PDHonline Course E366 (3 PDH)

ASHRAE 90.1 for Electrical Design

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ASHRAE 90.1 for Electrical Design

Thomas Mason, PE

Please let me repeat the accurate but inflammatory come-on from the course outline:

> ASHRAE 90.1-2010, Chapter 8, POWER, requires that at least 50% of the 120V power receptacles in offices and classrooms must be automatically shut down when the machine thinks that no one is there.
>
> Chapter 9, LIGHTING, requires general lighting either have manual on-control or automatic 50%-on control and automatic off-control when the machine thinks that no one is there. Each space must have an accessible manual control including off-50% and on.
>
> Spaces with 250 sq-ft of windows must have general lighting automatic photocell control with at least two steps, nominally 50% and off. Spaces with 900 sq-ft of skylights must have general lighting automatic photocell control with at least two steps, nominally 50% and off.
>
> The construction documents must identify the independent commissioning agent who will certify that actual lighting and receptacle control operation meets the design specifications.
>
> Table 9.5.1 lists the maximum general lighting power densities permitted for 33 area types. Schools get whole-building .99 watts per square foot, down from 1.2 w/sq-ft for 90.1-2004. Table 9.6.1 lists permitted w/sq-ft for 95 individual rooms. Classrooms get 1.24, down from 1.43 in 90.1-2004. Low bay manufacturing gets 1.19. Retail gets 2.00 plus 1.0 kW per area.
>
> Chapter 10, OTHER EQUIPMENT, has table 10.8B for minimum NEMA motor efficiency, which replaces EPACT-1992. A new 10 HP, 1800 rpm, TEFC motor must be 89.5% vs 89.5% under EPACT.
>
> This is the briefest summary, with definitions of only the terms used and ignoring most of the qualifications and exceptions in the Standard. The Standard runs ~228 pages and the three electrical chapters run ~ 16 pages. Enforcement, as envisioned by ASHRAE, is enumerated in Chapter 4, after the definitions. Unlike NFPA, ASHRAE gives directions on the intended enforcement and provides very little opportunity for local interpretation or waivers by the Authority Having Jurisdiction.

Why is this course organized this way and what is this box ?
First, the box. To use your time most effectively, we started paraphrasing and discussing ASHRAE 90.1-2010, the *Energy Standard for Buildings Except Low-Rise Residential Buildings* immediately. Yes, the introductory material indicates how the course is organized, but not why. To respond to all the associated-but-not-central questions of the course, these boxes, called “sidebars” are used. They are not core material, but supplementary explanations.

A critical and fair question is, "What are the important parts of ASHRAE 90.1-2010?"

One answer is, "The changes since the last revision. We are all experienced professionals and don't need to discuss the un-changed content." That interpretation is followed by the inflammatory excerpts. The content of this course will explore each, in detail and provide design examples that comply with the intent.

A very different answer is, "Each table, exception and paragraph of ASHRAE 90.1-2010 is critical - when it answers the problem you are having today with a design or installation." That is, also, the answer pursued by this course.

By following the structure of the definitions and the three relevant chapters of the Standard, it is an easy transition from the course content to the Standard. Remember, it is the Standard which is enforced, not the course.

Chapter 3, DEFINITIONS

Sometimes we skip over the Definitions section of a document because we are familiar with the terms used in the field. This is an error with ASHRAE 90.1-2010. The Standard writers are not electrical engineers, but they are regulating electrical design. Recognizing the distinctions between ASHRAE and NFPA / NECA definitions will help avoid awkward situations involving Plans Examiners, Inspectors and LEED reviewers, who are trained in neither electrical or air conditioning. Or worse, if they are trained but not using the ASHRAE electrical words in the ASHRAE meaning.

Addition and *Alteration* are poorly defined. This is of critical importance in determining when the standard applies and when conventional design can be applied. As with NFPA, one-for-one replacement with like-kind is permitted, up to a point. That point can only be determined with confidence by the *Authority Having Jurisdiction*.

Why are we talking about NFPA, NECA and Authority Having Jurisdiction ? This is the ASHRAE 90.1-2010 course.

Because published information (WattStopper ads and Electrical Construction and Maintenance Magazine) report that ASHRAE 90.1-2010 has been forced on the States, effective 2012.

This is a course for electrical designers, to help get building designs approved for Building Permit. NFPA is the National Fire Protection Association, publishers of the *National Electrical Code*, heretofore the standard for electrical design. NECA is the National Electrical Contractors Association, publishers of *Standard Practice of Good Workmanship in Electrical Construction (ANSI)*. The Authority Having Jurisdiction (*AHJ*) is the formal identification of the person who approves or denies the Building Permit and Occupancy Permit when construction is complete.

The ASHRAE definition of *AHJ* is the person enforcing their Standard. Be very, very careful with this definition. Only the NFPA definition of AHJ keeps your project on schedule. Satisfying a LEED reviewer will make the project Architect and Owner happy, but if the municipal building official is not happy, there will be BIG problems.

The ASHRAE definition of *automatic control device* is control without manual intervention. This does

not closely match real-world automatic controls. Usually we install what we call automatic controls to permit a person at a console to remotely start or stop or adjust a piece of equipment. It is very manual. It is not clear if this distinction will cause trouble.

The ASHRAE definition of *ballast* is fine for fluorescent and HID lamps but does not recognize the same function required for LEDs. For LEDs, the present term is regulator, but the function matches the ASHRAE definition of voltage, current, waveform and initialization.

The ASHRAE definition of *branch circuit* includes the NFPA definition and a few other things. For NFPA, the branch circuit is the line from the branch panel to the load. ASHRAE chooses the words, *final protective device to the load*. There is no reference to the panel. We would normally consider the wiring upstream of a wall-mounted circuit breaker to be the branch circuit and the wiring downstream to be simply the load circuit.

ASHRAE limits *building exit* to a portal used only for emergency or convenience exit. A personnel door used daily for deliveries would not fit in, but still requires emergency egress lighting and a fire alarm pull station.

Building grounds lighting, for ASHRAE, must be fed by the building electrical service. A lot of us lease pole lights from the local utility. On the other hand, the lighting budget calculations refer to site lighting, not building grounds lighting.

The ASHRAE definition of *circuit breaker* is very similar to that of NFPA, but this would be a good point to reference a fused switch. However, fuses and fused switches are not in the Standard.

The ASHRAE definition of *computer room* is a space housing data processing equipment exceeding 20 watts / sq-ft. My netbook runs 50 watts and is roughly 1 sq-ft. If they have regulations on computer rooms, there will be trouble. But, there aren't any such rules now. Computer room is not a recognized category on any of the present electrical tables.

The ASHRAE definition of *continuous daylight dimming* is peculiar. Continuous means at least four preset levels. There is no requirement for continuous transition. The ASHRAE definition of daylight dimming requires turning the lights completely off when sufficient daylight is available. This offers an opportunity for serious trouble if the required commissioning agent insists on adjusting the daylight harvesting system to this definition.

When ASHRAE says *critical circuit*, there is water flowing in a pipe.

Daylight area is of critical importance for HVAC designers and Architects. The electrical designer must provide daylight harvesting (control photocells) above a minimum daylight area, as computed by formulas and rules. This author recommends that the electrical designer provide daylight harvesting where there appears to be 250 sq-ft of windows in a space or where there appears to be 900 sq-ft of skylight. The Architects will tweak and modify the design right up to Issue for Permit and they are happy to advise us.

The ASHRAE definition of *demand* refers to average Btu/h. Electrical demand has a substantial influence on monthly billing. It is surprising, with the LEED emphasis on actual electricity dollar-costs, that electrical demand is not part of the Standard.

Design energy cost refers to energy cost. It implies, but does not explicitly state, billing. On a monthly bill, energy can be separated from demand, with a little trouble. Usually the energy and cost modeling for LEED is done by an HVAC designer or Architect and they don't ask for guidance or interpretation.

Disconnect is defined in an electrical sense, but electricity is not mentioned. An isolation valve would fit the ASHRAE definition if we used their definition of circuit, ala critical circuit.

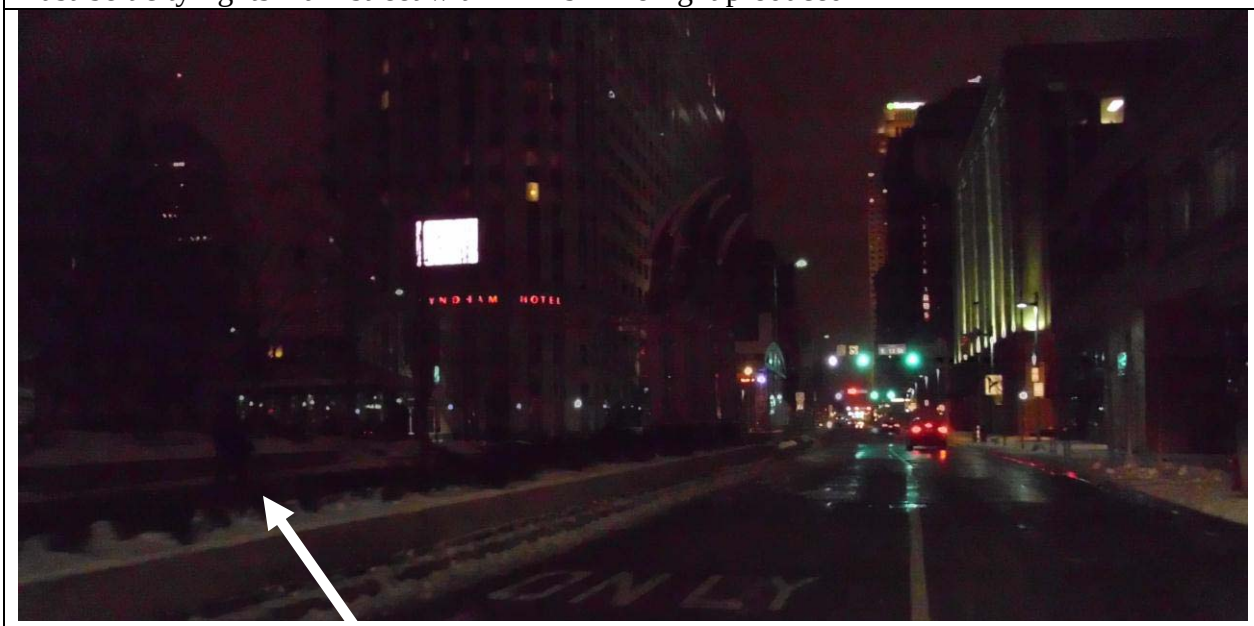
Distribution has a wonderful definition. Fans, pumps and transformers are grouped as auxiliary equipment, but not heat exchanges, which are much more similar to transformers than pumps or fans.

