# Lighting – A Natural Way to Increase Milk Production

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## ■ Background

Research in Canada, USA and elsewhere suggests that cows may produce more milk when lighting intensity (expressed in foot candles (FC)), in the housing facility for the milking herd is bright (16 – 20 FC), stays on for a continuous period of 16 – 18 hours, and is well distributed throughout the area. Typical increases in milk productivity can range from 5 to 16 per cent. Ongoing research also indicates cows need a daily dark interval of at least 4 hours and therefore continuous 24 hour lighting is not necessary or else the effect of improved lighting may be lost.

Many of the dairy barns inspected by the author used 100 – 300 watt incandescent bulbs, with light levels averaging 2 – 5 FC, and generally with poor distribution or uniformity. Barns lighted to 2 FC with incandescent lamps will require more power to relight to 20 FC, even with current more efficient sources. However, it is possible that installations with 5 FC incandescent lighting levels can achieve power reductions when relighted to 20 FC with more efficient sources.

"The light spread should be fairly uniform throughout the feeding and housing area at around 12 – 20 FC. Outermost corners may drop to 7 – 12 FC, however, where they spend most of their time should receive 16 – 20 FC of intensity. Cows need 16 – 17 hours of continuous light (natural and supplemental) and also a continuous block of dark time to make this work." [6]

Based on upgraded installations to 20 FC known by the author, general comments have been very positive and include improved working conditions, easier to observe and detect heats, higher daily dry matter intake, and increases in milk production. Production on several pilot farms is being monitored.

## ▪ Characteristics Of Light Sources (** Salient Features)

### Incandescent (including halogen):

- Oldest, least efficient. Instant light upon turn on.
- Very low first cost, very costly to operate.
- Wide range of wattages.
- Easily dimmable. Short lamp life.

### Fluorescent:

- Very efficient. Requires a ballast or transformer.
- Reduced light at cool temperatures.
- 34 watt 4 foot T12 fluorescent most popular.

** New 32 watt 4 foot T8 fluorescent most efficient.
** Cool temperature T8 fluorescent ballasts available.
** Good lamp life of 12,000 – 15,000 hours.

### Compact Fluorescent:

- Fairly efficient, available in small wattages (13 – 26 watts).

** Also available with standard medium (screw-in) base.

- Reduced light at cool temperatures.

### Metal Halide (MH):

- Efficient, requires a ballast.
- Requires “warm-up” of about 8 minutes, and a re-strike period.
- 175, 250 and 400 watt most practical wattage range.
- Excellent for 12’ ceilings and higher.
- Lamp life 8,000 – 15,000 hours.

** New PULSE START version is most efficient.

### High Pressure Sodium (HPS):

- Extremely efficient, but color output is LIGHT AMBER.
- Wide wattage range of 70 – 400 watts.

** Most economical first cost option.

- Requires “warm-up” of about 5 minutes, and a re-strike period.
- Lamp life 20,000 – 24,000 hours.

### Mercury Vapor (MV):

- Not recommended as source quickly becoming obsolete.

### Low Pressure Sodium (LPS):

- Not recommended as color of light is very poor.

