Skylighting for the Northeast

Skylighting and Lighting Quality
Sample Warehouse Layouts
Skylight and Controls Specifications

WAREHOUSE SKYLIGHTING

knowhow

INTRODUCTION

The construction of a new warehouse or any industrial building offers an excellent opportunity to include skylights and gain all of the advantages of daylighting. Energy cost savings, increased employee productivity, improved lighting quality, greater worker safety, building value, and reduced maintenance costs… all can result from a well-designed daylighting system.

"The workers in our facilities love the quality of the light. It's made an immense difference in attitudes. Since we relocated to a new daylit facility we've had a much better safety record."

Facility Manager, Nashua, NH

Warehouse and industrial buildings are particularly well suited to the use of skylights to provide daylight, since they typically have a large expanse of roof over a single-story open area. Skylighting has been successfully employed in many warehouse and industrial spaces around the country and, with correct design, can save building owners a significant amount of money in even the most extreme climates.

Higher Profits

Skylighting systems save dollars by using automatic photocontrol systems to turn off the electric lights when interior daylight levels are high. As this guide shows, a well-designed system can save about 1/2 of the lighting energy used in a typical building, which will more than offset any additional heat loss or gains due to the skylights. The designs presented in this brochure save annual energy costs of $0.05 to $0.20 per square foot of building, based on Northeastern U.S. weather and current energy costs. For a 100,000 SF building, that would result in bottom line energy savings of $5,000 to $20,000 per year, every year: a worthwhile addition to anyone's annual profits.

Photo by Ed Asmus

In this industrial warehouse, skylighting provides improved lighting conditions, and net building energy savings.

Employees' Morale

Studies have shown better human performance in daylit buildings. Daylight provides excellent lighting quality and also an important connection to the outdoors. Upon moving into a new daylit building, many business owners report higher employee morale and loyalty.

Maintenance Savings

Daylighting also produces maintenance savings. With photocontrols turning off the electric lights when they are not needed, lamps last longer and re-lamping costs are reduced. Meanwhile, illumination levels are often twice as high as they would be without the skylights.

Lower Risks

Modern skylights provide reliable, high quality illumination every day, whether sunny or overcast. The excellent lighting quality may also help reduce worker accidents and errors.

QUALITY ISSUES FOR WAREHOUSE SKYLIGHTING

- **Use diffusing skylights**
  Diffuse daylight is more efficient and prevents excessive glare from sunspots or hotspots.
- **Distribute skylights uniformly**
  Space skylights no more than 1.5 times the ceiling height apart.
- **Turn off the electric lights!**
  Use automatic photocontrols to dim or turn off lights when interior daylight levels are high.
- **Select skylights with maximum light transmission**
  Maximize light per unit of skylight glazing for the best energy performance.
- **Paint ceilings white**
  Paint the ceiling and all structural elements white; also use light-colored floor materials.

skylighting design principles

Years ago, every warehouse and industrial building used daylight as its primary source of light. Now, with modern skylight products and sophisticated lighting controls, energy analysis and a new appreciation for the value of daylight, daylighting is returning to the workplace.

Incorporating skylights into warehouse-type buildings can be relatively simple once a few basic principles are understood.

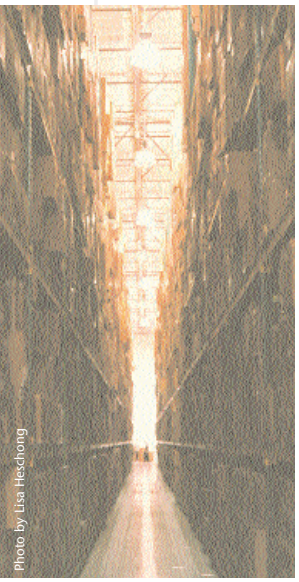


Photo by Lisa Heschong

(Left) Metal halide fixtures produce dark shadows on boxes. (Right) Diffuse skylights provide better illumination on the box faces top to bottom.

Vertical Illumination

Most building managers have been trained to ensure that a minimum number of footcandles are provided at a horizontal task surface. However, in most warehouse and industrial spaces, the amount of light falling onto the vertical surfaces, whether storage racks or machinery, is often far more critical.

Diffuse daylight from skylights is an excellent way to provide high quality illumination on these vertical surfaces. Horizontal illumination levels may actually be lower than from traditional industrial fixtures. However, a worker's ability to read labels on boxes or see critical settings on a machine will considerably improve as the ratio of vertical to horizontal footcandles increases. With the gentle light from diffusing skylights, shadowing is reduced and all surfaces become more evenly illuminated.

Skylight Spacing

A general rule-of-thumb for greatest lighting uniformity is to space skylights on a uniform grid no more than 1.5 times ceiling height. Thus, the higher the ceiling, the further apart skylights can be spaced and the larger the skylights that can be used. With low ceilings use smaller skylights with closer spacing.

Diffusion

Diffusing the light from skylights is extremely important. Diffusion spreads the daylight evenly and gently across the space, both improving efficiency and reducing glare. Good diffusion is most easily achieved by selecting a glazing material that fully diffuses the sunlight. (See specification discussion on page 7.)

Glare

Glare in warehouses or industrial spaces can be a serious problem for workers, interfering with their performance. Glare is often created by the contrast between very bright sources seen against dark surfaces, or by the reflection of bright lights on shiny surfaces.

The most important step in minimizing glare is to choose a diffusing skylight to prevent overly bright sunspots. Skylights should be overhead,

"When I show my skylit buildings to lease, prospective tenants are always impressed with how bright they are and how nice the lighting is. Then I point out that we haven't even installed any electric lighting yet".

Marketing Manager, Industrial Site Developer

Fluorescent or Metal Halide?

It is currently common practice in the Northeast to use 400 Watt metal halide fixtures in industrial and warehouse spaces. Adding skylights and automatic photocontrols to these spaces can save considerable amounts of energy, and improve overall light quality.