Efficiency has a non-engineering definition, performance. We were all raised that efficiency is a unit-less measure of output divided by input.

Equipment includes lamps, luminaires, ballasts, elevators and escalators. This begins the great schism from IEEE definitions. IEEE defines units, assemblies, and components, in decreasing levels of complexity (IEEE Dictionary of Electrical and Electronic Terms). Clearly ASHRAE is mixing levels of complexity and distinguishing nothing.

Eye adaptation sounds benign, but may be introducing a re-definition of footcandle. Eye adaptation is the valid recognition that humans perceive light level based upon context. However, up until now, lighting requirements have been in footcandles, not recognizing context. The people who sell LED lighting want to re-define lighting requirements to permit very, very low footcandle levels in a dark surroundings, as a parking lot. Though valid by itself, this re-definition does not recognize loss of visual acuity that accompanies age. Older persons need the full 1 fc and cannot navigate in .1fc, redefined as adequate to sell LEDs.

Rust-belt city lights main street with LED's - no light produced



Pedestrian

The ASHRAE definition of *feeder conductors* does not quite match normal electrical usage. For

ASHRAE such circuits are limited to use between service equipment and branch circuit panels. For the rest of us, feeders serve sub-feeder panels, transformers, motor control centers and large equipment. NFPA does not distinguish between feeders and branch circuits, though they appear in different places.

The definition of *general purpose motor* may become important. The ASHRAE 90.1-2010 efficiency requirements only apply to some of the electric motors in use in a building. At present, the required motors match high-efficiency motors required by EPACT and those provided by major suppliers, so there is no conflict.

Installed interior lighting power includes general lighting, task lighting and furniture lighting systems, as cubicles. COMCHECK, the Department of Energy software package required by most Plans Reviewers, considers only general lighting, that is, ceiling lights, for lighting density (watts / sq-ft) compliance.

Watch closely as task lighting is included in computations or given an exception.

Kilowatt and *kilovolt-ampere* match normal electrical definitions but power factor is not defined. As with *demand*, this may be another place to be glad we don't have to explain a difficult concept to Architects.

Lamp has a good definition for what is included but can be faulted for what is not included – LED, halogen, induction lighting and rf-lighting. Halogen incandescents have been around a long time and contribute to energy conservation. LED, induction and rf-lighting were being offered commercially in the period that this standard was being revised. It is an error to overlook their contributions.

Lighting power density is another weak definition. It is watts per sq-ft, but doesn't define the numerator or denominator of the fraction. The numerator should be *catalog net watts of the fixture as supplied.* This value can be substantially modified by ballast selection in fluorescent and HID fixtures. Some designers use lamp watts and ignore ballast losses.

The denominator for lighting power density should define how the walls are considered. If you include the wall cross section, you get gross sq-ft. If you measure inside the walls, you get net sq-ft. For LEED submittals I have reviewed, gross sq-ft is used for building calculations and net sq-ft is used for space calculations.

Low-rise residential building is important because it defines what is NOT covered by the Standard. Not included are single family and multi-family structures of three or fewer stories above grade.

The ASHRAE definition of manufacturer is very peculiar. It includes the production firm and any firm who purchases equipment from a specification. The intention is probably a re-label situation, but that is not what it says.

Multi-level occupancy sensor is new to me and may not be commercially available. It is a conventional occupancy sensor that mostly turns lights off. However, it permits manually turning on nominally 50% of the lights or 100% of the lights or an alternate set of lights or manually turning off the lights. This sounds like a conventional occupancy sensor upstream of manual switches.

Proposed building performance is a computer model projection. I have worked on several LEED

projects that did this modeling and no one ever talked to me. The new LEED requirements include coming back after the building has been in service for a year and validating the modeled energy usage. After this has been in place for some time, we should be able to calculate usage more accurately.

Pump system power is a bit peculiar and certainly a bad definition. They define electrical demand as nameplate horsepower. It is a bad mechanical design which runs pumps at nameplate horsepower. In the mechanical section of the Standard, they forbid the mechanical designer to choose a pump more than one size larger than the calculations suggest (with exceptions).

Purchased energy rates recognizes power demand "as determined by the adopting authority." I think this is used as an input for the LEED energy modeling, but they accept only a net cents-per-kilowatt-hour. Again, LEED energy modeling is usually done by the HVAC designer, architect or a sub-consultant with the software and experience. The Architect directs the effort and does the LEED submission and reviews the entries of others.

Record drawings is a conformed set. This means that all bulletins, addenda and field changes have been incorporated. It is one step better than the as-built set because it recognizes all authorized changes, in addition to field modifications. This definition is mentioned here because the Standard requires giving the owner a set of record drawings and preparing accurate record drawings is time consuming. In my world, anticipating preparation of record drawings means investing more clerical resources in tracking bulletins and addenda.

Single-line diagram is another example of ASHRAE not understanding electrical design or representation. They say that, "Common multiple connections are shown as one line." It took me a while to figure out that they think the busbars in a panel or switchboard are a common connection. Connections on a busbar are separated by inches. Logically, they are common, but physically they are very separate. A true common connection would be the Big Axx Wire Nut used for safety grounds in industrial control panels before fabricators discovered busbars.

A better definition of single-line diagram would emphasize the need for recording voltage levels and ratings, including short-circuit withstand.

Why do you include short-circuit withstand in discussing an energy conservation standard ?
ASHRAE is providing guidance for electrical design and enforcement. One of the most serious deficiencies I encounter in electrical design is compliance with the National Electrical Code (NEC) requirement for applying power distribution equipment within its short-circuit withstand rating. I am not asking ASHRAE to mandate electrical safety, However, the NEC does not require submittal of the one-line diagram to the Owner and most electrical designers do not document short-circuit withstand on their one-line diagrams. ASHRAE has taken leadership in regulating electrical design, I think they should require safety information be documented.

Task lighting is directed at a surface or area. That doesn't distinguish it from general lighting.

Voltage drop is defined as losses in the lines. We know, however, that transformers also cause a voltage drop, usually about 5% at full load. The Chapter 8 limitation is 2% voltage drop for feeders and 3% for branch circuits at design load. This sidesteps the transformer issue, but, where voltage drop is

enforced, it is done by use of a hand-held meter that applies a momentary load and compares the pre-load voltage with the load-voltage. Unless there is a buck-boost transformer in the circuit, the load current does not show up in transformer voltage drop.

Chapter 8, POWER

The goal of the course content here is to identify and explain enforceable sections. Note that actual enforcement will be performed by the Plans Examiner, LEED Reviewer and construction Electrical Inspector. This is new material for the Examiner and Inspector and it will take months or years for them to develop acceptance checklists. However, the LEED Reviewer has been very critical on similar items for some years now and is more interested in rejecting submittals than accepting them. It is extremely rare to get a constructive response from LEED.

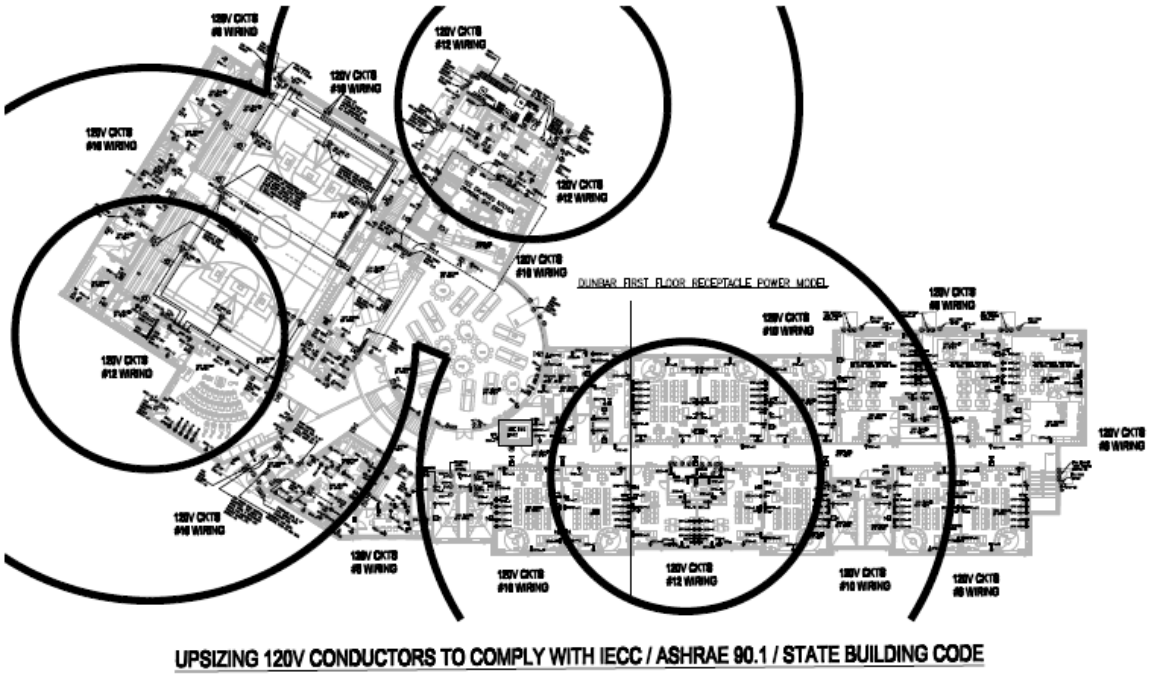
Low voltage dry-type distribution transformers must comply with EPACT / NEMA TP-1, with exceptions. Since you almost cannot buy anything except EPACT transformers, this is not a challenge.

However, Square D also sells super-premium dry-type transformers and K-type low-harmonic transformers. As expected, super-premium transformers have higher efficiency than EPACT / NEMA TP-1 standard transformers and are not a problem. K-transformers have lower efficiency than EPACT / NEMA TP-1 transformers but are much more expensive and only specified where a serious need exists. The justification for the higher cost should apply as justification for an ASHRAE exception.

8.1.5 Alterations to Existing Buildings permits relocation and reuse of existing (HVAC) equipment. However, if you modify the equipment or buy new, then restrictions of the Standard apply. I added the *HVAC* because the section has extremely limited application to electrical equipment. The exception might be a very old non-EPACT transformer which cannot be re-used in a new part of the building.