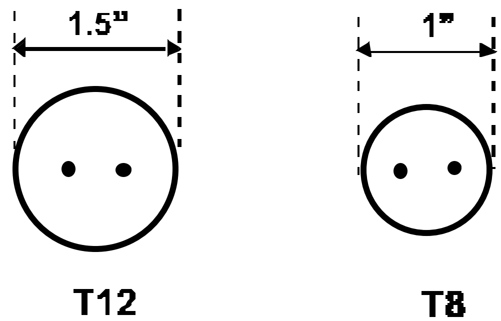


**Figure 1. Fluorescent Comparisons**

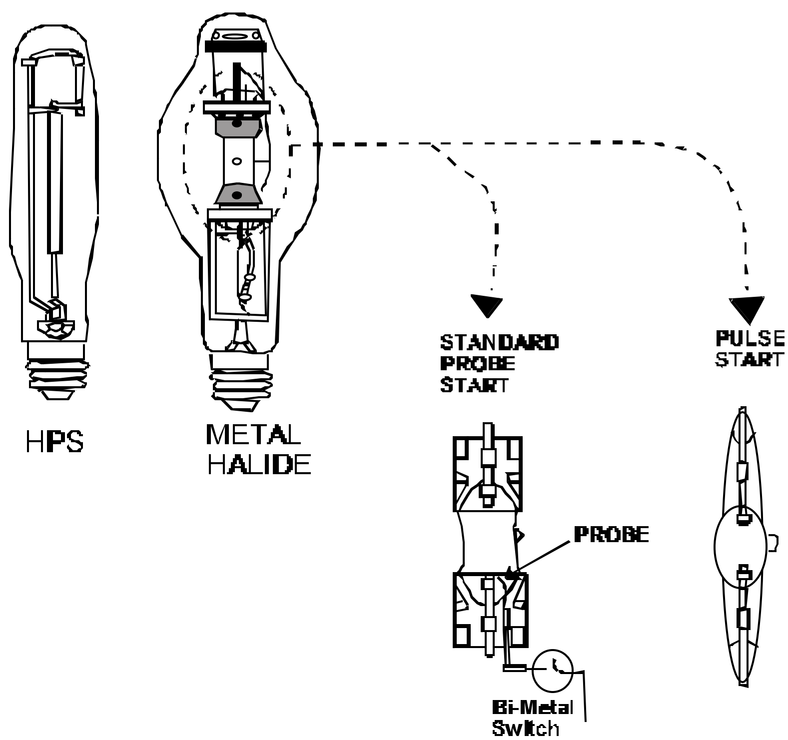


**Figure 2. High Pressure Sodium & Metal Halide Lamps[1]**

## ■ Lighting Design Criteria

Keep in mind that lighting is designed as a system, with a specific lamp and fixture combination. It would be foolish to use an efficient lamp in a poorly performing fixture. In general, the higher the lamp wattage in either fluorescent, metal halide, or high pressure sodium, the more efficient is the lamp. For dairies, ceiling height usually dictates wattage limitation, partly because of glare, but mainly for coverage, or uniformity reasons. Since a design level of 20 FC is relatively low in commercial terms, limitation is usually with the fixture layout, in order to avoid extreme “hot spots”. Fluorescent is very advantageous with 8 - 11 foot ceiling heights because uniformity is much easier to achieve.

Whether loose or tie stall application, fixture placement should not necessarily be very uniform over an area. In tie stalls, it is important that the feed stall portion be brightly lighted toward the normal viewing direction of the cow. It is further recommended that the walls immediately in front of these cows be painted with a highly reflective light finish, as this will greatly impact lighting level and uniformity. Aisle areas can be treated separately, possibly lighted to 15 FC, but it may be necessary to raise this level up to 20 FC in order to achieve the uniformity for udder visibility (See Figure 3). Recommendations are normally based on horizontal FC, but vertical components are also crucial. Visual brightness to the cow’s normal viewing direction is based on vertical FC levels, however, during feeding, the horizontal component is important. Very wide beam fixtures are not recommended because of very possible shadow problems (as well as glare). For loose stall areas, the feeding area, and the resting areas can be accentuated with a fixture layout, which uses “spill” light for the circulation zones. High reflectance ceilings and walls are still recommended because of a slight reduction in fixture quantity and power usage. Minimize spill light through windows (See Figure 4).

