

STANDARD

ANSI/ASHRAE/IES Standard 90.1-2010

(Supersedes ANSI/ASHRAE/IESNA Standard 90.1-2007)

Includes ANSI/ASHRAE/IES Addenda listed in Appendix F

Energy Standard for Buildings Except Low-Rise Residential Buildings

I-P Edition

See Appendix F for approval dates by the ASHRAE Standards Committee, the ASHRAE Board of Directors, the IES Board of Directors, and the American National Standards Institute.

This standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the standard. The change submittal form, instructions, and deadlines may be obtained in electronic form from the ASHRAE Web site (www.ashrae.org) or in paper form from the Manager of Standards. The latest edition of an ASHRAE Standard may be purchased from the ASHRAE Web site (www.ashrae.org) or from ASHRAE Customer Service, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. E-mail: orders@ashrae.org. Fax: 404-321-5478. Telephone: 404-636-8400 (worldwide), or toll free 1-800-527-4723 (for orders in US and Canada). For reprint permission, go to www.ashrae.org/permissions.

© 2010 ASHRAE

ISSN 1041-2336



Illuminating
ENGINEERING SOCIETY



ASHRAE Standing Standard Project Committee 90.1
Cognizant TC: TC 7.6, Systems Energy Utilization
SPLS Liaison: Doug Reindl
ASHRAE Staff Liaison: Steven C. Ferguson
IES Liaison: Rita M. Harrold

Michael C.A. Schwedler, *Chair**
Mark M. Hydeman, *Vice-Chair**
Stephen V. Skalko, *Vice-Chair**
Susan Isenhour Anderson*
Wagdy A.Y. Anis*
Peter A. Baselici*
Randall Blanchette
Jeffrey G. Boldt*
David J. Branson*
Donald M. Brundage
Ron Burton*
Ernest A. Conrad
Charles C. Cottrell
S. Craig Drumheller*
Keith I. Emerson*
Drake H. Erbe*
Allan B. Fraser*
James A. Garrigus*
Jason J. Glazer*
Chad Groshart

Brian David Hahnen
S. Pekka Hakkarainen*
Susanna S. Hanson
Richard V. Heinisch*
Ned B. Heminger
John F. Hogan*
Jonathan Humble
Hyman M. Kaplan*
Ronald D. Kurtz*
Michael D. Lane*
Richard Lord
Ronald Majette*
Itzhak H. Maor*
Merle F. McBride
Raymond Frank McGowan
James Patrick McClendon*
Michael W. Mehl
Harry P. Misuriello
Frank T. Morrison
Jeff Park

Timothy M. Peglow*
Eric E. Richman*
Michael I. Rosenberg
Steven Rosenstock*
Kenneth Sagan
Martha Gail Salzberg
Leonard C. Sciarra*
Maria Spinu*
Frank A. Stanonik*
Jeffrey R. Stein
Wayne Stoppelmoor
Christian R. Taber*
William J. Talbert
Michael Tillou*
Martha G. VanGeem
Michael Waite*
Daniel J. Walker
McHenry Wallace, Jr.*
Richard D. Watson*
Jerry W. White, Jr.*

**Denotes members of voting status when this standard was approved for publication.*

ASHRAE STANDARDS COMMITTEE 2009–2010

Steven T. Bushby, *Chair*
H. Michael Newman, *Vice-Chair*
Robert G. Baker
Michael F. Beda
Hoy R. Bohanon, Jr.
Kenneth W. Cooper
K. William Dean
Martin Dieryckx
Allan B. Fraser
Katherine G. Hammack
Nadar R. Jayaraman
Byron W. Jones
Jay A. Kohler
Carol E. Marriott

Merle F. McBride
Frank Myers
Janice C. Peterson
Douglas T. Reindl
Lawrence J. Schoen
Boggarm S. Setty
Bodh R. Subherwal
James R. Tauby
James K. Vallort
William F. Walter
Michael W. Woodford
Craig P. Wray
Wayne R. Reedy, *BOD ExO*
Thomas E. Watson, *CO*

Stephanie Reiniche, *Manager of Standards*

SPECIAL NOTE

This American National Standard (ANS) is a national voluntary consensus standard developed under the auspices of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). Consensus is defined by the American National Standards Institute (ANSI), of which ASHRAE is a member and which has approved this standard as an ANS, as “substantial agreement reached by directly and materially affected interest categories. This signifies the concurrence of more than a simple majority, but not necessarily unanimity. Consensus requires that all views and objections be considered, and that an effort be made toward their resolution.” Compliance with this standard is voluntary until and unless a legal jurisdiction makes compliance mandatory through legislation.

