamps shall be four-foot thick-coat T8 type with a manufacturer specified color temperature of 3500 deg Kelvin. Lamp shall be one of the following:

Osram/Sylvania	FO32/835
Phillips	F32T8/TL835
General Electric	F32T8/SPX35.

Initial lumen output shall be 3000 lumens or greater with a mean lumen output of 2800 lumens or greater at 40 % of rated lamp life. Minimum CRI of 82.

B. 2-foot BIAX Lamp type: Lamps shall be 22 1/2" biaxial type with a manufacturer specified color temperature of 3500 deg Kelvin. Lamp shall be Phillips PL-L 40W/35 or equivalent by Sylvania or General Electric.

C. Lamp life: All straight fluorescent lamps shall be rated at 20,000 hours or greater average lamp life, based on 3-hour burn cycles, unless otherwise specified.

D. Compact Fluorescent Lamps: Lamps shall have a color temperature of 2700 K. All compact fluorescent lamps shall be rated at 10,000 hours or greater average lamp life, based on 3-hour burn cycles. Lamp CRI shall be 80 or greater. All lamps shall be 13 Watt, Twin Tube with GX23 base, similar to Phillips 13W PL-S.

E. Acceptable Manufacturers: Phillips, General Electric, or Osram/Sylvania, NO SUBSTITUTES.

2.07 Ballasts

A. Ballast for T8 lamps and BIAX lamps: Ballast shall be discrete electronic type, UL listed, Class P thermally protected, and sound class A. Average ballast life shall be rated at 60,000 hours or greater based on 3-hour average burn cycles. Input Current Total Harmonic Distortion (THD) shall not exceed 20 %. Minimum power factor of 0.90. Ballast shall instant-start lamps on parallel circuits, allowing remaining lamps to maintain full output if companion lamps fail or are removed. The ballast shall be designed for T8 lamps and BIAX lamps only and shall not adjust output current or voltage for T12 or T10 lamps. Ballast manufacturer shall have been producing electronic ballasts for the U.S. market for at least 5 years with a failure rate less than 2%. Warranty: Ballast shall carry a non-prorated parts and labor warranty against failure due to defects in material or workmanship for at least FIVE YEARS from the date of acceptance by the Owner. Ballast shall withstand line transients as defined in IEEE Publication 587, Category A.

Acceptable Manufacturers: the manufacturer shall be MagneTek or ADVANCE. SUBSTITUTES ARE NOT PERMITTED.

B. Ballast for Compact Fluorescent lamps: Ballast shall be core and coil, Class P thermal rating, UL approved, and a Class A sound rating. High Power Factor (HPF) type where indicated on drawings. Rated lifetime shall be 24,000 hours or greater.

C. Input Wattage: For all fluorescent ballasts, the ANSI standard input Wattage with specified lamps shall not exceed the following maximum values:

Lamp type	# of Lamps	Maximum Input wattage
4-foot T8	4-lamp	116 Watts
4-foot T8	3-lamp	89 Watts
4-foot T8	2-lamp	64 Watts
Compact 13 Watt	1-lamp	18 Watts
Compact 13 Watt	2-lamp	36 Watts
F40 BIAX	3-lamp	105 Watts

2.08 EXIT signs

A. All EXIT signs for interior use shall be of the Light-Emitting-Diode (LED) type. Unit shall be UL listed and meet NFPA Life Safety Code 101. Unit shall be electronically protected from voltage surges, brown outs, and short circuits.

B. LED's shall be red on black background with white faceplate. Unit shall be enclosed in a textured black metal case. Sign faces shall be protected with minimum 1/8" clear Lexan shield.

C. Maximum line wattage draw with or without battery installed shall be 7 Watts for single-face signs and 11 Watts for double-face signs.

D. Battery Back-up units shall have a UL listed rechargeable battery with a 7-year full warranty. Electronics shall protect the battery against brown-out conditions, overcharge and deep-discharge hazards. Battery shall provide a minimum of 2-hours of sign operation in the event of a power failure. Derangement lights shall be located on the face of the unit with a battery test button on the bottom of the unit.

E. Acceptable Manufacturers: Trace Lite Corporation or Exitronix, Exitron Series.

F. Unit shall carry a 20 year full warranty on the electronics, LED's, transformers, case, and all parts except the battery.

(NOTE: Provide Part 3 - Execution **)**

SECTION 16915 - OCCUPANCY SENSORS

PART 1 - GENERAL

1.01 GENERAL PROVISIONS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division-1 Specifications sections, apply to the work of this section.