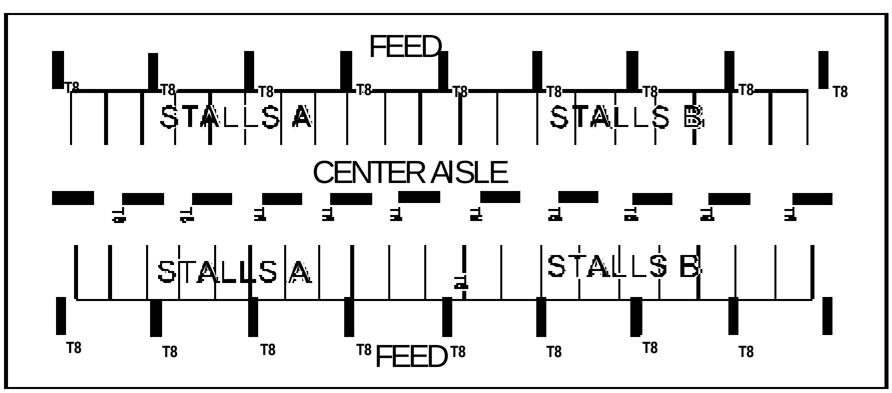


**Figure 3. Typical Fixture Layout**

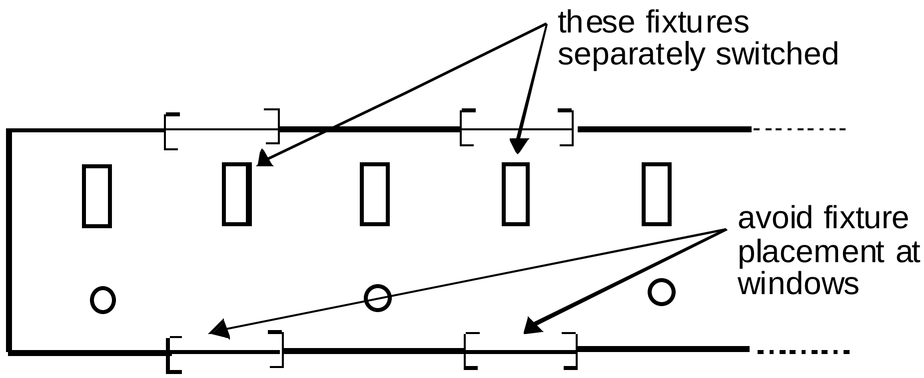


**Figure 4. Fixture Placement**

Good grade, totally enclosed and gasketted fixtures should be used. It is still necessary to "over-design" the lighting by about 30 per cent from initial light levels (based on 100 hour lamp burn-in period). In other words 27 FC initially will be required (See Figure 5).

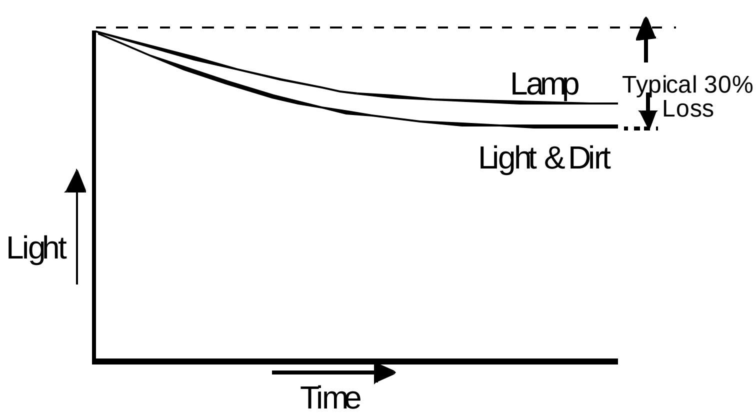


**Figure 5. Light Loss Factor**

Lighting for milking parlours should be 20 FC but can be exceeded slightly. This will then co-ordinate well with the cow's normal environment.

When comparing different design alternatives from manufacturers or contractors, use the below generic guidelines.

- Fixture type/specifications/quantity
- Lamp type/lumen rating/rated life/replacement cost
- Light loss factor (LLF)
- Average maintained lighting level
- Warranty/spare parts and lamps
- Input power/cost of operation and installed cost.
- Recommended fixture layout.

Although metal halide and fluorescent systems are preferred because of the white light, high pressure sodium economics are very attractive. Today, there is no research specifying that the amber light characteristics of high pressure sodium are "bad".

**Table 1 Some typical design guidelines to meet the targeted 20 FC level with a ceiling height of 8 – 15 feet, using good grade (specification quality) fixtures, and reasonable reflectances (approx. 30%) are as outlined:**

| SOURCE | SYSTEM WATTS | WATTS/ SQ. FT. | MOUNTING HEIGHT |
|---|---|---|---|
| **HPS (100, 150 watt)** | 135, 190 | 0.65 – 0.75 | 12' – 15' |
| **HPS (250 watt)** | 300 | 0.62 – 0.70 | 14' – 17' |
| **MH (150, 175, 200 watt) PULSE START** | 190, 210,235 | 0.70 – 0.80 | 12' – 15' |
| **MH (250 watt) PULSE START** | 290 | 0.65 – 0.75 | 14' – 17' |
| **MH (175, 250 watt) STANDARD** | 220, 300 | 0.90 – 1.00 | 12' – 15' |
| **FLUORESCENT –2 Lamp (4 FT, T8, ELECTRONIC)** | 62 | 0.65 – 0.75 | 8' – 11' |
| **STANDARD INCANDESCENT** | N/A | 3.00 – 3.50 | 8' – 12' |

The above guideline was developed for a typical 100 cow herd, ranging from 10,000 – 12,000 sq. ft. of housing area. SYSTEM WATTS, as indicated above includes total input power which includes lamp and ballast losses.
HPS - High Pressure Sodium
MH - Metal Halide

### Example:

1. Using Table 1, consider 175 watt Metal Halide PULSE START.
2. Range recommendation is 0.70 – 0.80 watts/sq. ft., using 0.75 watts/sq. ft.
3. For a 10,000 sq. ft. area, required wattage is 10,000 x 0.75 or 7500 watts.
4. System watts for 175 watt Metal Halide PULSE START is 210.
5. Therefore, number of fixtures is 7500 watts ) 210 watts = 35.71 or 36 fixtures.
6. Area lighted per fixture would then be 10,000 sq. ft. ) 36 fixtures or approximately 280 sq. ft. (17 ft. x 17 ft. grid). This would be valid at 12' - 15' mounting heights.