8.4.1 Voltage Drop limits feeder conductor voltage drop to 2% at design load and branch circuit voltage drop to 3% at design load. These requirements repeat the ambiguity of previous ASHRAE 90.1 issues in not defining design load or indicating means of enforcement. Most electrical designers view design load as initial design load. That is, a general purpose receptacle is 180VA, per NEC 220.14.I. However, when the custodian plugs in a 2000VA floor buffer, the voltage drop is important, or the buffer just grinds and smokes. (See the discussion of voltage drop in the definitions section of this course content.)

Design Example - Voltage Drop Compliance
The following illustrates increasing the wire size to dedicated 120V receptacle circuits more than 65-ft (#12 -->#10) or 130-ft (#10-->#8). This does not apply to 3-phase, 120V receptacle circuits which have been mostly eliminated by NEC 210.4.



UPSIZING 120V CONDUCTORS TO COMPLY WITH IECC / ASHRAE 90.1 / STATE BUILDING CODE

The centers of the circles are receptacle panels. The first circle is the 65-ft length for #12 wire to 120V receptacles. The second circle is upsizing to #10. Outside the second circle, #8 is required.

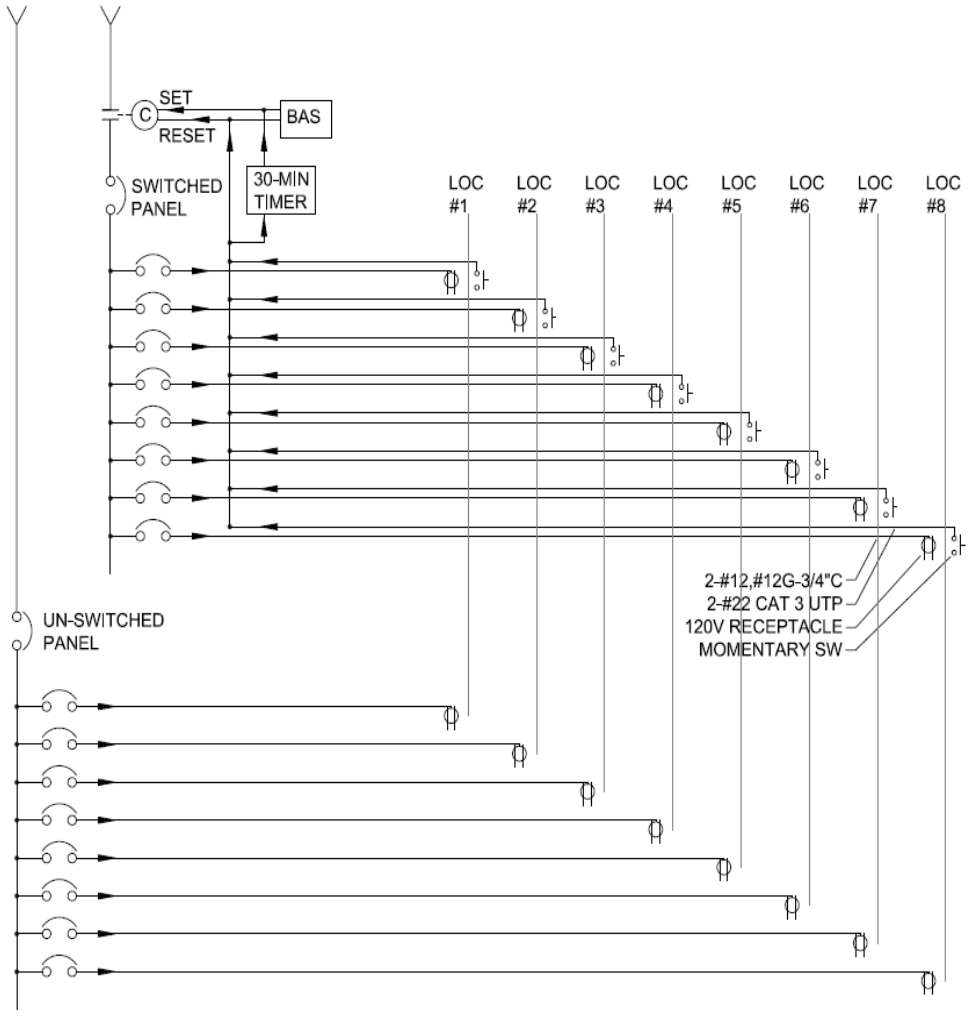
8.4.2 Automatic Receptacle Control requires automatic shutoff of 50% of the 120V receptacles in private offices, open offices and computer classrooms. Automatic shutoff can be by timeclock, occupancy sensor or another system which thinks that the space is un-occupied.

There is no mention of local override in the Standard. That doesn't mean that it is forbidden, but it does mean that additional cost will be added to the project to create a fully usable space. A favorite quotation from Architects and Owners is, "But, is it required by Code?" I come in to work at 6:30AM, when it is quiet. The HVAC doesn't come on until 7:30. I will have to be careful where I plug in my computer and screen in an office compliant with ASHRAE 90.1. The Architects and corner-office folk like to work until 8 or 9PM. I am sure the building operator will leave the outlets on for them.

Please consider the impact of an occupancy sensor on the receptacle for a desktop computer. I think the timeclock option will be more popular.

There are exceptions for 24-hr equipment and safety and security. Some would say that personal computers require 24-hr operation so that software updates can be remotely installed during non-work hours. It will be interesting to see how this requirement is interpreted by various Authority Having Jurisdiction.

Design Example - Receptacle Control, Contactor with Override
The following illustrates a possible scheme for providing control for 50% of the 120V receptacles using a power contactor. Short-time mass override is included.

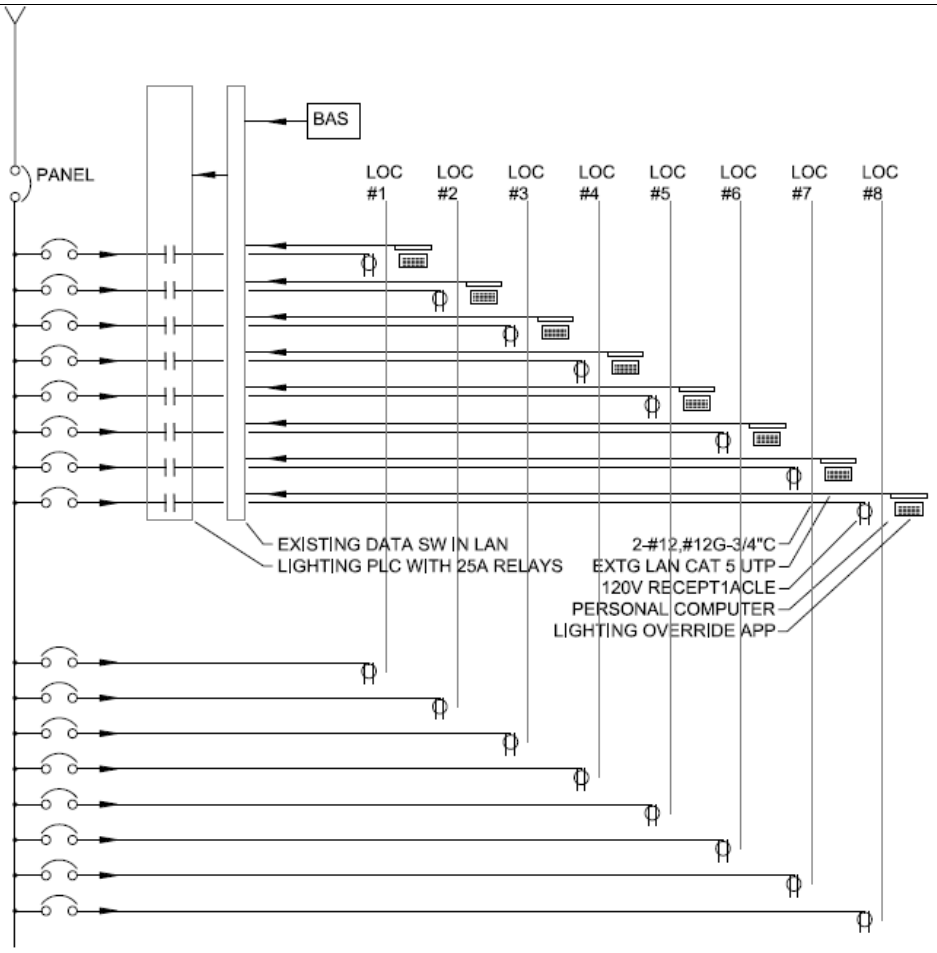


RECEPTACLE CONTROL SCHEME, CONTACTOR WITH OVERRIDE

Incoming bulk power from the transformer or distribution panel is at the top. Circle-C represents the contactor to shut off the receptacles. The Building Automation System (BAS) provides the signal for shut-off, either from a timeclock application, to be consistent with other building services, or from local occupancy sensors. Circuits are shown to the switched receptacles, accompanied by low-voltage wiring to local momentary switches to initiate a 30-minute override (returning all outlets). The 30-minute time follows the lighting override requirements of other standards. A stand-alone timer was selected to permit trouble shooting the installation without a programmer present.

Beyond the operational problems, this scheme requires that office changes consider override switch relocations as module walls are shifted.

Design Example - Receptacle Control, PLC-Style with Override
The following illustrates a possible scheme for providing control for 50% of the 120V receptacles using a special-purpose PLC. Short-time individual override is included.



RECEPTACLE CONTROL SCHEME, PLC WITH SOFTWARE OVERRIDE

Symbols used here are the same as those used in the contactor scheme, except that the dedicated PLC switches individual receptacle circuits, and the override request affects only individual receptacle circuits. Note that the PLC receives commands from anyone on the local area network, not just the BAS. The BAS remains the system timeclock, but the local application (app) initiates the override and terminates it after 30-min.

Office changes for this scheme may involve programming. If a person moves, but leaves his computer, then the computer provides override for the local outlet. If the person takes his computer with him, then his computer provides override for a remote outlet at his former location. (The required procedure is not much different than telephone changes for an office change.)

The PLC-Style scheme is based upon a commercial receptacle control product, (http://www.dinrelay.com) with firmware for individual circuit control from a LAN port. [There are a wide range of commodity brick PLC's available. This one has higher power rating than most (25A relays) and lower price ($120 with password-protected Ethernet).]