An alternative practice, gaining increasing acceptance, is to use linear fluorescent fixtures instead of metal halide. Fluorescent sources can offer a number of advantages over metal halide, including improved visual quality, energy efficiency, control capability, and maintenance performance.

Building owners can see substantial energy savings by switching to a fluorescent strategy, independent of any decision to include skylights (see comparison chart on page 4-5). A fluorescent system can operate at substantially less power of an equivalent metal halide (MH) system while creating less glare and providing more lighting uniformity.

Restrike

Metal halide lamps can not be re-started immediately after being switched off. Many lamps take 10 to 15 minutes to "re-strike." (Newer, premium lamps may have much shorter re-strike times.) To accommodate this delay in re-starting, photocontrols should allow a time delay of at least twice the re-strike period before switching lights back on again. As an additional safety measure, to insure minimum illumination at all times, about 1/3 of MH lamps should always be left on during occupied hours. Such control provisions make MH fixture switching systems less efficient than fluorescent multi-lamp switching.

Uniformity

Metal halide lamps use only one, high-powered lamp per fixture. When a fixture is switched off, (or when it burns out), it leaves a relatively large dark area in the space. Fluorescent fixtures, on the other hand, have multiple lamps within each fixture, and each lamp can be circuited to switch separately. Thus, fluorescent fixtures can easily provide partial illumination with no loss in uniformity.

First Costs and Maintenance

Metal halide systems use 1/2 or 1/3 the number of fixtures and lamps of fluorescent systems, reducing first costs. However, fluorescent systems have maintenance cost advantages in less need for spot re-lamping and, with the use of smart photocontrols, hours of operation can be equalized, simplifying group re-lamping.

Skylights combined with light-colored surfaces provide excellent light quality in this Rhode Island warehouse.

not in a worker's direct line of sight. Use the depth of the skylight well, white-painted structural elements, or other shielding elements to help block direct view of the skylight. Also, use light-colored ceilings and floors that will help reduce the visual contrast between the skylight (or any light source) and its surrounds.

Reflectances

Dark surfaces absorb light and light-colored surfaces reflect light. White paint reflects about 80% of the light that strikes it, while concrete or wood may reflect only 20-40%. Thus, a room with raw concrete surfaces will require 2 to 4 times as much light (and power) for the same level of illumination as a white-painted room.

The simple step of specifying light-colored ceiling surfaces and structural elements will vastly improve both lighting efficiency and lighting quality.

There are many options available. Instead of using exposed foil-faced or paper-faced insulation, order white vinyl facing. Structural members can be ordered with white finish instead of gray or black. Use light-colored concrete for floors instead of standard gray. Or order a universal coat of white paint for all walls and ceilings before moving into a new building.

Controls

Automatic photo control of electric lights is the critical component that produces savings from skylit buildings. The choice of a control strategy largely determines the magnitude of any energy savings.

Photosensors

Most warehouse and industrial skylighting systems place a photosensor facing up in the skylight well. These "open loop" systems, which sense only the daylight levels, are simple, relatively inexpensive and reliable. The photosensor sends a signal to a controller that determines when to raise or lower electric lighting levels in response to the available daylight, by slowly dimming or switching lamps.

Dimming

Continuous dimming systems are available for fluorescent systems that provide excellent performance, and maintain uniformity of electric lighting from all fixtures. Continuous dimming components are still relatively expensive and need to be carefully evaluated to see if they can be cost effective in warehouse and industrial applications.

Hi-lo Dimming

In some situations, hi-lo ballasts for either fluorescent or MH lamps can offer a cost effective alternative to continuous dimming. Hi-lo MH ballasts offer the advantage of being able to reduce light output from a fixture without needing to re-strike the lamp.

Both continuous dimming and hi-lo ballasts have lower efficiencies at low light output. Thus, at 20% light output the ballast may still be consuming 40% of its rated power. For layouts 1-3, SkyCalc shows dimming saves less energy than switching.

Switching

Automatic switching systems are by far the most common photocontrol solution in skylit warehouses and industrial buildings. They are generally simple, inexpensive, and provide adequate uniformity for most needs. Fluorescent systems are easily switched within each fixture, by turning off one or more lamp per fixture (see diagram on page 6). Even metal halide systems can be successfully switched on and off, if careful attention is paid to addressing re-strike and lighting uniformity issues.

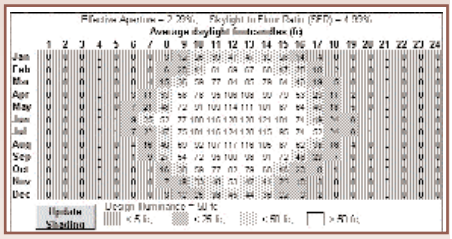
Optimize Your Design Using SkyCalc™

The optimum number and size of skylights needed to light a given building is determined by many factors, including the choice of skylight glazing material, building design and operation, local energy costs, and local climate conditions. In order to facilitate this complex calculation, a simple-to-use spreadsheet tool, SkyCalc, has been developed and can be downloaded for free from www.h-m-g.com.

Skylight to Floor Ratio (SFR)

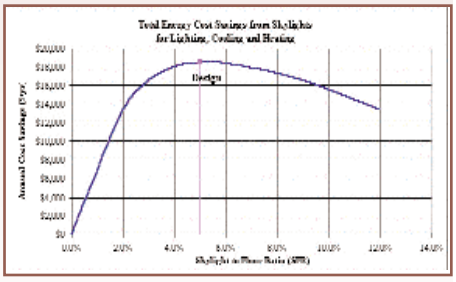
For industrial and warehouse buildings the appropriate area of the roof area devoted to skylights, referred to as the "skylight to floor area ratio" or SFR, varies from about 2% to 6%. In general, for any given skylight, more skylight area will be justified with:

- Higher desired light levels
- More power used for lighting (W/sf)
- Higher cost of electricity
- More heat-generating equipment in the building
- More daylight hours of operation per week
- Milder winter climate
- More energy used for air-conditioning



SkyCalc Illumination Plot

This illumination plots shows the average footcandles that can be expected from a given skylight design, by hour and month of the year. Un-shaded hours indicate "full daylight saturation" when daylight illumination levels will typically exceed the target for the electric lighting. The shaded areas are those hours when partial electric lighting will be needed.