ASHRAE obtains consensus through participation of its national and international members, associated societies, and public review.

ASHRAE Standards are prepared by a Project Committee appointed specifically for the purpose of writing the Standard. The Project Committee Chair and Vice-Chair must be members of ASHRAE; while other committee members may or may not be ASHRAE members, all must be technically qualified in the subject area of the Standard. Every effort is made to balance the concerned interests on all Project Committees.

The Manager of Standards of ASHRAE should be contacted for:

- interpretation of the contents of this Standard,
- participation in the next review of the Standard,
- offering constructive criticism for improving the Standard, or
- permission to reprint portions of the Standard.

DISCLAIMER

ASHRAE uses its best efforts to promulgate Standards and Guidelines for the benefit of the public in light of available information and accepted industry practices. However, ASHRAE does not guarantee, certify, or assure the safety or performance of any products, components, or systems tested, installed, or operated in accordance with ASHRAE's Standards or Guidelines or that any tests conducted under its Standards or Guidelines will be nonhazardous or free from risk.

ASHRAE INDUSTRIAL ADVERTISING POLICY ON STANDARDS

ASHRAE Standards and Guidelines are established to assist industry and the public by offering a uniform method of testing for rating purposes, by suggesting safe practices in designing and installing equipment, by providing proper definitions of this equipment, and by providing other information that may serve to guide the industry. The creation of ASHRAE Standards and Guidelines is determined by the need for them, and conformance to them is completely voluntary.

In referring to this Standard or Guideline and in marking of equipment and in advertising, no claim shall be made, either stated or implied, that the product has been approved by ASHRAE.

CONTENTS

ANSI/ASHRAE/IES Standard 90.1-2010, Energy Standard for Buildings Except Low-Rise Residential Buildings (I-P Edition)

SECTION	PAGE
Foreword.....	4
1 Purpose	4
2 Scope.....	4
3 Definitions, Abbreviations, and Acronyms	5
4 Administration and Enforcement.....	21
5 Building Envelope	23
6 Heating, Ventilating, and Air Conditioning.....	39
7 Service Water Heating	70
8 Power	73
9 Lighting	75
10 Other Equipment	86
11 Energy Cost Budget Method	90
12 Normative References	99
Normative Appendix A: Rated R-Value of Insulation and Assembly U-Factor, C-Factor, and F-Factor Determinations	103
Normative Appendix B: Building Envelope Climate Criteria	134
Normative Appendix C: Methodology for Building Envelope Trade-Off Option in Subsection 5.6	145
Normative Appendix D: Climatic Data	154
Informative Appendix E: Informative References	199
Informative Appendix F: Addenda Description Information	201
Informative Appendix G: Performance Rating Method.....	209

NOTE

Approved addenda, errata, or interpretations for this standard can be downloaded free of charge from the ASHRAE Web site at www.ashrae.org/technology.

© 2010 ASHRAE

1791 Tullie Circle NE · Atlanta, GA 30329 · www.ashrae.org · All rights reserved.

ASHRAE is a registered trademark of the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
ANSI is a registered trademark of the American National Standards Institute.

(This foreword is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

FOREWORD

The original Standard 90 was published in 1975 and revised editions were published in 1980, 1989, and 1999 using the ANSI and ASHRAE periodic maintenance procedures. Based upon these procedures, the entire standard was publicly reviewed and published in its entirety each time. As technology and energy prices began changing more rapidly the ASHRAE Board of Directors voted in 1999 to place the standard on continuous maintenance, permitting the standard to be updated several times each year through the publication of approved addenda to the standard. Starting with the 2001 edition, the standard is now published in its entirety in the fall of every third year. This schedule allows the standard to be submitted and proposed by the deadline for inclusion or reference in model building and energy codes. All approved addenda and errata are included in the new edition, issued every three years. This procedure allows users to have some certainty of the timing of publication of new editions.