## ▪ Lighting Economics

Economics of lighting systems based on the expected product life cycle is dependent upon:

### Initial Installed Cost of the System:

This would include fixture and lamp cost, wiring and switching, permit fees, any necessary panel upgrades/modifications, hardware, and all of the affiliated labour costs. Any salvage of existing wiring will reduce cost.

### Cost of Operation:

Annual energy costs will be appreciable. In most cases, this will usually result in increased hydro billing. This should include an allowance for bulb and ballast replacement. Keep in mind that if an incandescent system is being replaced, there will be savings for cost avoidance of replacement light bulbs. For older fluorescent, or mercury vapor systems, there will be similar maintenance cost avoidance savings. Energy should normally be based on 16 hours per day, or approximately 5800 hours per year. Alternative operation at 18 hours per day would represent about 6500 hours per year.

The selected alternative must have the lowest combined cost of initial installed cost and total accrued operational cost. All systems analysed in this paper are expected to last approximately 20 years, with yearly maintenance and cleaning, including some ballast replacement.

### Example:

The foregoing graphs represent the relative economics of various systems. Based on 10,000 sq. ft. area, 4.27 meter (14 foot) ceiling height, 20 FC average intensity, 0.7 light loss factor, 5800 annual operating hours, power cost of 5.164 per kWh.

System data used is as outlined:

**Table 2. Lighting System Economic Summary (Unit Costs)**

| SYSTEM | FIXTURE | | INSTALL. COST | REPL. LAMP | | LAMP LIFE | BALLAST ALLOW. |
|---|---|---|---|---|---|---|---|
| | QTY. | COST | | QTY. | COST | | |
| **175MH** | 40 | $230 | $75 | 23.2/yr | $28 | 10,000 hrs | $1.00/yr |
| **175MH PS** | 31 | $280 | $75 | 11.98/yr | $49 | 15,000 hrs | $2.00/yr |
| **150 HPS** | 32 | $190 | $75 | 7. 73/yr | $23 | 24,000 hrs | $2.00/yr |
| **T8 (2 lamp)** | 107 | $ 77 | $50 | 69.6/yr | $2.60 | 15,000 hrs | $1.00/yr |