SkyCalc Cost Savings Graph

For a given design, SkyCalc™ plots net building energy savings (heating, cooling and lighting) as a function of the percentage of roof area devoted to skylights (SFR).

warehouse layouts

Efficient, High Quality Lighting!

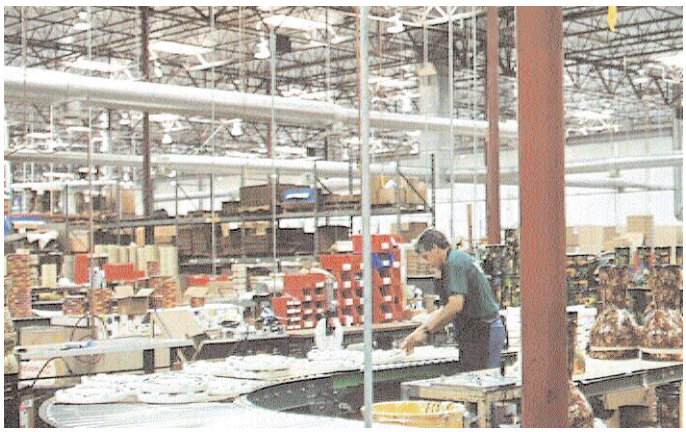


Photo by L. Heschong

Skylights in a drum assembly plant provide high illumination levels and excellent three-dimensional visibility.

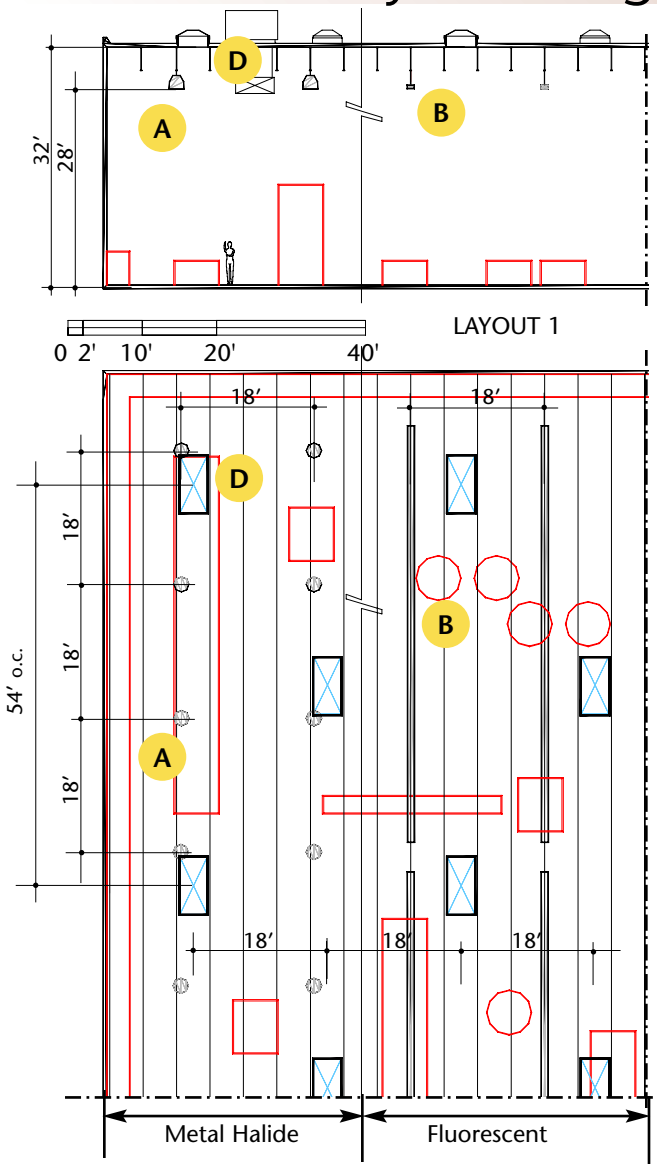
COMPARISON CHART FOR DIFFERENT SKYLIT V

	Layout 1- 3.3% SFR		Lay
Space Type	Light Industrial		Op
Design Illumination	50fc		30f
Lamp Type	Metal Halide	Fluorescent	Me
Fixtures	High Bay	8′ Reflector	Hig
Power Density	1.36 w/sf	0.88 w/sf	0.9
Control Strategy	2/3 on off	4/4 on off	2/3
Light Savings	48%	40%	42%
Uniformity	*	****	*
Comfort & Quality	**	****	**
Lighting Cost Upgrade	*	**	*
OVERALL VALUE	**	****	**

Provisos:

1. The discussions and graphics in this guide have been generalized and greatly simplified in order to pr designer and electric engineer to integrate these general concepts with the specifics of your building and
2. Projections of energy savings are based on SkyCalc analysis using typical weather data, average year 2 Actual savings will obviously vary according to actual design, building operation, weather, and energy p

warehouse layout 1- light industrial



Activities in this sample light industrial space might include component processing, assembly, shipping and receiving. This design sets an electrical illumination criteria of an average of 50 horizontal footcandles, avoidance of glare and uniform distribution. It uses two different strategies: 400 Watt metal halide high bay fixtures spaced on an 18' grid, or 8' industrial fluorescent luminaires using four T8 lamps in continuous rows 18' apart.

Both designs use 4' x 8' skylights in 18' rows, spaced 54' apart on a staggered grid. The clear, prismatic double-glazed acrylic skylights occupy 3.3% of the roof area. With this design[2], daylight illumination levels average approximately 50 footcandles midday in winter and 130 footcandles midday in summer. In this case, using triple glazed skylights would save an additional $10 to $15 per skylight per year. Using double-glazed, standard white bubble units instead of clear prismatic would reduce energy savings by about $60 to $80 per skylight per year and require 50% more units.