The 2010 edition of the standard has extensive changes resulting from continuous maintenance proposals from the public and the committee volunteers. The committee welcomes suggestions for improving the standard. Users of the standard are encouraged and invited to use the continuous maintenance procedure to suggest changes. A form for submitting continuous maintenance proposals (CMP) to suggest changes is included in the back of this standard. The committee takes formal action on every CMP received.

The Committee's unanimously approved Workplan goal for the 2010 edition was to reduce energy cost by 30% compared to the 2004 version of the standard. Toward that goal, 109 addenda were processed by the committee and approved by the ASHRAE and IES Boards of Directors and are included in this edition. This edition also corrects all known typographical errors in the 2007 standard.

The most significant changes included are:

1. The Scope has been expanded so that 90.1 can cover receptacles and process loads (e.g. data centers).
2. The building envelope (opaque elements and fenestration) requirements have become more stringent. Continuous air barrier and cool/high albedo roof requirements have been added.
3. Most interior lighting power densities have been lowered, additional occupant sensing controls and mandatory daylighting requirements are added for specific spaces, and a new five-zone exterior lighting power density table has been added.
4. Most equipment efficiencies are higher, energy recovery is required in more applications, economizers are required in

more climates, and more energy-conserving controls are required

5. Modeling requirements (e.g. for LEED® certification) have been clarified and expanded.

For brief descriptions and publication dates of the addenda to 90.1-2007, see Appendix F.

At the time of printing, energy cost savings are estimated to be 23.4% and energy savings are estimated at 24.8%; however, not all addenda had been included in analysis for these energy savings estimates. Final saving estimates will be issued by ASHRAE when available.

The 90.1 standard is a fluid document. As technology evolves the project committee is continually considering new changes and proposing addenda for public review. When addenda are approved, notices will be published on the ASHRAE and IES Web sites. Users are encouraged to sign up for the free ASHRAE and IES Internet Listserv for this standard to receive notice of all public reviews and approved and published addenda and errata.

The Chair and Vice Chairs extend grateful thanks to the committee volunteers, public review commentors, and all involved throughout the open, consensus-building process.

1. PURPOSE

To establish the minimum energy efficiency requirements of buildings, other than low rise residential buildings, for:

1. design, construction, and a plan for operation and maintenance, and
2. utilization of on-site, renewable energy resources.

2. SCOPE

2.1 This standard provides:

- a. minimum energy-efficient requirements for the design, construction, and a plan for operation and maintenance of:
 1. new buildings and their systems
 2. new portions of buildings and their systems
 3. new systems and equipment in existing buildings
 4. new equipment or building systems specifically identified in the standard that are part of industrial or manufacturing processes

- b. criteria for determining compliance with these requirements.

2.2 The provisions of this standard do not apply to:

- a. single-family houses, multi-family structures of three stories or fewer above grade, manufactured houses (mobile homes), and manufactured houses (modular), or
- b. buildings that use neither electricity nor fossil fuel.

2.3 Where specifically noted in this standard, certain other buildings or elements of buildings shall be exempt.

2.4 This standard shall not be used to circumvent any safety, health, or environmental requirements.

3. DEFINITIONS, ABBREVIATIONS, AND ACRONYMS

3.1 General. Certain terms, abbreviations, and acronyms are defined in this section for the purposes of this standard. These definitions are applicable to all sections of this standard. Terms that are not defined shall have their ordinarily accepted meanings within the context in which they are used. Ordinarily accepted meanings shall be based upon American standard English language usage as documented in an unabridged dictionary accepted by the *adopting authority*.