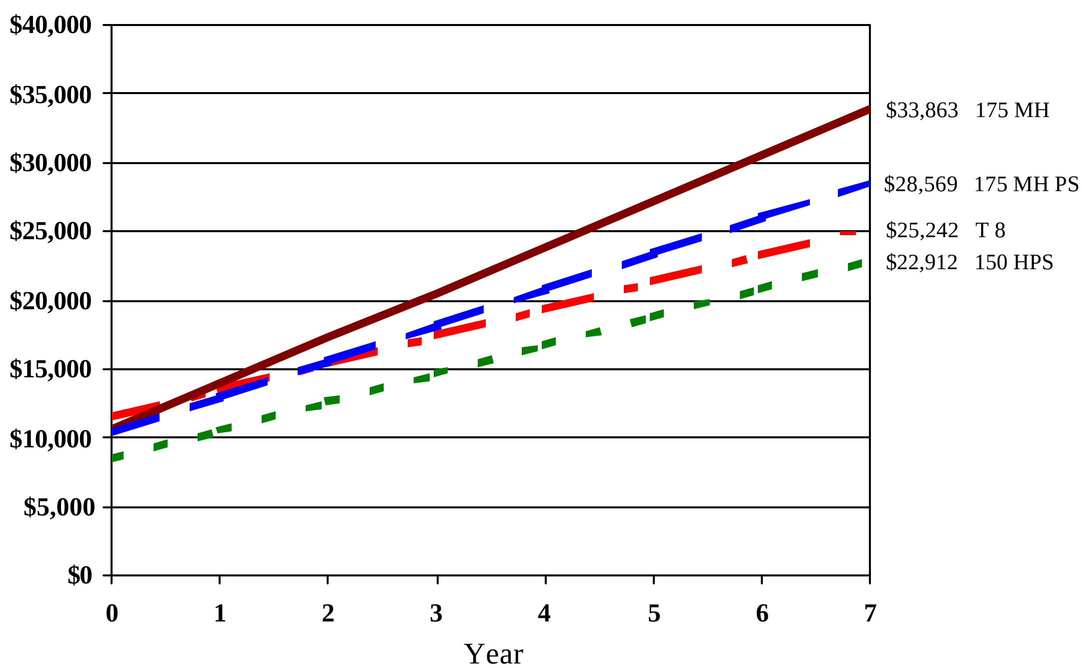


**Figure 6. Total Accrued System Cost - Cost includes initial cost plus accrued operating cost**

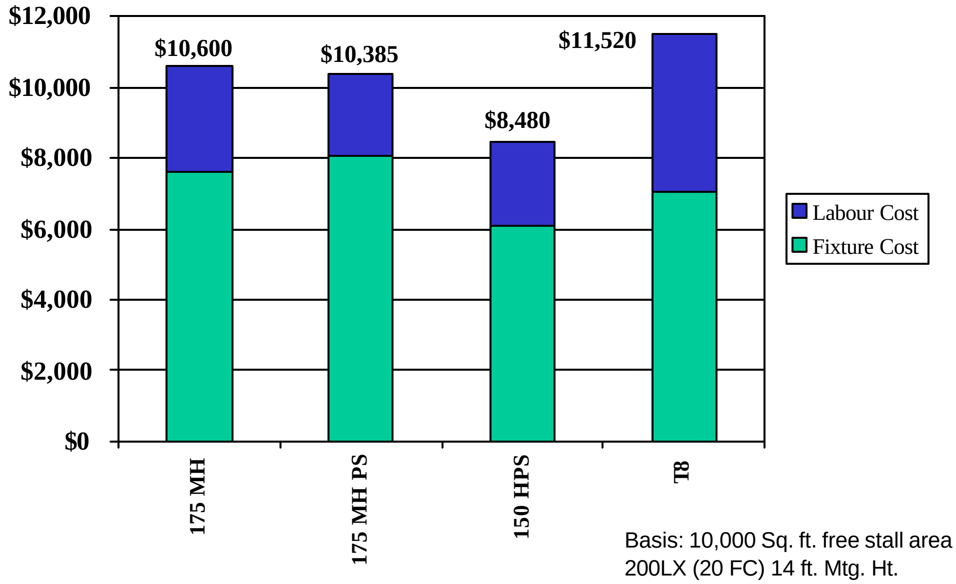


**Figure 7. Lighting System - Total Installed Costs**

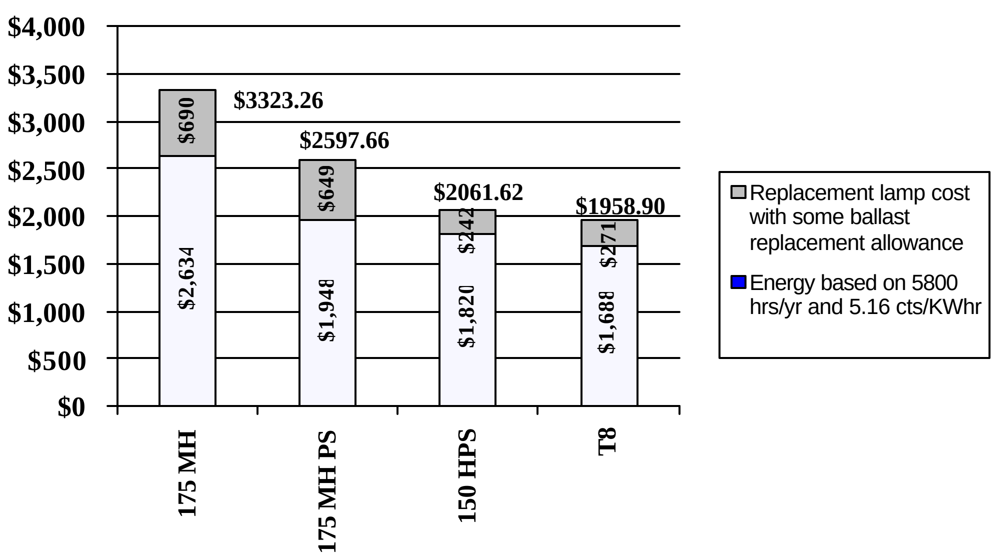


**Figure 8. Annual Operating Costs**

Economics of retrofitting or upgrading of existing barns will vary considerably, primarily if major rewiring is required. Typical studies done to date have indicated that simple paybacks of 3 years and less are very possible, based on a milk yield increase of only 6.25 per cent. This includes:

- Slight increase in feed intake.
- Culling an additional 6% of animals to stay within quota.
- 20 year lighting system life.
- Extra energy to run upgraded system.
- Interest rate of 7% on investment.