Section 8.7.1 of ASHRAE 90.1-2010 requires that record drawings of the actual installation be delivered to the Owner within 30-days of system acceptance. [30-days for power; 90-days for lighting.] The set must include an electrical one-line diagram and floor plans relating areas served to panels. Also included is a requirement for verification of proper operation of lighting and receptacle

controls.

In the definitions discussion for this course we looked at the additional cost of preparing accurate record drawings. We look at this task as a burden on the designer and drafter, but it is also a burden on a conscientious installing Contractor and Construction Manager. The requirement for "areas served" drawings might be met by conventional circuiting plans, or the AHJ may require dedicated sheets showing the panels and associated areas served. Most likely, the AHJ will ignore the requirements, as they do present requirements for load calculations and limiting panels to 80% of the main breaker rating.

Section 8.7.2 contains requirements and a note that they should not be enforced. The requirements are for useful operating and maintenance (O&M) manuals. I have worked public spending jobs that had such requirements and I have invested many hours in phone calls and rejection forms trying to get materials that identify the actual items installed, local service contacts and a Sequence of Operation. Contractors will copy catalog pages for you but they refuse to circle the item installed.

The non-enforcement section is a clarification that the AHJ should only check on deliver of the O&M, not expect to see it. This does not suggest content compliance. The non-enforcement is for power drawings only. It is not repeated in the lighting chapter.

The radical change here is that the Standard mandates compliance actions after occupancy. Heretofore, the Certificate of Occupancy marked the end of oversight by the local Building Standards department. It is not clear what response is available to the AHJ if the O&M is not delivered on time. LEED is talking about retroactively yanking certification for a building.

Chapter 9, LIGHTING

The scope of this chapter is somewhat interesting. Interior spaces of buildings would be expected, with the caveat that they may be referring to gross area or net area.

Driveways, parking lots and walkways are regulated by the International Energy Conservation Code and Department of Energy COMCHECK, but not by the ASHRAE 90.1 lighting scope. In an interesting editorial decision, driveways, parking lots and walkways ARE regulated by the text and Table 9.4.3.B.

How can the Standard exclude it from the Scope but include it in the content ?
First, we must move past the consideration of editorial error, to be corrected by errata. This course is being prepared from a December, 2011, download of the June, 2009, Standard, which claims to have incorporated all errata up to the date of publication. No, this is evidence that no one on the Technical Committee or Editorial Board reads the Standard closely.

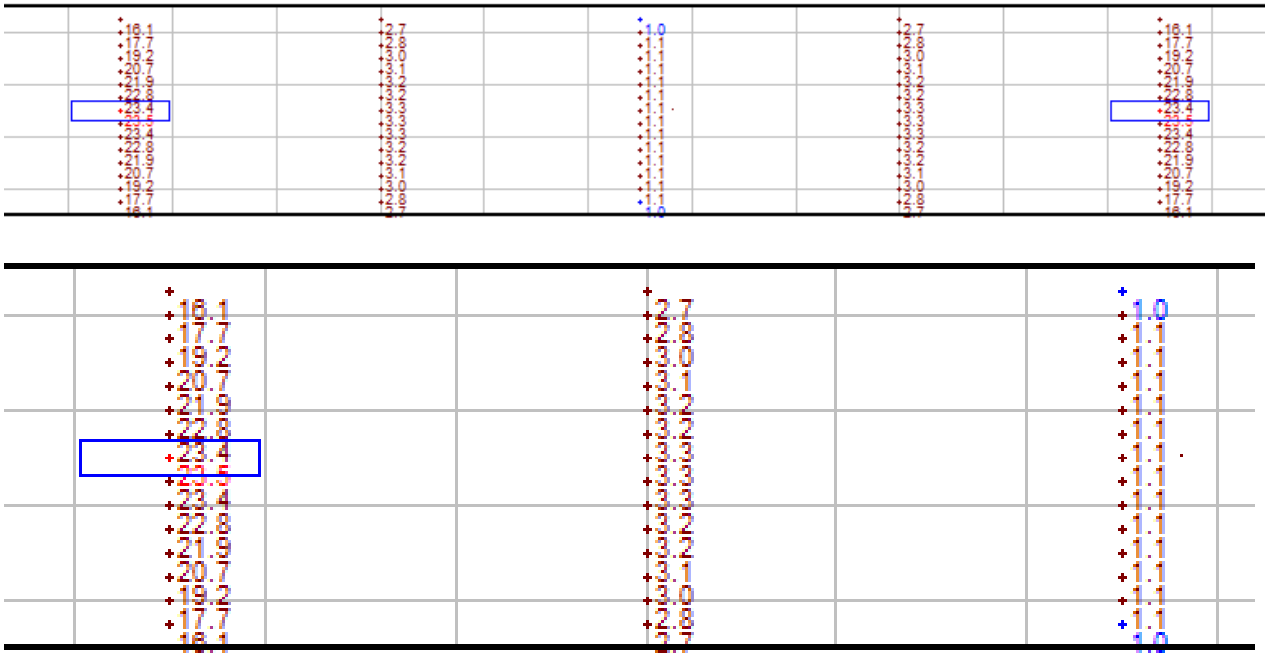
The wording of the Scope section excludes lighting leased from the electric utility, that required by a life-safety statute and that within dwelling units.

This is another case where we must simply ignore the published Scope. The corridors of public

buildings must be lighted to comply with NFPA 101 and OSHA general-duty clause and 29CFR 1926.56 (5 fc). 29CFR 1926.56 also sets a minimum of 30 fc for offices. Strict reading of the ASHRAE 90.1 lighting Scope says that the standard does not apply to corridors or offices, since the lighting there is regulated by life-safety standards. However. ASHRAE does very much wish to regulate lighting in corridors and offices.

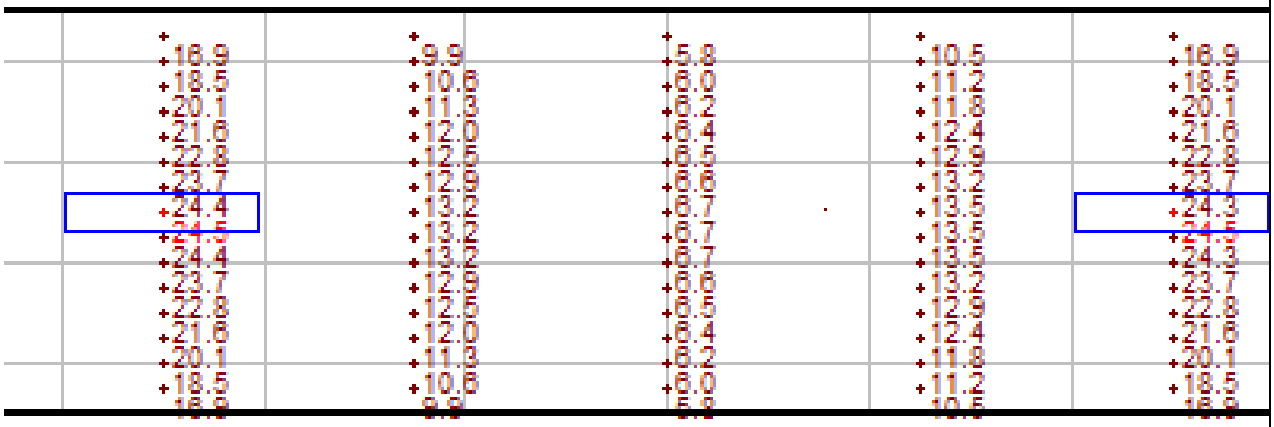
Design Example - Corridor: OSHA 5fc and ASHRAE .66 w / sq-ft

If you have an 8-ft corridor and use a 2-tube F32 T-8 lay-in fixture with 10-ft ceiling height and industry standard reflectances, what is the spacing to get 30fc and what is the w / sq-ft ?



As indicated above, a very popular commercial lighting design software recommends 40-ft c-c, yielding 7.7 fc average and 1.0 fc minimum, for .18 w/sq-ft.

Does this solution remind you of the receptacle solution of putting 100 switched receptacles in a closet so that you can use 100 un-switched receptacles for office equipment?

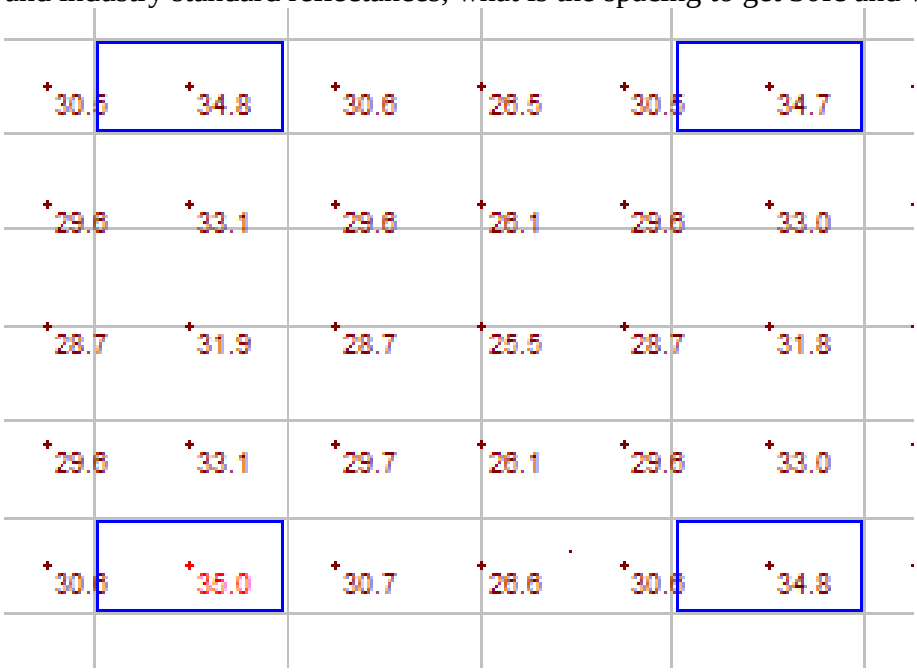


The above report results if we interpret the OSHA standard to be **minimum** 5fc, rather than

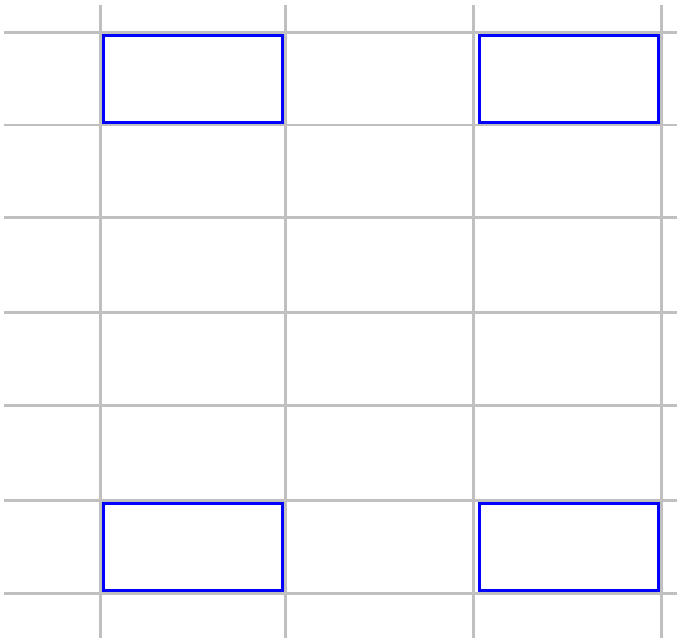
average 5 fc. The modeling program suggests 20-ft c-c spacing, with .64 w/sqft.