Switching photocontrols are used in both cases. The first 1/3 of the metal halide fixtures closest to the skylights are switched off at about 20 footcandles of daylight illumination. A second 1/3 turns off when about 35 footcandles is reached. As a safety precaution, 1/3 are always left on during occupied hours. The fluorescent lamps are switched in quarter levels, one or two lamps per 4-lamp fixture. Use of 4-lamp electronic ballasts will produce the most efficient system (see discussion of control diagram on page 6).

The chart below shows that a skylit fluorescent system (2+3) will save about 62% of the lighting energy of a basic metal halide system without skylights.

SkyCalc Energy Savings Analysis

	1) Add skylights to metal halide		2) From MH to fluorescent		3) Add skylights to fluorescent		2+3) From MH to Fl. w skylight	
3.3% SFR	Light savings	Savings per SF	Light savings	Savings per SF	Light savings	Savings per SF	Light savings	Savings per SF
NYC	49%	$0.24	37%	$0.28	41%	$0.16	63%	$0.44
Buffalo	47%	$0.21	37%	$0.26	39%	$0.13	62%	$0.39
Boston	48%	$0.16	37%	$0.21	40%	$0.10	62%	$0.30

WAREHOUSE LAYOUTS

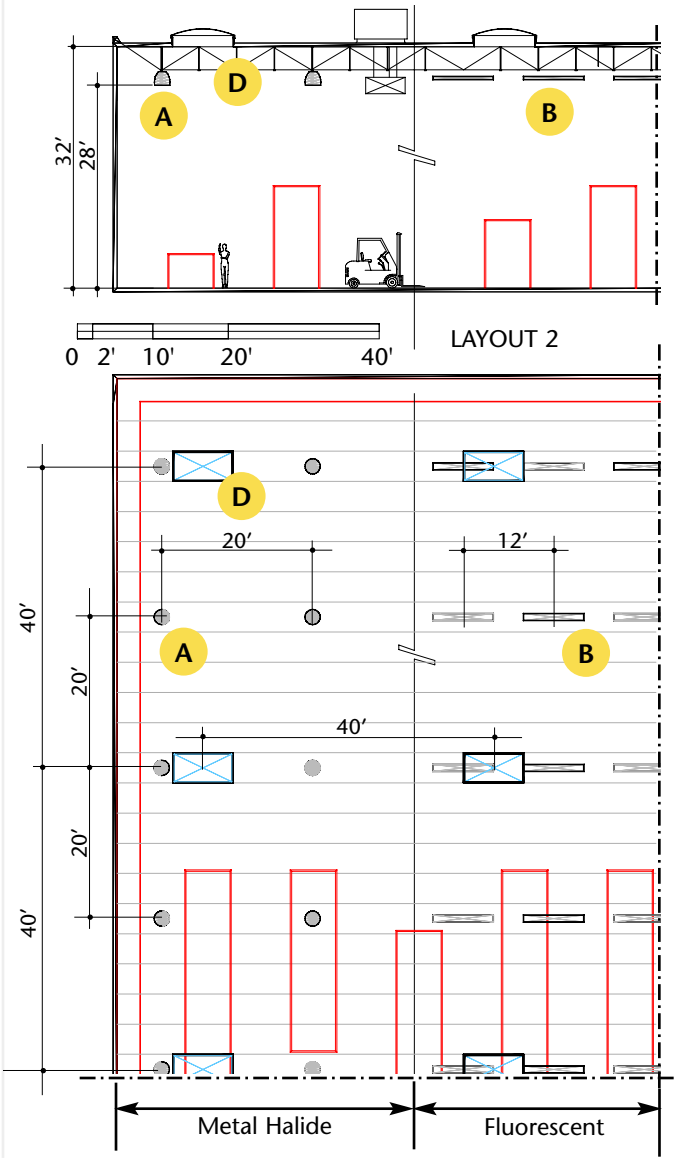
	Layout 2 - 2% SFR		**Layout 3 - 2.4% SFR**	
	Open Warehouse		Warehouse Aisles	
	30fc		10fc	
	Metal Halide High Bay	Fluorescent 8′ Reflector	Metal Halide Aisle Lighter	Fluorescent 8′ Reflector
	0.67 w/sf	0.52 w/sf	0.65 w/sf	0.37 w/sf
	4/4 on off	4/4 on off	1/1 on off	2/2 on off
	50%	50%	52%	64%
	***	***	*	***
	***	***	**	****
	**	**	*	**
	***	***	*	**

esent useful advice in this condensed format. Consult with your architect, lighting to refine the details.
2000 energy prices, and various design and operation assumptions for each example.
rices.

Photo by L. Heschong

All the metal halide fixtures are turned off in the shipping and receiving area of a major warehouse. Note how the white walls and light colored concrete floor help distribute the daylight.

warehouse layout 2 - open warehouse



Activities in this sample open warehouse space might include packing, processing, active storage, bulk storage, shipping, or receiving. This design sets an electrical illumination target of 30 horizontal footcandles, again using both a metal halide and a fluorescent strategy. With lower light levels and less heat generating equipment in the space than the light industrial example, this warehouse needs less overall skylight area to achieve an optimum energy performance. This design locates 4' x 8' clear prismatic skylights on a 40' square grid, producing a 2% SFR.

Using the same switching scheme as the light industrial example, metal halide fixtures are located on a 20' x 20' grid, or alternatively, 8' industrial fluorescents are spaced at 20' x 12'. Because the overall lighting power density is lower for this layout than the light industrial layout, the energy savings from the daylight is also proportionately lower.

The open space allows for broad distribution of daylight from the skylights. In the warehouse in the photo, white vinyl faced insulation increases the reflectance of the warehouse ceiling, while a special light-colored concrete floor helps to reflect light upwards. Painting the open web joist white would further improve the lighting quality in the space. In this example, increasing the SFR from 2% to 3% by placing the skylights closer together will increase the average daylight illumination by 50%, and increase savings slightly, by $2 to $10 per skylight per year.

The chart below shows that a skylit fluorescent system (2+3) will save about 74% of the lighting energy of a basic metal halide system without skylights.