B. The sensors shall be installed in rooms according to the Contract drawings, and shall be compatible with all features of the balance of the lighting system.

1.02 WORK INCLUDED:

A. Occupancy sensors to control lighting in rooms specified by the Contract documents.

B. Survey to determine appropriate type, number and location of sensors to achieve performance requirements. Documentation of survey using the Occupancy Sensor Commissioning form provided in these specifications.

C. Associated wiring, power packs, relays, switch-packs and all labor and accessories as may be needed to provide a complete and fully functioning occupancy sensor system in conformance with all performance requirements.

D. Signage at switches to notify personnel of the presence of an occupancy sensor.

E. Sensor Commissioning to obtain specified performance.

F. Provide One-year service on the installed sensors, including reinspection and on-call services as described in this section. Provide 3-year warranty on parts. Provide 3% warranty stock of each part to the Owner for the warranty period.

1.03 QUALITY CONTROL:

A. Time Delay Test: Sensor shall deactivate lighting after a time interval within the range specified for the type of space. Sensor will be tested by leaving the room and timing the interval to deactivate lights. Test shall be conducted with HVAC systems in operation.

B. Entry Test: Sensors shall activate lighting within 2 seconds of entrance by a person beyond 3 feet into the space at each door to the space covered. Sensor shall not activate when person passes room with door open but does not enter.

C. Hand Motion Test: Sensor shall provide 100% coverage and maintain lighting at all times that a fixed work station or desk or stationary task is occupied. Sensor must pick up hand motion of one foot distance back and forth, either parallel or perpendicular to the work surfaces. Test may be conducted by observing red LED indicating sensor triggering.

Occupancy Sensor Commissioning Form

Building Name:______________________

Plans Room Name & Number	Actual Room Number (at Door)	Number of Fixtures: Type: Total Watts:
Sensor Model Number:	Final Number Installed:	Wiring Diagram Number:
Time Delay Test		
Specified: 6 to 12 Minutes	Measured by CQC:	Measured by Quality Assurance:
Sensitivity:	P = Pass F= Fail	Final Setting (1-10):
Entry Test	CQC:	QA:
Hand Motion Test at Task	CQC:	QA:
1/2- Step Perimeter Test	CQC:	QA:
Drawing: (All rooms with more than one sensor)	Dimensions of each Wall Doors and Windows Partitions and obstacles	Sensor Locations Fixture Locations Fixture Circuitry
CQC Manager (Initial and Date):	SCALE: 1/4" = ____ FEET Ceiling Height: ____ FEET	Quality Assurance (Initial and Date):

D. Perimeter half-step test: Sensors shall provide coverage of a minimum of 75% of non-task with a sensitivity to 1/2-step motion. Test by walking around the perimeter of the room and noting any cut-off points to detection where the red, LED indicator does not respond to 1/2-step motion. Draw the coverage pattern on Occupancy Sensor Commissioning form provided and estimate the percentage coverage.

E. Sensor Commissioning: Contractor shall perform sensor commissioning to verify and document performance of sensors for each room covered prior to requesting substantial completion inspection. Complete Occupancy Sensor Commissioning form for each room and submit with request for inspection.

F. Warranty: Sensors and accessories shall carry a manufacturer's warranty against defects in materials and workmanship for FIVE years.

G. Service Contract: Sensors shall be provided with on-call service contract for one year from the date of substantial completion of each building. The service contract shall include:

1. Service Calls: A repair technician must come to the site within the same or next business day of a service call from the Owner during business hours. Business hours are defined to be Monday through Friday, 8 a.m. to 4 p.m., including holidays. All labor costs, including travel and tools, shall be covered under the service contract provided.

2. Component Replacement: The service provider shall replace, at no additional charge, failed sensors with new sensors of identical specifications and manufacturer.

3. Coordination with Warranty: The provider of the service work shall be authorized by the manufacturer to determine and provide warranty work under the first-year of warranty. Coordination of responsibilities and costs between the warranty and the service agreement is the responsibility of the service provider and shall be transparent to the Owner. The Owner shall not be liable for any additional expenses or handling or collection responsibilities for warranty work during the first year.

4. Reinspection: After two months, and again after 11 months past Substantial Completion of each building, the contractor will survey the building to find and replace any sensors which have failed or are not performing satisfactorily according to the specifications. This inspection is in addition to on-call service during the first year described above. The inspection will be witnessed by a designated Owner representative. The contractor will provide manpower to conduct the inspection within 2 hours at each building. The contractor will provide a written check off of sensors using floor plans and fixture counts conducted prior to installation. All noted deficiencies must be repaired within 14 days.