Design Example - Office: OSHA 30fc and ASHRAE .98 w / sq-ft

If you have a 48x48open office and use a 2-tube F32 T-8 lay-in fixture with 10-ft ceiling height and industry standard reflectances, what is the spacing to get 30fc and what is the w / sq-ft ?



The above report is that the program suggests 12-ft x 10-ft c-c spacing with .50 w/sq-ft.

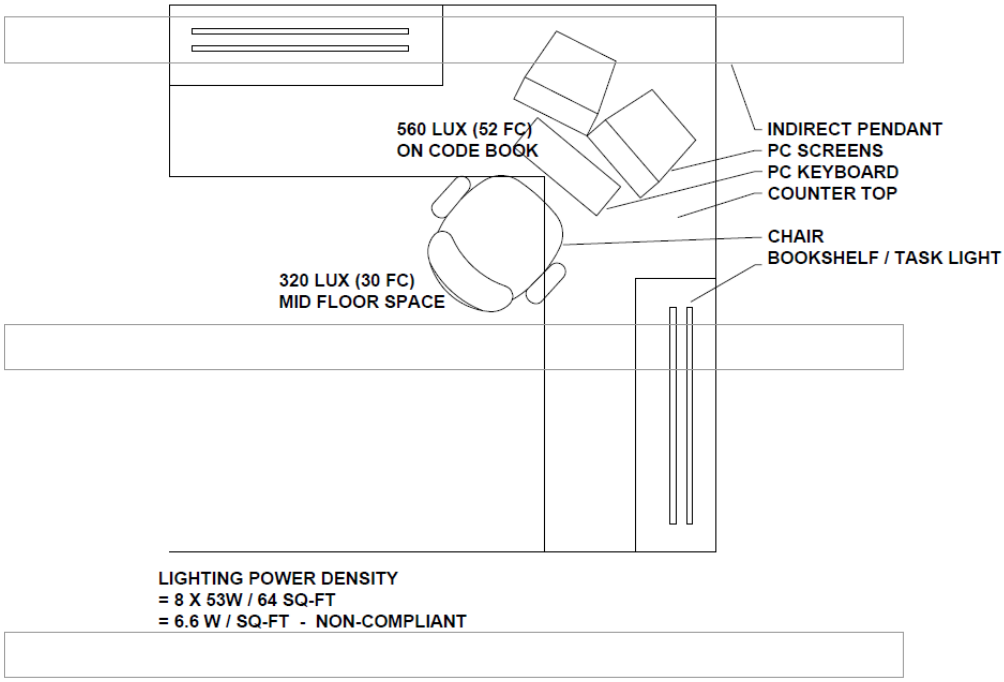


The program refused to do photometrics for 35 fc **ave**, 30 fc **min** but the program suggests 8-ft x 10-ft spacing for .63 w/sq-ft.

Please note that the above design examples are very 1970. In 2010, most office designs use indirect or semi-indirect lighting and task lights. Task lights are under-bookshelf 4-ft fluorescents or articulated

arms with compact fluorescents. However, ASHRAE 90.1-2010 is regulating 1970-era designs and has no mention of task lighting.

Reality check - real-world engineering office lighting, 52 / 30 fc, 6.6 w/sq-ft



REAL-WORLD OFFICE LIGHTING EXAMPLE

The above illustration reports the lighting as-found in the author's workspace. The space was designed in the mid-1990's, and so represents something between ASHRAE 90.1-2010 and the present. There are plots of current projects posted on the walls, along with copies of frequently-consulted design tables. All are readable from the work location.

For purposes of establishing context, ASHRAE allocates 1.89 w/sq-ft for a hospital operating room and 1.81 w/sq-ft for a research laboratory handling anthrax.

There are prerequisites, in the LEED meaning of the word. These are requirements which must be met before the lighting power budget (w/sq-ft) can be calculated.

A peculiar exclusion is mentioned in 9.9.2.3.p - task lighting which has an automatic shutoff. What is peculiar is that task lighting is nowhere included in the interior lighting budget.

Regardless of the method selected, essentially all general lighting must be manually or automatically controlled to turn on to no more than 50% power, with exceptions of corridors, stairwells, restrooms and the primary building entrance.

All lighting must have automatic shutoff by either timeclock, occupancy sensor or an unspecified other control or alarm system. Corridors, stairwells, restrooms, storage rooms and the primary building entrance are excluded in a later paragraph. There is just a little wiggle-space regarding safety and security of the room or building occupant.

The problem with automatic controls.

Automatic controls can be expected to work correctly. The problem is not with the controls, but with the inability of motion controls to perceive occupancy when there is no motion and the inability of infrared sensors to seen through partitions and file cabinets. When you sit still, as in reading, you have no perceptible motion. (The PIR sensor identifies changes in infrared in different windows. It does not identify breathing infrared sources.)

Present generation occupancy sensors time out and turn off the lights. [They will also time out and turn off receptacles soon.] Most of us just stand up and wave, or walk around the dark room until the occupancy sensor resets.

The National Electrical Code forbids use of occupancy sensors in electrical rooms (110.26.D). ASHRAE gives an exception in a later paragraph for electrical and mechanical rooms.

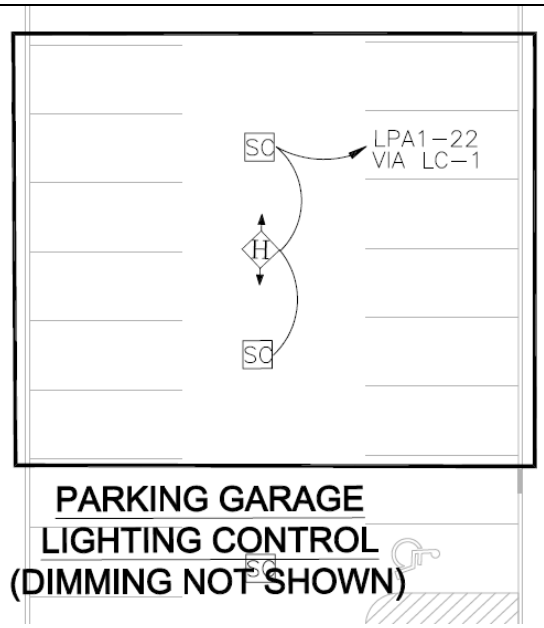
Each space enclosed by ceiling-height partitions must have at least one control device with off-50% and on positions. The device is not required to be manual. [Author's note: It is inconceivable, as this is written, to control lights exclusively by timeclocks and occupancy sensors.]

9.4.1.2b requires an off-control occupancy for classrooms, lecture halls, conference rooms, lunch and break rooms, storage rooms, copy and printing rooms, offices up to 25- sq-ft, restrooms and locker rooms.

For spaces not identified in 9.4.1.2b, timeclock shutoff is required, with local override permitted of no more than 120 minutes.

9.4.1.3 requires that parking lots require controls on **each fixture** to reduce power at least 30% when there is no motion detected for a period not greater than 30-minutes. The lighting zones must be no larger than 3600 sq-ft (12 parking spaces). [On my last parking garage project, this comes out to one dimming control for every two fixtures.]

Design Example – Parking Garage Lighting Control



Where, Square-SC is a fixture selected for compliant light levels, along with dimming ballast
Diamond-H is a motion detector with primary sensitive in both longitudinal directions and 30-minute time-delay
LPA1-22 is a single-pole circuit breaker on 480Y277V panel LPA1
LC-1 is a lighting contactor with BAS timeclock and H-O-A switch

In addition parking garage lighting controls for fixtures near outside openings must respond to daylight. Ramps without parking and HID or induction lamps less than 150 watts are excluded. (This is the first recognition of induction lighting - not included in the definitions section.)

The organization of the Standard is ambiguous at this point. 9.4.1.3 was for parking garages. 9.4.1.4 appears to be for building interior spaces, not garages. This is the section that requires photocell control on fixtures next to windows for 250 sq-ft or larger.

The photocell sensitivity adjustment must be remote from the photocell. This requires an analog photocell (but not necessarily analog signal transmission) and a computer to make the control decision. Vendors selling discrete photocells for motion detector systems or for dimming fixtures are required to upgrade to analog photocells. (Such stand-alone products are not commercially available at the time of this writing. Computerized systems in the Reference Links of this course are compliant.)

The sensitivity adjustment must be accessible without a ladder. This provision forces that a control box be placed not higher than 78-in above finished floor or remote computer adjustment be a feature of the system selected.

The wording on the dimming control requirements is convoluted. I am fairly certain it mandates something like a minimum of off-50%-100% steps. I say *50%* when they say *50-70%* and I say *off* when they say *no greater than 35% (including off).* With wording this obscure, you can be sure that some enforcement persons will choose a different meaning.

It is unfair to malign the enforcement persons that way.
Well, it is certainly unkind, but the source is a controversy on the 2003 National Electrical Code.

NFPA added a requirement requiring ground-fault circuit interrupters (GRFI) on electric water coolers. In their wisdom, NFPA chose the term *fountains*. For three years, local inspectors required GFCI on the pumps for display fountains - even after NFPA issued an errata notice.