3.2 Definitions

above-grade wall: see *wall*.

access hatch: see *door*.

addition: an extension or increase in floor area or height of a building outside of the *existing building envelope*.

adopting authority: the agency or agent that adopts this standard.

alteration: a replacement or *addition* to a building or its *systems* and *equipment*; routine maintenance, *repair*, and *service* or a change in the building's use classification or category shall not constitute an *alteration*.

annual fuel utilization efficiency (AFUE): an efficiency descriptor of the ratio of annual output *energy* to annual input *energy* as developed in accordance with the requirements of U.S. Department of Energy (DOE) 10 CFR Part 430.

astronomical time switch: a device that turns the lighting on at a time relative to sunset and off at a time relative to sunrise, accounting for geographic location and day of year.

attic and other roofs: see *roof*.

authority having jurisdiction: the agency or agent responsible for enforcing this standard.

automatic: self-acting, operating by its own mechanism when actuated by some nonmanual influence, such as a change in current strength, pressure, temperature, or mechanical configuration. (See *manual*.)

automatic control device: a device capable of automatically turning loads off and on without *manual* intervention.

balancing, air system: adjusting airflow rates through air *distribution system* devices, such as fans and diffusers, by manually adjusting the position of dampers, splitter vanes, extractors, etc., or by using *automatic control devices*, such as constant air volume or variable-air-volume (VAV) boxes.

balancing, hydronic system: adjusting water flow rates through hydronic *distribution system* devices, such as pumps and coils, by manually adjusting the position valves or by using *automatic control devices*, such as *automatic flow control valves*.

ballast: a device used in conjunction with an electric-discharge *lamp* to cause the *lamp* to start and operate under the proper circuit conditions of voltage, current, wave form, electrode heat, etc.

ballast, electronic: a *ballast* constructed using electronic circuitry.

ballast, hybrid: a *ballast* constructed using a combination of magnetic core and insulated wire winding and electronic circuitry.

ballast, magnetic: a *ballast* constructed with magnetic core and a winding of insulated wire.

baseline building design: a computer representation of a hypothetical design based on the proposed building project. This representation is used as the basis for calculating the *baseline building performance* for rating above-standard design.

baseline building performance: the annual *energy* cost for a building design intended for use as a baseline for rating above-standard design.

below-grade wall: see *wall*.

boiler: a self-contained low-pressure appliance for supplying steam or hot water.

boiler, packaged: a *boiler* that is shipped complete with heating *equipment*, mechanical draft *equipment*, and *automatic controls*; usually shipped in one or more sections. A *packaged boiler* includes factory-built *boilers* manufactured as a unit or *system*, disassembled for shipment, and reassembled at the site.

branch circuit: the circuit conductors between the final *over-current* device protecting the circuit and the outlet(s); the final wiring run to the load.

budget building design: a computer representation of a hypothetical design based on the actual proposed building design. This representation is used as the basis for calculating the *energy cost budget*.

building: a structure wholly or partially enclosed within exterior *walls*, or within exterior and *party walls*, and a *roof*, affording shelter to persons, animals, or property.

building entrance: any doorway, set of *doors*, turnstile, vestibule, or other form of portal that is ordinarily used to gain access to the building by its users and occupants.

building envelope: the exterior plus the semi-exterior portions of a building. For the purposes of determining *building envelope* requirements, the classifications are defined as follows:

building envelope, exterior: the elements of a building that separate *conditioned spaces* from the exterior.

building envelope, semi-exterior: the elements of a building that separate *conditioned space* from *unconditioned space* or that enclose *semiheated spaces* through which thermal *energy* may be transferred to or from the exterior, or to or from *unconditioned spaces*, or to or from *conditioned spaces*.

building exit: any doorway, set of *doors*, or other form of portal that is ordinarily used only for emergency egress or convenience exit.

building grounds lighting: lighting provided through a building's electrical *service* for parking lot, site, roadway, pedestrian pathway, loading dock, or security applications.

building material: any element of the *building envelope* through which heat flows and that is included in the component *U-factor* calculations other than air films and insulation.

building official: the officer or other designated representative authorized to act on behalf of the *authority having jurisdiction*.