1.04 SUBMITTALS:

A. Submit shop drawings and product data in accordance with Section 01340 Submittals and the General Conditions.

B. **SUBMIT** complete performance and dimensional data along with manufacturing details and wiring diagrams and photograph.

C. **SUBMIT** manufacturer's installation instructions and wiring diagram.

D. **SUBMIT** parts and labor warranty.

E. **SUBMIT** completed Occupancy Sensors Commissioning form with all preliminary survey information and drawings, proposed sensors and layout, and approval signature from the sensor manufacturer.

F. **SUBMIT** total quantities of each type for each building.

G. **SUBMIT** completed room-by-room survey forms noting all changes in quantities and describing all visible existing damage to switches and ceilings.

Failure by the contractor to submit any of the above materials will cause rejection of the submittal. The Contractor is responsible for delays so incurred.

PART 2 - PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS:

Sensor shall be manufactured by:

The Watt Stopper
Unenco
Novitas

SUBSTITUTE MANUFACTURERS ARE NOT PERMITTED.

2.02 SENSOR REQUIREMENTS:

A. Sensors shall be of passive infrared type or ultrasonic type.

B. Sensor shall be designed for mounting to the ceiling or on the wall above 8 feet high. Sensors designed to replace wall switches are NOT acceptable.

C. Ultrasonic sensors shall be crystal controlled to within 0.005 %.

D. Sensor shall have a red LED indicator that flashes each time motion is detected by the sensor. This indicator will be used in commissioning the sensor.

E. Sensor shall have a field-adjustable, continuously variable sensitivity setting.

F. Sensor shall have a field-adjustable time-out setting that is either continuously adjustable or has a maximum of 2 minute increments within the range of 6 to 12 minutes.

G. All sensors shall be U.L. listed.

2.03 Signage

A. Signs shall be engraved lamacroid material, professionally cut and beveled. Sign shall blue background with white letters with the following wording:

Lights are controlled by a motion sensor
when this switch is "ON".

B. Signs shall have double-side foam tape for mounting to walls.

C. Sign shall be approximately 6 inches wide by 2 inches high.

D. SUBMIT a sample for acceptance.

E. Manufactured by Advanced Designs of Rockville (301) 762-0155 or approved equal.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Instructions: Install in accordance with manufacturer's written installation instructions and wiring diagrams.

B. Do not mount ultrasonic sensors within 6 feet of an HVAC diffuser or grill. Do not mount where forced air will blow directly by or at the sensor.

C. Do not mount sensors higher than 12 feet above floor.

D. Mount a sign on the wall slightly above each switch bank that control lights on motion sensors.

3.02 APPLICATION

A. Provide all sensors as required for the Work defined in Section 01000 Part 2 - PROGRAM.

B. Quantities: Contractor shall verify required sensor types and quantities for all buildings prior to ordering.

C. Voltages: The Contractor is responsible for determining correct voltages prior to ordering and installation.

3.03 SENSOR COMMISSIONING

A. Contractor shall adjust aiming, sensitivity, and minimum cycle time of sensors to achieve the performance requirements stated in Quality Assurance.

B. Where necessary, the Contractor shall change sensor to one with different coverage, view angles or placement to achieve the performance requirements stated in Quality Assurance, at no additional cost to the Owner.

C. The Contractor will test each sensor against the Performance requirements prior to placing the sensor into use.

D. Contractor shall provide documentation of sensor commissioning of each room with request for substantial completion inspection by the Owner.

E. Final adjustments to actual occupancy will be made on a call back basis when requested by the Owner during the first year of operation, at no additional cost to the Owner.

END OF SECTION

SECTION 8

COMMISSIONING

Chapter 8

Commissioning

Introduction

The design team shall develop a commissioning plan that spans the design, construction and operation of the building. During the design the team shall ensure that all necessary design elements are included and coordinated to ensure that the construction of the building proceeds smoothly. During the construction, the commissioning process shall include proper inspections and contractor coordination to ensure that the building is constructed and is properly placed in operation and the maintenance staff are trained and oriented in the proper operation of the building. The College will provide the design team with draft commissioning standards and work with the design team to ensure proper commissioning.

Attachement 8-1, Commissioning Specification

Note: A sample commissioning specification will be provided by the College.