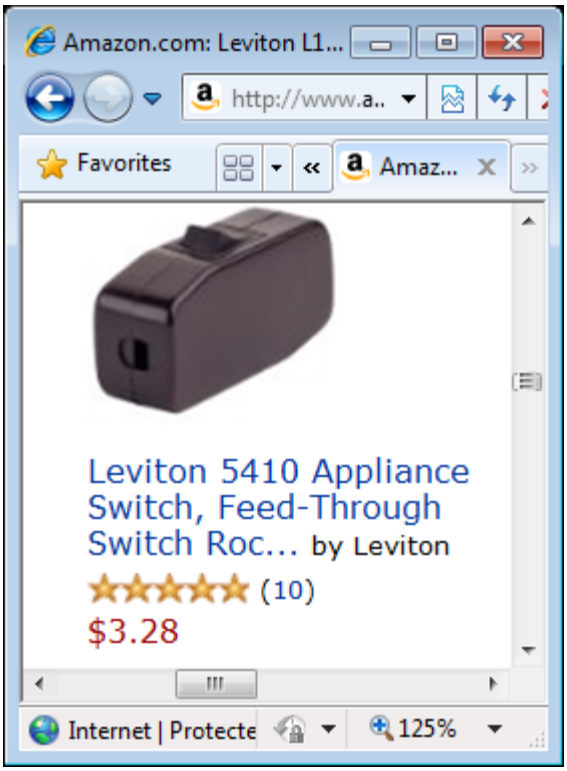
9.4.1.5 requires photocell control under skylights of greater than 900 sq-ft total area. [Note that the complex lighted area calculations apply here. 900 square feet is not length times width of the glass. Please let your Architect pursue the nuances. You have been warned that skylights → photocells → dimming controls → dimming ballasts.]

The requirements for analog response, no-ladder adjustment and a minimum of off-50%-100% operation apply.

9.4.1.6 is a catchall for additional poorly defined requirements.

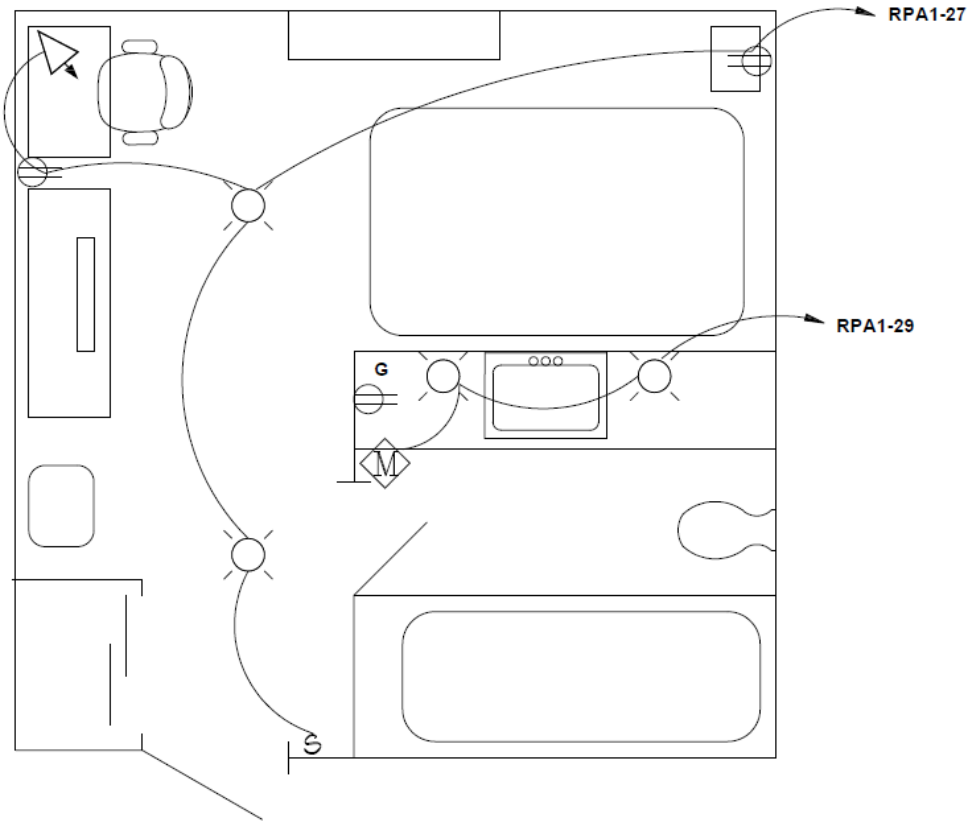
Display or accent lighting must have a control. The NEC considers a plug and receptacle, either wall-plug or in-line connector, a control device. Does ASHRAE mean a switch or relay? Does the breaker back at the panel constitute a control device?

Display cases must have a control. A retrofit of flexible conduit and a surface switchbox would comply. (This is not recommended, on aesthetics grounds.) Leviton sells a feed-through appliance switch which might be more acceptable. It is shown below:



A switch at the entry to control all lights and receptacles except the bathroom is required for motel rooms and similar (not clarified). The bathroom lights must automatically go off within 60-minutes of the the guest leaving the space.

Design Example - Motel Room Retrofit



MOTEL ROOM OCCUPANCY CONTROL RETROFIT

Where, S is a conventional light switch for both lights and receptacles
Diamond-M is a motion-detector light switch
Triangle-arrow is a dual-technology motion detector for both lights and receptacles.

In a motel retrofit, you run wiring in surface raceway, mostly on the ceiling. The homeruns to panels are via larger surface raceway in the hall, either below or above the drop ceiling.

It appears that ASHRAE has mandated that any local alarm clock must be on the GFCI receptacle in the bathroom as must be your cell phone charger. Also, you must get up to go to the bathroom at least every thirty minutes or the tv will go off as you lay there watching it.

Task lighting is defined here, and implicitly included in the lighting power budget. Task lighting must have an integral switch or a local wall switch. Automatic shut-off of task lighting was excluded previously. This is especially interesting, in that most task lighting is plugged into the receptacles which must now have automatic shut-off.

If you have grow lights for a pot farm, there must be a switch, though it is excluded from the automatic controls.

Stairwell lighting must automatically reduce power at least 50% within 30-minutes. Note that this is a direct contradiction of 9.9.2.3. It was noted previously that the Technical Committee, Editorial Board and Department of Energy all saved money on proofreading.

Paragraph 9.4.1.7 begins the requirements for control of exterior lighting.

All exterior lighting must be photocell controlled, to turn off when daylight is present.

Building wall-wash and landscape lighting must be shut off between midnight and 6AM, or when the business is closed, whichever is less. There is an exception here recognizing AHJ authority to modify this requirement.

Signs must operate at a minimum power reduction of 30% from midnight to 6AM or when the business is closed or when there has been no motion detected for a maximum of 15-minutes. I am thinking of the monster-sized video signs along The Strip in Las Vegas. The casinos are open 24/7, but I am guessing there are 15-minute periods during which there is no one on the sidewalk in front. There is no exception here for the AHJ to release this requirement.

There is an exception to automatic shutoff for vehicle entrances and exits.

9.4.4 requires functional testing of lighting controls. (Note that the ASHRAE presentation places this between exterior lighting calculations and interior lighting calculations.) Functional testing must be defined in the construction documents, along with identification of the independent third-part who will perform the testing. There is no enforcement method indicated, except denial of the Building Permit or denial of LEED certification because the plan is inadequate. There is no requirement of submitting the results or correcting deficiencies found.

The testing required includes specified detector count, location and adjustment for turning off the lights. When the sensor is to automatically turn on the lights, this operation must be tested.

The testing required includes verification that time switches and software schedules are in place and work.

The testing required includes verification that photocells respond to daylight.

9.4.3 starts the explanation of the exterior building lighting power allowance. The text is almost unreadable. It is better to study the tables and forms, like COMCHECK.

	ASHRAE 90.1, following Table 9.4.3B, Permissible Power for Building Exteriors					
	Item	Zone				
		0	1	2	3	4
Tradable		Undeveloped	Developed rural	Residential	All others	Urban 24/7
*	Base	0	500W	600W	750W	1300W
*	Uncovered parking and driveways	0	.04w/sq-ft	.06w/sq-ft	.10w/sq-ft	.13w/sq-ft
*	Walk < 10-ft	0	.70w/lf	.70w/lf	.80w/lf	1.00w/lf
*	Walk > 10-ft	0	.14w/sq-ft	.14w/sq-ft	.16w/sq-ft	.20w/sq-ft
*	Stairways	0	.75w/sq-ft	1.00w/sq-ft	1.00w/sq-ft	1.00 w/sq-ft
*	Tunnels	0	.15w/sq-ft	.15w/sq-ft	.20w/sq-ft	.30w/sq-ft
*	Landscaping	0	.04w/sq-ft	.05w/sq-ft	.05w/sq-ft	.05w/sq-ft
	Main entrances	0	20w/lf	20w/lf	30w/lf	30w/lf
	Other doors	0	20w/lf	20w/lf	20w/lf	20w/lf
	Entry canopies	0	.25w/sq-ft	.25w/sq-ft	.40w/sq-ft	.40w/sq-ft
	Sales canopies	0	.60w/sq-ft	..60w/sq-ft	.80w/sq-ft	1.00w/sq-ft
	Outdoor sales	0	.25w/sq-ft	.25w/sq-ft	.50w/sq-ft	.70w/sq-ft
	Street frontage	0	0	10w/lf	10w/lf	30w/lf
	Building facades	0	0	2.50w/lf	3.75w/lf	5.00w/lf
	ATMs	0	270w+90W per addl	270w+90W per addl	270w+90W per addl	270w+90W per addl
	Gatehouse	0	.75w/sq-ft	.75w/sq-ft	.75w/sq-ft	.75w/sq-ft
	Emergency loading	0	.50w/sq-ft	.50w/sq-ft	.50w/sq-ft	.50w/sq-ft
	Drive-thru	0	400W per line	400W per line	400W per line	400W per line
	Parking for all-night retail	0	800W per entry			
	Roadway entry	60W	0	0	0	0