SkyCalc Energy Savings Analysis

	1) Add skylights to metal halide		2) From MH to Fluorescent		3) Add skylights to Fluorescent		2+3) From MH to Fl. w skylight	
2.0% SFR	Light savings	Savings per SF	Light savings	Savings per SF	Light savings	Savings per SF	Light savings	Savings per SF
NYC	42%	$0.20	47%	$0.19	52%	$0.10	75%	$0.37
Buffalo	41%	$0.18	47%	$0.26	49%	$0.09	73%	$0.34
Boston	42%	$0.13	47%	$0.26	50%	$0.06	74%	$0.25

Control Diagram

Tandem Wiring for Fluorescent Multi-Lamp Switching

This schematic wiring diagram shows how lamps can be individually switched in a three-lamp fixture, allowing three levels of light output. This diagram is for two-lamp ballasts, here connecting two fixtures. The same principle applies to four-lamp ballasts, where one ballast could power one lamp each in four adjoining fixtures. Check with ballast manufacturer for recommended distance limits on ballast leads.

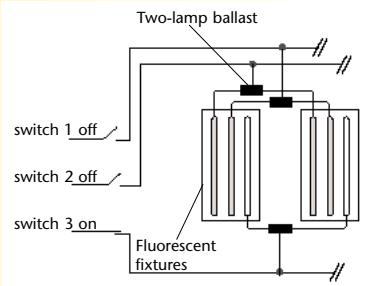
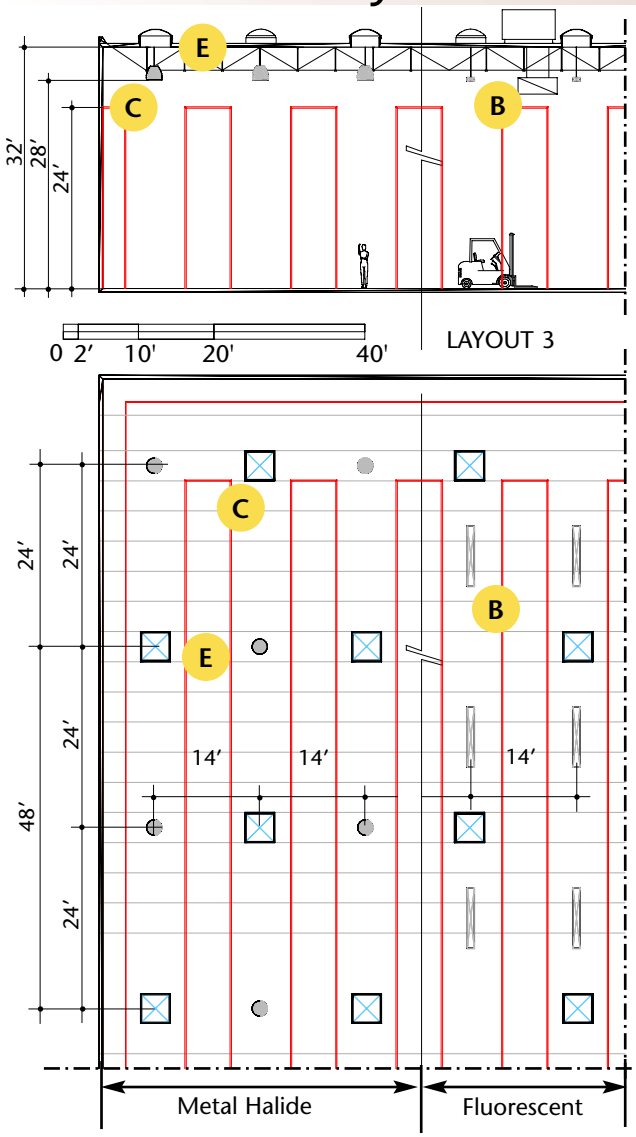


Photo by L. Heschong

Illumination in tall warehouse storage aisles is vastly improved with the addition of skylights.

warehouse layout 3 - warehouse aisles



Storage aisles for new warehouses are becoming ever taller and narrower as owners strive to economize on real estate for storage space. Automated equipment can help workers navigate these tight spaces in their fork lifts. However, providing low glare, uniform illumination on the vertical faces of tall, close racks is an extreme challenge for lighting designers. Skylights can solve this problem, and save energy while they do so.

This layout assumes 8' wide racks, 24' high. Smaller, 4' x 4' clear prismatic skylights are spaced 48' apart in each aisle, for an SFR of 2.4%. Skylight spacing is staggered to take advantage of some daylight spill from one aisle to the next. Special "aisle-lighter" metal halide fixtures are used to distribute light widely down the aisle. Even so, electric vertical illumination levels are likely to vary by a factor of 1:10. One MH fixture is placed between each skylight, also spaced 48' apart. Because of this 1:1 ratio of fixtures to skylights, using multi-level MH switching as in previous layouts would result in unacceptably dark areas in some parts of the aisles. Instead, almost all of the MH fixtures are switched off together when daylight levels exceed the target threshold. 20% of the fixtures are left on all the time for safety. This on-off control scheme saves about 50% more energy than using hi-lo ballasts.

In the fluorescent scheme, luminaires are spaced 24' apart. Once again the 4-lamp fixtures can be switched in multi-lamp steps, and all the way off to provide the greatest photocontrol savings. This time, half levels are judged to be most cost effective while maintaining sufficient illumination uniformity. The fluorescent system provides both greater energy efficiency and higher lighting quality than the metal halide design.