C-factor (thermal conductance): time rate of steady-state heat flow through unit area of a material or *construction*, induced by a unit temperature difference between the body surfaces. Units of *C* are Btu/h·ft²·°F. Note that the *C-factor* does not include soil or air films.

circuit breaker: a device designed to open and close a circuit by *nonautomatic* means and to open the circuit automatically at a predetermined *overcurrent* without damage to itself when properly applied within its rating.

class of construction: for the *building envelope*, a subcategory of *roof*, *above-grade wall*, *below-grade wall*, *floor*, *slab-on-grade floor*, *opaque door*, *vertical fenestration*, or *skylight*. (See *roof*, *wall*, *floor*, *slab-on-grade floor*, *door*, and *fenestration*.)

clerestory: that part of a building that rises clear of the *roofs* or other parts and whose *walls* contain windows for lighting the interior.

code official: see *building official*.

coefficient of performance (COP)—cooling: the ratio of the rate of heat removal to the rate of *energy* input, in consistent units, for a complete refrigerating *system* or some specific portion of that *system* under designated operating conditions.

coefficient of performance (COP), heat pump—heating: the ratio of the rate of heat delivered to the rate of *energy* input, in consistent units, for a complete heat pump *system*, including the compressor and, if applicable, auxiliary heat, under designated operating conditions.

computer room: a room whose primary function is to house *equipment* for the processing and storage of electronic data and that has a design electronic data *equipment* power density exceeding 20 watts/ft² of *conditioned floor area*.

conditioned floor area: see *floor area*.

conditioned space: see *space*.

conductance: see *thermal conductance*.

continuous air barrier: The combination of interconnected materials, assemblies and sealed joints and components of the *building envelope* that minimize air leakage into or out of the *building envelope*.

continuous daylight dimming: method of *automatic lighting control* using daylight *photosensors* where the lights are dimmed continuously or use at least four preset levels with at least a five-second fade between levels and where the *control* turns the lights off when sufficient daylight is available.

continuous insulation (c.i.): insulation that is continuous across all structural members without thermal bridges other than fasteners and *service* openings. It is installed on the interior or exterior or is integral to any *opaque* surface of the *building envelope*.

control: to regulate the operation of *equipment*.

control device: a specialized device used to regulate the operation of *equipment*.

construction: the fabrication and erection of a new building or any *addition* to or *alteration* of an existing building.

construction documents: drawings and specifications used to construct a building, *building systems*, or portions thereof.

cool down: reduction of *space* temperature down to occupied *setpoint* after a period of shutdown or setup.

cooled space: see *space*.

cooling degree-day: see *degree-day*.

cooling design temperature: the outdoor dry-bulb temperature equal to the temperature that is exceeded by 1% of the number of hours during a typical weather year.

cooling design wet-bulb temperature: the outdoor wet-bulb temperature for sizing cooling *systems* and evaporative heat rejection *systems* such as cooling towers.

critical circuit: the hydronic circuit that determines the minimum differential pressure that the pump must produce to satisfy the zone loads (e.g., the circuit with the most open valve). The *critical circuit* is the one with the highest pressure drop required to satisfy its load. At part load conditions, the *critical circuit* can change based on zone loads.

daylight area:

- a. **under skylights:** the *daylight area under skylights* is the combined *daylight area* under each *skylight* without double counting overlapping areas. The *daylight area* under each *skylight* is bounded by the opening beneath the *skylight*, plus horizontally in each direction, the smallest of (See Figure 3.1):
 1. 70% of the ceiling height ($0.7 \times CH$), or
 2. the distance to any *primary sidelighted area*, or the *daylight area under rooftop monitors*, or
 3. the distance to the front face of any vertical obstruction where any part of the obstruction is farther away than 70% of the distance between the top of the obstruction and the ceiling ($0.7 \times [CH - OH]$), where *CH* = the height of the ceiling at the lowest edge of the *skylight*, and *OH* = the height to the top of the obstruction.
- b. **under rooftop monitors:** the *daylight area under rooftop monitors* is the combined *daylight area* under each *rooftop monitor* without double counting overlapping areas. The *daylight area* under each *rooftop monitor* is the product of the width of the vertical glazing above the ceiling level and the smallest of the