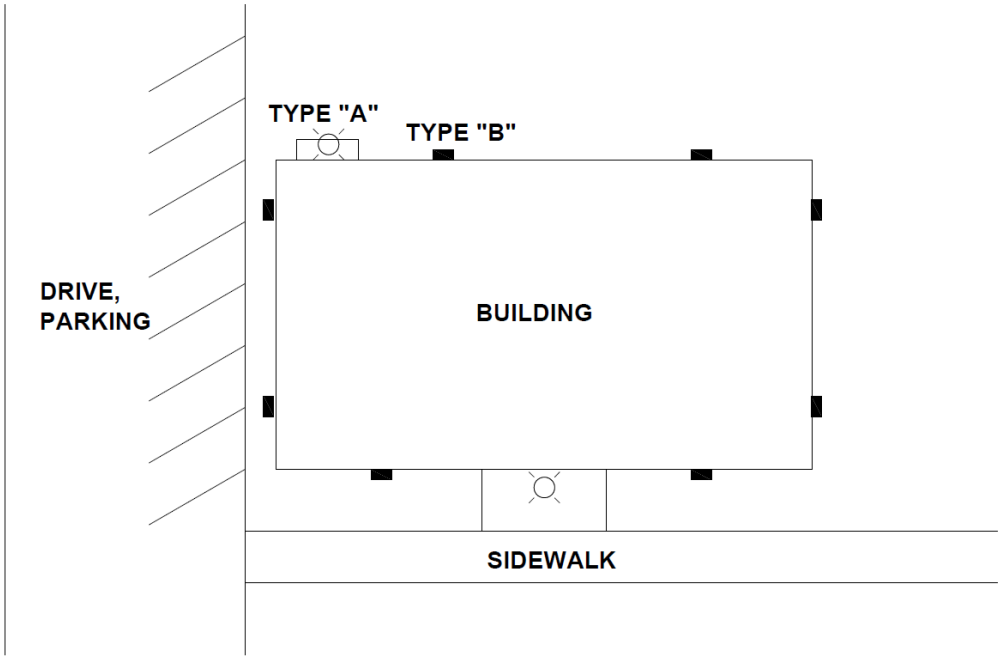
The first task is to figure out where the building is, in ASHRAE terms. The choices are Zone 0,1,2,3, or 4. Zone *0* is undeveloped, as a rural park or field. Zone *1* is a developed park or rural area. They are distinguishable by the visibility of stars. If you can see the stars, it is Zone *0*.

Zone *2* is residential with corner businesses and small sausage factories that only operate first shift.

Zone *3* is all other areas. Zone *4* is high activity 24/7 commercial and industrial districts.

The casino video signs and other signs are excluded from the computations. Sports lighting is excluded. Industrial production, transportation and storage are excluded. Lighting of public and historic monuments, structures and buildings is excluded. Searchlights are excluded.

Most Simple Calculation Example - Building Exterior Allowance



MOST SIMPLE EXTERIOR ALLOWANCE

Most Simple Building Exterior Allowance Calculations

		Zone 4 Permitted	Measured	Extension	Used/1	Used/2
*	Base	1300W	-	1300		
*	Drive, park	.13w/sq-ft	6348 sq-ft	825	600	600
*	Walk	1.00w/sq-ft	1440 sq-ft	1440	800	800
	Main Ent	30w/lf	24 lf	720	600	600
	Other door	20w/lf	12 lf	240	400	200
	Façade	5.00w/lf	164 lf	820	1400	700
	Allowed/Used Exterior Lighting Power			5345	3800	2900

	5345 / 19 =
Total fixtues = 19	281
Case /1, try 200w ea	
Case/2, reduce Type "A1" to 100w, Type "C" to 100w	

The building is patterned after a 24/7 convenience store in a commercial area. A single entrance is provided to force robbers to pass in front of the security camera. There is a back door to comply with building codes but intended to be used by employees only. Parking is assumed to be lighted from street lights. The building exterior lighting was selected by an electrical engineer, not by a project Architect.

Computations were performed as follows:
1) Sections of the allowance table were placed in a spreadsheet. In this example, Base, Drive/parking, Walk, Main Entrance, Other door and Façade were used. Columns were established for permitted energy, measured sq-ft or lf used, net permitted, amount used is the first design case and amount used in the second design case.

Note how *tradable* and *non-tradable* values apply. Base, drive/parking and walk are tradeable. That means that the designer has choices.

Non-tradable means that the line totals must match. The allowable watts for the main entrance must not be exceeded by the fixture watts installed for the main entrance.

2) Enter the measured values. This is exceeding simple if the project is in AutoCAD. Draw a polyline around the driveway / parking lot and say, "LIST". AutoCAD tells you the area in sq-ft. Same for the façade perimeter. LIST reports the linear feet. Any distance on the plan can be accessed by DISTANCE and two mouse clicks.

3) Perform the extension multiplication. I get confused between *sq-ft* and *lf*, so I multiply on a calculator and enter the value into the spreadsheet with units.

4) Count the fixtures and multiply by watts per fixture to get the installed watts in each category.

5) Stop and look at the table for reasonableness test. I make mistakes and often find a decimal error or a value copied incorrectly. They usually stand out as unreasonable.

6) Examine the *allowed* vs the *installed*. If the result is compliant, you can file the calculations until the project lighting is revised. If they are non-compliant, it is pretty clear which category is high. You can re-define the categories or adjust count and/or wattage per fixture.

Re-defining the categories is attractive. The lights next to the parking could be façade or parking. Parking has lots of watts available. The lights next to the sidewalk can use the watts available there. If the Architect adds some parking on the side or back, the façade problem goes away.

In Case/1, the preliminary design worked for the main entrance but did not work for the other entrance or for the façade. Note that the total watts used for the project were well below the allowable.

This presents an ethical dilemma. Do we follow the initial design and just report the total project watts

or do we refine the design to comply for each line total? The exercise refines the design for compliance. ASHRAE does not include a certificate to assert compliance. COMCHECK does, but it only asks about the total project allowance and usage, not category compliance.

Paragraph 9.5.1 begins the requirements for control of interior lighting.

Compliance with ASHRAE 90.1-2010 lighting requirements is available by either of the following methods: Building Area, or Space-by-Space.

The building area method requires selecting the building type from Table 9.5.1, which sets the allowed w/sq-ft. The Standard says to use something similar if you don't find your type in the table.

Multiply the gross area (outside l x w) by the allowed w/sq-ft.

Add up the net fixture wattages of the building [Sum (fixture watts x count)] and compare it with the allowed wattage.

If the installed wattage is too high, there are several corrective approaches. The easiest is to ask your lighting salesman for the part number of a similar fixture with compliant net fixture watts. Perhaps surprisingly, a 2x4 4-lamp T-8 F32 fixture can be purchased with input watts ranging from 146w to 93w.

You gotta be kidding me, 146w to 93w ?

The following is copied from Advance Fluorescent Ballast *Lighting Electronics Atlas 2010-2011*

No. of Lamps	Input Volts	Lamp Starting Method	Ballast Family	Catalog Number	Input Power ANSI (Watts)	Ballast Factor	Max. THD %	Line Current (Amps)	Min. Starting Temp. (°F/°C)	Dim.	Wiring Dia.
F32T8, FBO31T8, F32T8/U6 (32W)											
4	120	IS	AmbiStar‡	REB-4P32-SC	103	0.81	125	1.57	0/-18	B	66
		PS	Standard	RCN-4S32-SC	121	0.88	10	1.03	32/0		138
	277		Centium	VCN-4S32-SC	121	0.88	10	0.45			
	120-277	IS	Centium	ICN-4P32-LW-SC	97-95	0.77	10	0.81-0.34	0/-18	B	66
				ICN-4P32-SC	112	0.88	10	0.94-0.41			
			Optanium	IOP-4P32-LW-SC	96-94	0.77	10	0.81-0.35	-20/-29		
				IOPA-4P32-LW-SC							
				IOP-4P32-SC	109-106	0.87	10	0.92-0.39			
				IOPA-4P32-SC							
				IOP-4P32-HL-90C-G	146-143	1.18	10	1.23-0.53		G	
				IOPA-4P32-HL						A	
		PS		IOP-4PSP-LW-SC	TBD	0.71	10	TBD	0/-18	B	177
				IOP-4S32-LW-SC	93-91	0.71	10	0.77-0.33			138
				IOP-4PSP32-SC	110	0.88	10	0.93-0.40			177
				IOP-4S32-SC	110	0.88	10	0.92-0.40			138
	347	IS	Optanium	GOPA-4P32-LW-SC	92	0.78	10	0.27	-20/-29	B	66
				GOPA-4P32-SC	107	0.88		0.31			

‡ The above AmbiStar ballasts are normal power factor and labeled 'For Residential Use Only'

This introduces another ethical dilemma. You list a compliant part number on the fixture schedule, then bid the project. Is there any enforcement of the low-wattage ballast on the installed fixture?

The other two obvious corrective actions are to reduce the fixture count and select low-wattage sources. A popular scheme is to replace linear fluorescents with compact fluorescent cans. No comment is made here regarding the reduction of delivered footcandles.

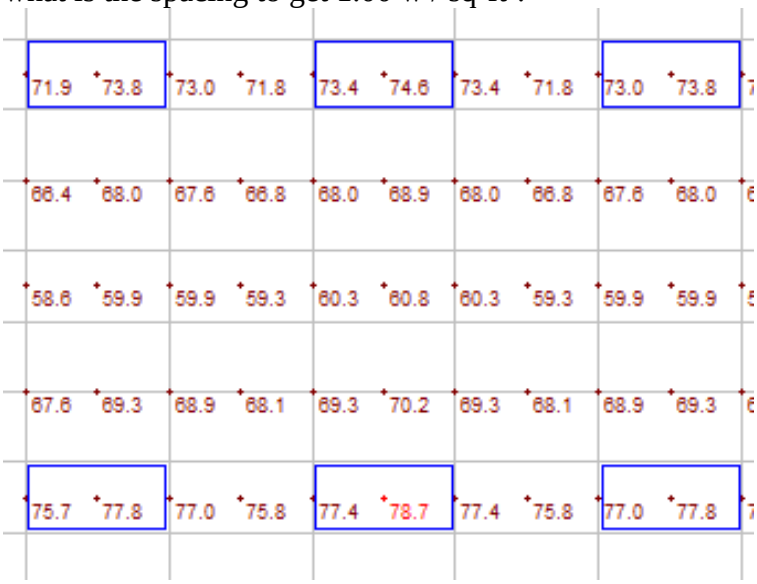
Copyright law has been interpreted that a data table cannot be copyrighted. However, engineers are not lawyers and a favorite technique of hired advocates is to file lawsuits with no expectation of success, just intimidate the adversary. For this reason, you are requested to perform your own internet search to find ASHRAE 90.1-2010 Table9.5.1, *Lighting Power Densities Using the Building Area Method*.

Several values will be reported, though, for reference purposes.