SkyCalc Energy Savings Analysis

2.4% SFR	1) Add skylights to metal halide		2) From MH to fluorescent		3) Add skylights to fluorescent		2+3) From MH to Fl. w skylight	
	Light savings	Savings per SF	Light savings	Savings per SF	Light savings	Savings per SF	Light savings	Savings per SF
NYC	53%	$0.13	57%	$0.12	64%	$0.08	85%	$0.21
Buffalo	52%	$0.12	57%	$0.12	63%	$0.07	84%	$0.19
Boston	53%	$0.08	57%	$0.09	64%	$0.04	85%	$0.13

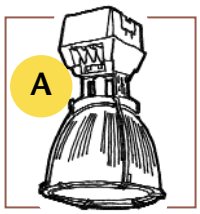
skylights and lighting fixture schedule

These highly abbreviated lamp and fixture descriptions are keyed to the warehouse layouts. Choose lamps which match daylight color (4100°K to 5000°K), and have longest life and highest lumen output per watt.

A. HIGH BAY PRISMATIC METAL HALIDE

LAMPS: (1) 400 W metal halide.

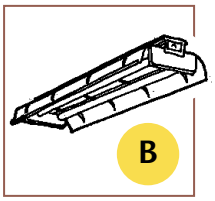
DESCRIPTION: Pendant mounted, open prismatic refractor housing. 15% uplight component. Field adjust lamp position for widest light distribution. 440 nominal input watts.*



B. FLUORESCENT INDUSTRIAL STRIP WITH REFLECTOR

LAMPS: (4) 32W T8; electronic ballasts.

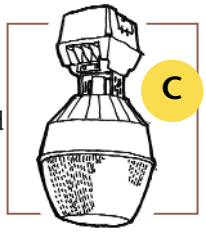
DESCRIPTION: 8' industrial luminaire with reflector. 15% uplight component. 85% minimum fixture efficiency. 4-lamp ballasts will be most efficient. Circuit for switching of lamps, individually or in pairs (see diagram on page 6).



C. AISLE LIGHTING PRISMATIC METAL HALIDE

LAMPS: (1) 400 W metal halide

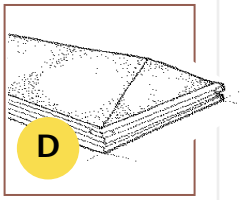
DESCRIPTION: Pendant mounted, open prismatic refractor housing. 440 nominal input watts. Field adjust for longest light distribution.*



* Fluorescent equivalents are also available for this fixture type.

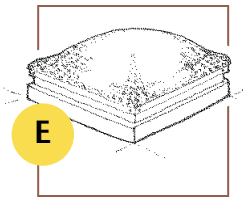
SKYLIGHT SPECIFICATIONS

Double-glazed, non-venting plastic unit skylights with condensate gutter attached to integral, insulating frame.



SHAPE: (**D**) 4' x 8 ' ,(**E**) 4' x 4', bubble, double arched, pyramid or barrel vault.

GLAZING MATERIAL: Choose highest light transmittance available. 70%+ visible light transmittance is recommended. Require proof from unit manufacturer that light transmission will remain stable over life of the unit, without yellowing or loss of structural strength.



DIFFUSION: Choose the most diffusing material available. There is currently no precise language that can be used to specify good diffusion, thus diffusion is best assessed by direct visual inspection. For example, sunlight passing through the diffusing glazing material should not concentrate the light into local hot spots, nor cast a discernable shadow from a hand held three feet above the ground. Clear diffusing materials include prismatic acrylic, clear fiberglass, and complex polycarbonate extrusions.

HEAT GAIN AND LOSS: Solar Heat Gain Coefficient = 70% maximum. Unit U-factor = 1.0 maximum (including framing effects).

UNIT SIZE: Choose specific dimensions for a given location via SkyCalc™ to optimize energy performance for a given layout pattern and skylight to floor area ratio (SFR).

SAFETY & MAINTENANCE: Check local fire and safety codes for minimum strength and other performance requirements. Include a safety grate to prevent forced entry or accidental falls. Occasional washing of the skylights in dry, dusty or urban locations will help maintain optimal performance.

CONTROLS PERFORMANCE SPECIFICATIONS

Control Zones: Determine all the different lighting and daylighting conditions in the building and set each as a control zone. A control zone may be determined by a change in: illumination needs, ceiling or fixture mounting height, pattern of skylight distribution, pattern of shelving, or other obstructions. Ensure that each zone is separately circuited and has its own photosensor and controller. Ensure that circuiting will allow for logical changes in electric light levels in response to daylight availability.

Photosensor Location: Place a photosensor that can read daylight illumination levels ranging from at least 100 to 10,000 foot candles in the throat of the skylight well, held off at least 12" from the side of the well. This is combined with an "open-loop" controller, which only responds to daylight levels. The illuminance reading at the sensor will be a constant multiple of daylight illuminance at the floor level. Use at least one sensor per control zone. Choose a location with representative daylight patterns, with no unusual shading from nearby equipment, trees, or structures. Alternatively, use an averaged signal from more than one sensor location. In warehouse and industrial buildings it is important to avoid excessive dust accumulation on the sensor. Access for maintenance, or a pneumatic blower, is advised for dusty areas.

Metal Halide Fixture Switching: For 2/3 multi-level step switching, fixtures are circuited in three groups: 1) those closest to the skylights, 2) intermediate distance, and 3) farthest from skylights and/or along the perimeter of warehouse. The first circuit should be programmed to automatically switch off after daylight levels have exceeded 40% of electric light level target for five minutes or more. The second circuit turns off when daylight levels exceed electric target by 80%. The third circuit is always left on during occupied hours.

A time delay of at least 10 minutes (or at least twice the lamp restrike period) should be imposed before the lights can switch back on when daylight levels drop. Specify a controller that is compatible with ballast type and circuit loads.

Multi-lamp Fluorescent Switching: Lamps are automatically switched within each 4-lamp fixture. Four levels of light output (25%, 50%, 75% or 100%) can be achieved by switching lamps individually (for greatest uniformity), or in pairs of lamps between pairs of fixtures (for greatest economy). See diagram on page 6. Allow a minimum of a five-minute time delay before switching on or off.

construction issues

Leakage

Modern unit skylights are far less prone to leaks than older, site-built skylights that caused many of the problems that building owners remember. Plastic molding techniques, factory-sealed gaskets, and precision metal frame details have improved the performance of the available products dramatically. Select manufacturer's products with a proven track record of life-time leak resistance. Operable or venting skylights may be more likely to have leak failures. Today, the greatest area of concern is with installation details and practices. Careful detailing, and tight specifications that call for installation warranties from contractors, are the best protections against leaks.