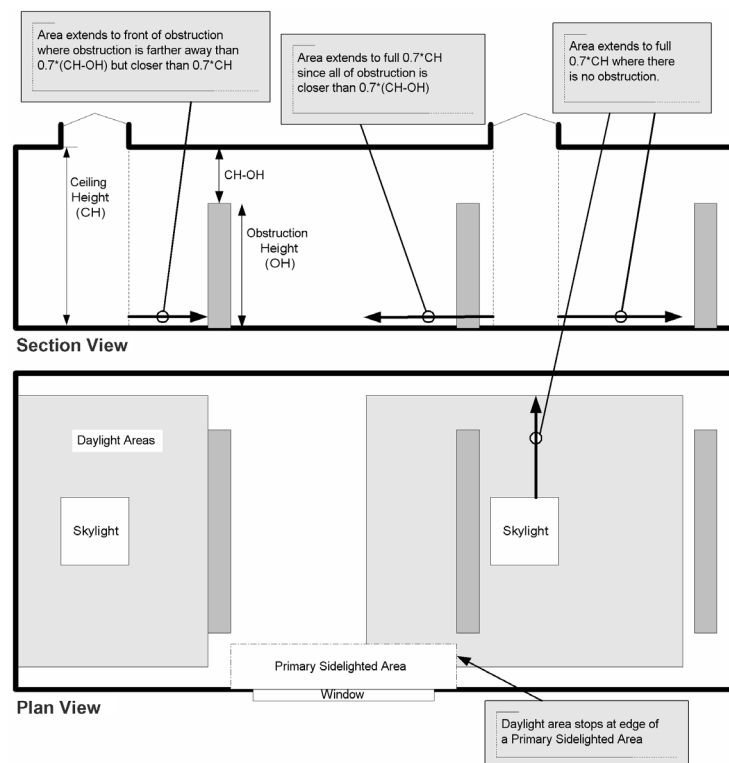


Figure 3.1 Computing the daylight area under skylights.

following horizontal distances inward from the bottom edge of the glazing, (See Figure 3.2):

1. the monitor sill height, MSH, (the vertical distance from the floor to the bottom edge of the monitor glazing), or
2. the distance to the edge of any *primary sidelighted area* or
3. the distance to the front face of any vertical obstruction where any part of the obstruction is farther away than the difference between the height of the obstruction and the monitor sill height (MSH-OH).

daylighted area: the floor area substantially illuminated by daylight.

dead band: the range of values within which a sensed variable can vary without initiating a change in the controlled process.

decorative lighting: see *lighting, decorative*.

degree-day: the difference in temperature between the outdoor *mean temperature* over a 24-hour period and a given base temperature. For the purposes of determining *building envelope* requirements, the classifications are defined as follows:

cooling degree-day base 50°F (CDD50): for any one day, when the *mean temperature* is more than 50°F, there are as many *degree-days* as degrees Fahrenheit temperature

difference between the *mean temperature* for the day and 50°F. Annual *cooling degree-days* (CDDs) are the sum of the *degree-days* over a calendar year.

heating degree-day base 65°F (HDD65): for any one day, when the *mean temperature* is less than 65°F, there are as many *degree-days* as degrees Fahrenheit temperature difference between the *mean temperature* for the day and 65°F. Annual *heating degree-days* (HDDs) are the sum of the *degree-days* over a calendar year.

demand: the highest amount of power (average Btu/h over an interval) recorded for a building or facility in a selected time frame.

demand control ventilation (DCV): a *ventilation system* capability that provides for the *automatic* reduction of *outdoor air* intake below design rates when the actual occupancy of *spaces* served by the *system* is less than design occupancy.

design capacity: output capacity of a *system* or piece of *equipment* at *design conditions*.

design conditions: specified environmental conditions, such as temperature and light intensity, required to be produced and maintained by a *system* and under which the *system* must operate.

design energy cost: the annual energy cost calculated for a *proposed design*.