Denny's Restaurant	.99 w/sq-ft
McDonalds	.90
Hyat Regency	1.00
Holiday Inn Express	1.00
Office	.90
Retail	1.40 (+.60 + 1 kW per area)
School	.99

Design Example - ASHRAE 1.00 w / sq-ft

Use a 2-tube F32 T-8 lay-in fixture with 10-ft ceiling height and industry standard reflectances, what is the spacing to get 1.00 w / sq-ft ?



The above report is that the program suggests 8-ft x 12-ft c-c spacing with 58 ave fc and.95 w/sq-ft.

There are two computational procedures which work very well, net fixture w/sq-ft and area-weighted w/sq-ft. They require approximately the same effort, but area-weighted w/sq-ft also produces the numbers needed for the space-by-space method, to be discussed next.

The net fixture w/sq-ft = sum[(Type A watts x Type A count) + sum(Type A watts x Type A count)+..]

Building sq-ft

Or, in spreadsheet form,

	A	B	C	D
1	**Net Fixture w / sq-ft Sample Calculations**			
2				
3	**Type**	**w input**	**count**	**tot watts**
4	A	(fill in)	(fill in)	=B4*C4
5	B	(fill in)	(fill in)	=B5*C5
6	C	(fill in)	(fill in)	=B6*C6
7	D	(fill in)	(fill in)	=B7*C7
8				
9	**Total**			=sum(D4..D7)
10				
11	**Building area =**		(fill in)	
12				
13	**Building w/sq-ft =**		=D9/C11	

Paragraph 9.6.1 begins the computational methodology for the space-by-space interior lighting allowance method.

1) For each space, as defined by walls at least 80% ceiling height, choose a type from Table 9.6.1. Calculate the gross area as midline of interior walls and outside surface of exterior walls.

CAUTION: You must distinguish between gross area and net area.

As indicated previously, LEED compliance forms were based upon net space area - interior w x interior l. This information was available directly from architectural reports required by the funding agency.

In order to get gross area, you must use AutoCAD to draw a polyline through the midpoint of the interior walls and trace out the room. Then read the LIST results for the polyline.

This is not trivial. I spent lots of weekends re-calculating space w/sq-ft as the Architects changed lighting plans in order to meet the space allowances, especially in small rooms, where the wall thickness would make a difference.

ASHRAE 90.1-2010 clearly states that the space-by-space method is based upon gross areas.

2) For each space, multiply the permitted w/sq-ft by the measured area to produce the allowed watts.

3) For each space, multiply the input watts per fixture by the count of that fixture type for the installed watts.

4) Compare the summed watts with the summed allowed watts.

CAUTION: Best available information is that LEED requires each space to comply but ASHRAE requires only that the total building comply.

The LEED AP on my projects was a very smart lady who gave me the LEED compliance procedure, which I used to fill out the LEED forms. I asked several times, and she kept saying to use net areas and each space must comply. She, too, spent weekends reducing lighting levels in restrooms to achieve compliance.

ASHRAE 90.1-2010, 9.6.1.d is unambiguous that tradeoffs are permitted so long as the installed interior lighting power does not exceed the interior lighting power allowance.

Homogenization is the term used by NFPA when they try to make US electrical standards compatible with European electrical standards.

These calculations, in spreadsheet form, might be as follows:

	A	B	C	D	E	F	G	H	I	J
1	**Space-by-Space w / sq-ft Sample Calculations**									
2										
3	**Room no**	**Space Type**	**Allowed w/sq-ft**	**Measured sq-ft**	**Allowed Watts**	**Type**	**w input**	**count**	**tot watts**	
4	A-101	(fill in)	(fill in)	(fill in)	=C4*D4	A	(fill in)	(fill in)	=G4*H4	
5						B	(fill in)	(fill in)	=G5*H5	
6						C	(fill in)	(fill in)	=G6*H6	
7						D	(fill in)	(fill in)	=G7*H7	
8	Room Total Watts=									=sum(I4..I7)
9	**Room Pass / Fail =**		=IF(E4<,J8),"GOOD","BAD"							
10										
11	A-102	(fill in)	(fill in)	(fill in)	=C11*D11	A	(fill in)	(fill in)	=G11*H11	
12						B	(fill in)	(fill in)	=G12*H12	
13						C	(fill in)	(fill in)	=G13*H13	
14						D	(fill in)	(fill in)	=G14*H14	
15	**Room Total Watts=**									=sum(I11.I14)
16	**Room Pass / Fail =**		=IF(E11<,J15),"GOOD","BAD"							
17										
18	**(more rooms)**									
19										
20	**Building area =**			=sum(D4..D99)						
21	**Building watts**								=sum(I4..I99)	=sum(J4..J99)
22	**Building Allowed w=**				=sum(E4..E99)					
23										
24	**Building Pass / Fail=**		=IF(E11<,C22),"GOOD","BAD"							

As you can see, some effort is required to create the basic computations for a single room but cut-and-paste duplicates the function for the entire building. Each room, however, requires identification of the space type, corresponding allowed w/sq-ft, measure the net sq-ft and count each fixture.

As indicated previously, I had the opportunity of repeating these computations again and again. It got down to about 2-hr per full iteration for a medium-large high school.

In 9.6.2, there is an addition which gives an additional 1.00 w/sq-ft for highlighting exhibits. The intention is art, but this could reasonably be interpreted as end-caps for retail. Beyond this, each sales space is permitted an additional 1000w + .60 w/sq-ft. Both of these additions must be timeclock

controlled to be off when the facility is not in use.

Why would retail get *1.40 w/sq-ft* in the Table, then an additional *kw + .60 w/sq-ft* ?
This provides an opportunity to discuss the makeup of technical standards committees. For the most part, parties with a $$$ interest in the outcome fund representatives, that is, voting lobbyists. It is clear that the retail lobby wanted more than 2.00 w/sq-ft. The overall committee thought that it would look suspicious for everybody else to get 1.00 w/sq-ft and retail get 2.00. So, the table says *1.40* and the footnote says *+.60*. Because a jewelry story really needs a kW of lighting on the diamond display, an additional kW for each sales area was added.

There is another addition in this paragraph regarding even more sales lighting with various other automatic controls. The wording is so convoluted as to be unreadable. It references Table 9.6.2 and seems to say an Additional Lighting Allowance = Fixture Wattage x Control Factor, where Control Factor is 0 - .20, from Table 9.6.2.

This is nuts because allowed wattage is based upon Standard requirements and fixture wattage is selected by the designer to meet the net allowance. We don't use the selected fixture to determine the allowance. It is pretty clear that the writers got confused between allowed wattage and installed wattage.

As this is an addition to the basic calculations and to the basic addition for the retail lobby, it can be safely ignored.

Section 9.7 (Lighting) restates the submittal requirements from 8.7 (Power). Record drawings must be delivered to the Owner within 90-days of occupancy, [vs 30-days for power] containing plans showing the lights, controls and circuiting. Operating and maintenance (O&M) manuals must also be submitted within 90-days, and must include setup control positions, recalibrating schedule and relamping schedule.

There was a disclaimer in the 8.7 version that the AHJ doesn't need to see the submittal, only a certification that it was delivered. That disclaimer is not present in 9.7.

The tragedy of lost footcandles.
A little over 100 years ago, when whale oil lamps were being replaced by natural gas fixtures, there was a discussion of necessary light levels for reading. The term footcandle was coined, to indicate the illumination delivered one foot away from a standard candle. (The standard candle was stored at the Bureau of Standards, now National Institute of Standards and Technology.) Lighting was associated with seeing and footcandles. Sometime later the Illuminating Engineering Society was formed. Again, seeing and footcandles were prominent. Now that ASHRAE has taken over lighting, footcandles are gone.

Chapter 10, OTHER EQUIPMENT

For electrical designers, Chapter 10 is about motors. There is discussion of some pumps and considerable discussion of elevators, but these are both mechanical design responsibilities.

Of consideration are open and TEFC NEMA B foot-mounted motors. Table 10.8A lists minimum efficiency for motors manufactured prior to 19Dec10. Table 10.8.B lists minimum efficiency for random wound motors manufactured after 19Dec10. Table 10.8.C lists minimum efficiency for form wound manufactured after 19Dec10. They are fairly large tables, ranging from 1200 to 3600 RPM and 1 to 500 HP. Selected motors are compared below to see if there is any meaning to the tables.

Selected Minimum NEMA B TEFC Motor Efficiencies					
RPM	**HP**	**Table 10.8A pre 2011**	**Table 10.8B post 2010 random wnd**	**Table 10.8C post 2010 form wnd**	**Toshiba 2011 cat**
1200	**1**	80.0	82.5	80.0	78.5
	5	87.5	89.5	87.5	89.5
	10	89.5	91.0	89.5	91.7
	50	93.0	94.1	93.0	94.1
	100	94.1	95.0	94.1	94.1
	200	95.0	95.8	95.0	96.2
	500	NR	95.8	NR	no got
1800	**1**	82.5	85.5	82.5	82.5
	5	87.5	89.5	87.5	88.5
	10	89.5	91.7	89.5	91.0
	50	93.0	94.5	93.0	94.1
	100	94.5	94.5	94.5	94.5
	200	95.0	95.8	95.0	95.4
	500	NR	96.2	95.8	94.5
3600	**1**	75.5	77.0	75.5	80.0
	5	87.5	88.5	87.5	88.5
	10	89.5	90.2	89.5	90.2
	50	92.4	93.0	92.4	93.0
	100	93.6	94.1	93.6	93.6
	200	95.0	95.4	95.0	95.0
	500	NR	95.8	95.4	95.4

This excerpt from the ASHRAE motor efficiency tables lets you see what the Standard is trying to do. You can install an older motor which meets a very slightly relaxed efficiency requirement. If you find

a newer motor on the pump skid delivered for the project, it must meet the newer efficiency requirement. If you buy a new Toshiba motor, you don't have to worry.

Why Toshiba ?
I had a bad experience recently when a US manufacturer repeatedly failed the acceptance test at his manufacturing facility. I had a project start-up coming up, so I expedited a Toshiba motor from a supplier in Houston (the only unit of my RPM and HP I could find in stock). The installed Toshiba measured substantially higher efficiency and substantially lower vibration than the catalog listing. I don't trust one particular US motor manufacturer and I do trust Toshiba. The data is presented for comparison only, not as a recommendation to buy Toshiba. Be warned that the 2011 Toshiba catalog has warnings on many pages, *Only Available until Current Inventory is Depleted*. I don't know what that means.

Chapter 11 starts explaining rules for energy modeling and is not part of this course for electrical design.