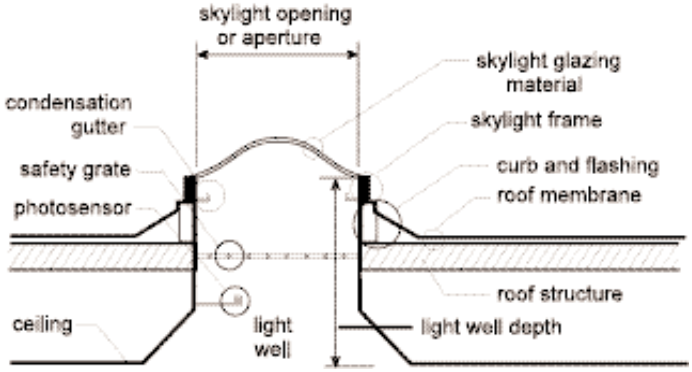
"I have 15 years experience building 200 warehouse stores with hundreds of skylights each. The skylights haven't presented a problem for leaks. We have systematized our design. The skylight curb and safety grate are constructed as an integral part of the building frame. The roofing specification requires a 25-year guarantee, which encourages careful attention to flashing and quality control."

Construction Manager, Large Wholesaler

Condensation

Condensation will normally occur on the inner surface of a skylight at night as warm indoor air rises, carrying moisture that condenses on the colder glazing and framing surfaces. Insulated frames and double or triple glazed skylights will reduce, but not prevent this condensation. Water marks from condensation drips are commonly mistaken for skylight leaks. The best solution is a "condensation gutter" mounted at the bottom of the skylight, which is sized to collect the maximum amount of condensate at night and allow it to re-evaporate during the day.

Skylight Components



Smoke Vents

Many warehouse and industrial buildings use rooftop smoke vents to provide additional safety in case of fire. Skylights can be purchased which also function as smoke vents.

Safety and Security

Building owners are justifiably concerned about the safety and security of using skylights in their buildings. To address safety and security concerns:

- Locate roof work areas and maintenance paths away from skylights
- Select glazing materials that are not easily shattered by heavy or sharp objects
- Install skylight units with tamper-proof screws
- Include a safety grate in the skylight well which can resist the fall of a heavy worker (300 lbs is often recommended)

The most common safety grate is a grid of steel bars spaced every six inches mounted inside to either the frame or the curb. This both protects people from accidental falls and prevents thieves from breaking in. Some manufacturers provide a safety grate as a factory-built option for their units. Other building owners include it as a standard site-built specification item.

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For more information contact:

warehouse layouts

Efficient, High Quality Lighting!

Photo by L Heschong

Skylights in a drum assembly plant provide high illumination levels and excellent three-dimensional visibility.

COMPARISON CHART FOR DIFFERENT SKYLIT WAREHOUSE LAYOUTS

	Layout 1- 3.3% SFR		Layout 2 - 2% SFR		Layout 3 - 2.4% SFR	
Space Type	Light Industrial		Open Warehouse		Warehouse Aisles	
Design Illumination	50fc		30fc		10fc	
Lamp Type	Metal Halide	Fluorescent	Metal Halide	Fluorescent	Metal Halide	Fluorescent
Fixtures	High Bay	8' Reflector	High Bay	8' Reflector	Aisle Lighter	8' Reflector
Power Density	1.36 w/sf	0.88 w/sf	0.97 w/sf	0.52 w/sf	0.65 w/sf	0.37 w/sf
Control Strategy	2/3 on off	4/4 on off	2/3 on off	4/4 on off	1/1 on off	2/2 on off
Light Savings	48%	40%	42%	50%	52%	64%
Uniformity						
Comfort & Quality						
Lighting Cost Upgrade						
OVERALL VALUE						

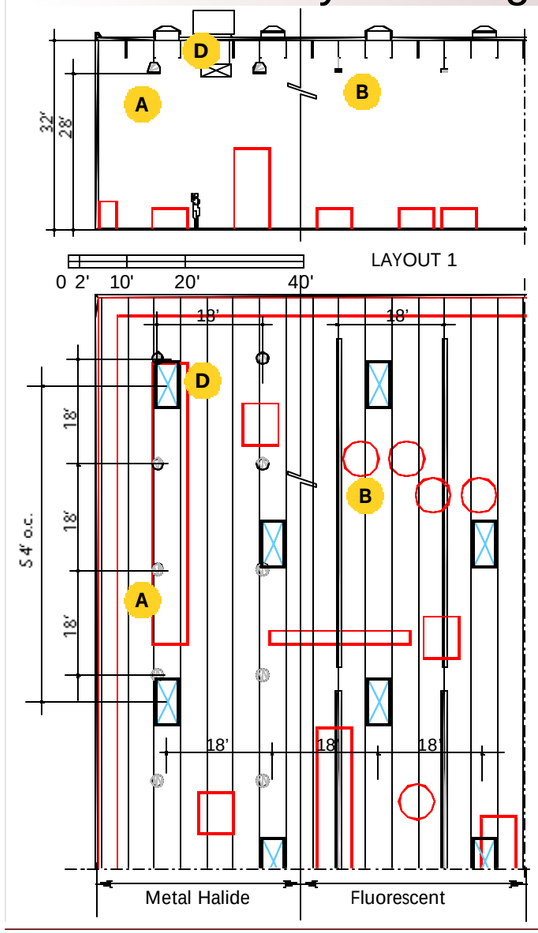
Provisos:

1. The discussions and graphics in this guide have been generalized and greatly simplified in order to present useful advice in this condensed format. Consult with your architect, lighting designer and electric engineer to integrate these general concepts with the specifics of your building and to refine the details.
2. Projections of energy savings are based on SkyCalc analysis using typical weather data, average year 2000 energy prices, and various design and operation assumptions for each example. Actual savings will obviously vary according to actual design, building operation, weather, and energy prices.