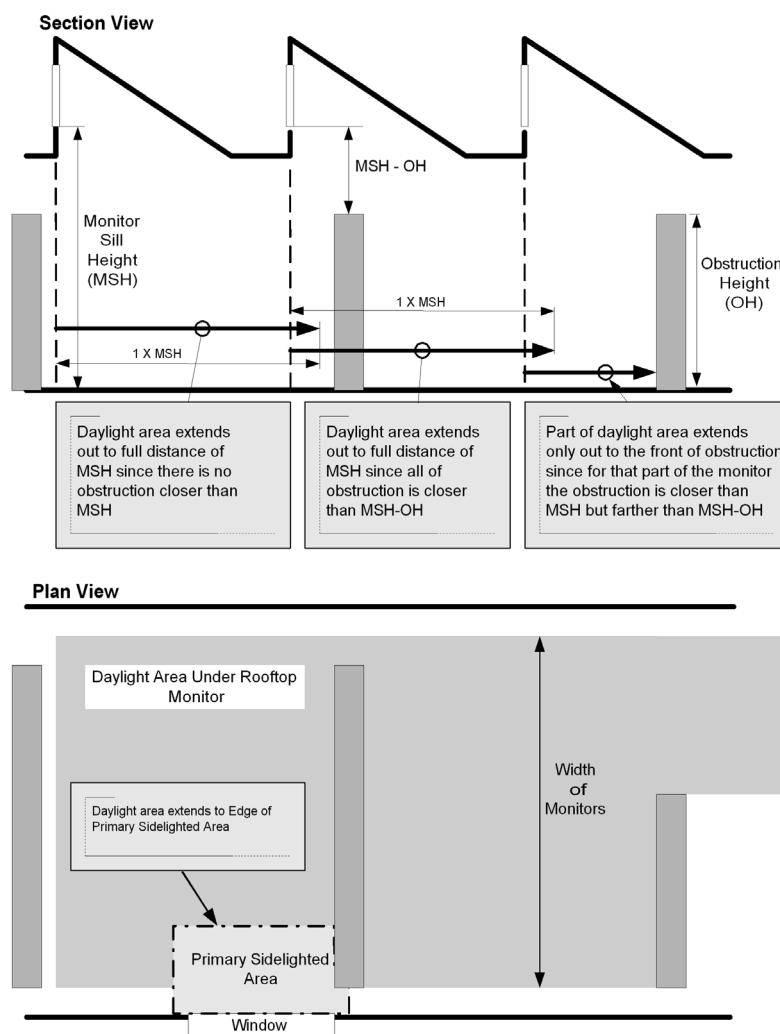


Figure 3.2 Computing the daylight area under rooftop monitors.

design professional: an architect or engineer licensed to practice in accordance with applicable state licensing laws.

direct digital control (DDC): a type of *control* where controlled and monitored analog or binary data (e.g., temperature, contact closures) are converted to digital format for manipulation and calculations by a digital computer or microprocessor, then converted back to analog or binary form to control physical devices.

disconnect: a device or group of devices or other means by which the conductors of a circuit can be disconnected from their source of supply.

distribution system: conveying means, such as ducts, pipes, and wires, to bring substances or *energy* from a source to the point of use. The *distribution system* includes such auxiliary equipment as fans, pumps, and *transformers*.

door: all operable opening areas (which are not *fenestration*) in the *building envelope*, including swinging and roll-up doors, fire doors, and access hatches. Doors that are more than one-half glass are considered *fenestration*. (See *fenestration*.)

For the purposes of determining *building envelope* requirements, the classifications are defined as follows:

nonswinging: roll-up, metal coiling, sliding, and all other doors that are not *swinging doors*.

metal coiling door: an upward acting *nonswinging door* assembly consisting of interlocking horizontal slats or sheets that, upon opening the *door*, roll up around a horizontal barrel above the *door* opening.

swinging: all operable *opaque* panels with hinges on one side and *opaque* revolving doors.

door area: total area of the *door* measured using the rough opening and including the *door* slab and the frame. (See *fenestration area*.)

ductwork: a *system* of ducts for distribution and extraction of air.

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