Photo by L Heschong

All the metal halide fixtures are turned off in the shipping and receiving area of a major warehouse. Note how the white walls and light colored concrete floor help distribute the daylight.

warehouse layout 1- light industrial



Activities in this sample light industrial space might include component processing, assembly, shipping and receiving. This design sets an electrical illumination criteria of an average of 50 horizontal footcandles, avoidance of glare and uniform distribution. It uses two different strategies: 400 Watt metal halide high bay fixtures spaced on an 18' grid, or 8' industrial fluorescent luminaires using four T8 lamps in continuous rows 18' apart.

Both designs use 4' x 8' skylights in 18' rows, spaced 54' apart on a staggered grid. The clear, prismatic double-glazed acrylic skylights occupy 3.3% of the roof area. With this design[2], daylight illumination levels average approximately 50 footcandles midday in winter and 130 footcandles midday in summer. In this case, using triple glazed skylights would save an additional $10 to $15 per skylight per year. Using double-glazed, standard white bubble units instead of clear prismatic would reduce energy savings by about $60 to $80 per skylight per year and require 50% more units.

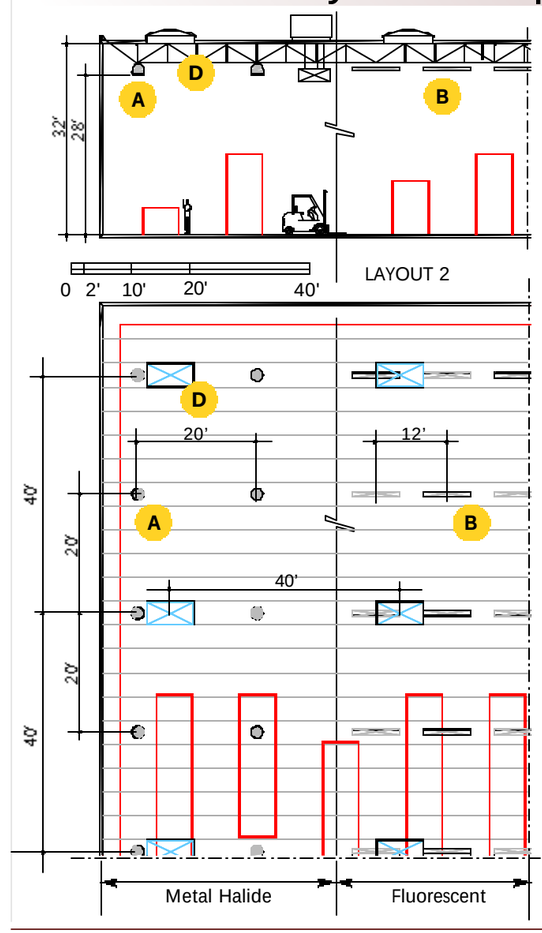
Switching photocontrols are used in both cases. The first 1/3 of the metal halide fixtures closest to the skylights are switched off at about 20 footcandles of daylight illumination. A second 1/3 turns off when about 35 footcandles is reached. As a safety precaution, 1/3 are always left on during occupied hours. The fluorescent lamps are switched in quarter levels, one or two lamps per 4-lamp fixture. Use of 4-lamp electronic ballasts will produce the most efficient system (see discussion of control diagram on page 6).

The chart below shows that a skylit fluorescent system (2+3) will save about 62% of the lighting energy of a basic metal halide system without skylights.

SkyCalc Energy Savings Analysis

3.3% SFR	1) Add skylights to metal halide		2) From MH to fluorescent		3) Add skylights to fluorescent		2+3) From MH to Fl. w skylight	
	Light savings	Savings per SF	Light savings	Savings per SF	Light savings	Savings per SF	Light savings	Savings per SF
NYC	49%	$0.24	37%	$0.28	41%	$0.16	63%	$0.44
Buffalo	47%	$0.21	37%	$0.26	39%	$0.13	62%	$0.39
Boston	48%	$0.16	37%	$0.21	40%	$0.10	62%	$0.30

warehouse layout 2 - open warehouse



Activities in this sample open warehouse space might include packing, processing, active storage, bulk storage, shipping, or receiving. This design sets an electrical illumination target of 30 horizontal footcandles, again using both a metal halide and a fluorescent strategy. With lower light levels and less heat generating equipment in the space than the light industrial example, this warehouse needs less overall skylight area to achieve an optimum energy performance. This design locates 4' x 8' clear prismatic skylights on a 40' square grid, producing a 2% SFR.

Using the same switching scheme as the light industrial example, metal halide fixtures are located on a 20' x 20' grid, or alternatively, 8' industrial fluorescents are spaced at 20' x 12'. Because the overall lighting power density is lower for this layout than the light industrial layout, the energy savings from the daylight is also proportionately lower.

The open space allows for broad distribution of daylight from the skylights. In the warehouse in the photo, white vinyl faced insulation increases the reflectance of the warehouse ceiling, while a special light-colored concrete floor helps to reflect light upwards. Painting the open web joist white would further improve the lighting quality in the space. In this example, increasing the SFR from 2% to 3% by placing the skylights closer together will increase the average daylight illumination by 50%, and increase savings slightly, by $2 to $10 per skylight per year.

The chart below shows that a skylit fluorescent system (2+3) will save about 74% of the lighting energy of a basic metal halide system without skylights.

SkyCalc Energy Savings Analysis

2.0% SFR	1) Add skylights to metal halide		2) From MH to Fluorescent		3) Add skylights to Fluorescent		2+3) From MH to Fl. w skylight	
	Light savings	Savings per SF	Light savings	Savings per SF	Light savings	Savings per SF	Light savings	Savings per SF
NYC	42%	$0.20	47%	$0.19	52%	$0.10	75%	$0.37
Buffalo	41%	$0.18	47%	$0.26	49%	$0.09	73%	$0.34
Boston	42%	$0.13	47%	$0.26	50%	$0.06	74%	$0.25