## Fixture Selection Considerations

Fixture construction and quality is important for ease of maintenance as well as long life expectancy. Whatever the source, fixtures must be tightly enclosed, with durable housing and good gasketting. Fluorescent should always be used at lower heights because of low glare and good coverage. Low wattage high pressure sodium (70 watt and 100 watt) can also be used at lower heights (approximately 10 ft). For ceiling heights above 12 feet, there is a wide range of MH and HPS wattages which are available.

Outlined below are guidelines for selection purposes:

### a. Light Spread Properties[2]:

Fixtures are given a rating by a spacing-to-mounting height (S/MH) ratio which describes their light spread. For example, if a fluorescent has a spacing-to-mounting height ratio of 1.4 and is mounted 8 feet above grade, then the spacing between fixtures should not exceed (1.4 x 8 ft) 11.2 feet for good uniformity. A ratio of 1.3 to 1.6 is good for fluorescent. For metal halide or high pressure sodium fixtures, a ratio of 1.5 to 1.9 should be used for best performance.

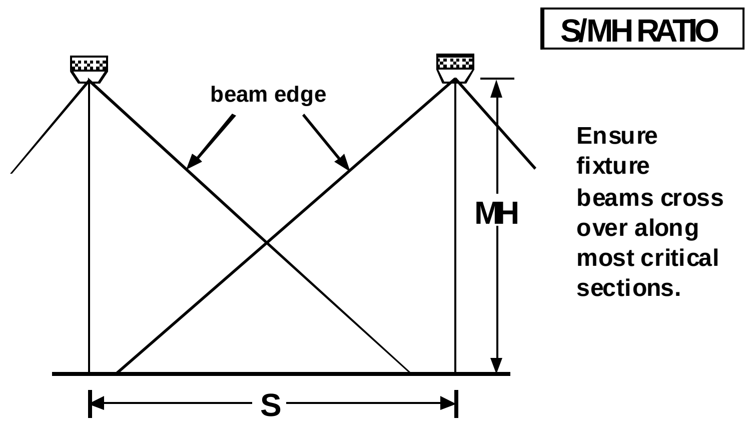


**Figure 9. Spacing-to-Mounting Height Ratio**

## b. Color Output:

If the ability to define all of the colors between the blue and red spectrum is important, then T8 fluorescent (premium 80 CRI - Colour Rendering Index) lamp is the best. However, MH is very close and would also be a very good choice. Metal halide pulse start is slightly better than standard metal halide over the life of the lamp. High pressure sodium output is light amber in color but does not provide accurate rendition in the blue-green region. If in doubt, try a sample fixture.

## c. Cold Temperature Rating:

T8 fluorescent, when equipped with –18°C potted electronic instant start ballasts should not be applied at temperatures colder than –10°C (approximately +15°F) for good reliable starting as well as maintaining reasonable light output. In a tightly gasketted vapor-tight fixture, light output will be reduced down to about 70% of normal at –10°C ambient. Fluorescent requires a good electrical ground. Metal halide and high pressure sodium sources will operate normally with no light losses and no starting problems down to –30°C.

## d. Mounting Details:

For vapor-tight fluorescent fixtures, it is very important that mounting holes not be drilled through the body. Fixtures are available with molded “swing-out” brackets.

For metal halide or high pressure sodium fixtures, the low bay style can be mounted by using a hook and cord option for maintenance convenience. Keeping the top of the housing a minimum of 8cm (3 inches) from the ceiling will result in cooler ballast operation (longer ballast life). Check with local building codes first.

## e. General Fixture Construction:

**Fluorescent[3]:** Vapor tight body, either fibreglass or other corrosion resistant material, with well fitted and held in place gasketting and captive lens catches. Lens should be acrylic, either clear or pebbled. Avoid fully prismatic lenses, which break or crack very easily at the lens basket corners. Ensure a wide body fluorescent channel, minimum 11cm (4.25 inches), is provided or equivalent reflector. Lamp centres minimum 6cm (2.25 inches) for good performance. Ballast to be rated for $-18^{o}$C, with potted electronics.

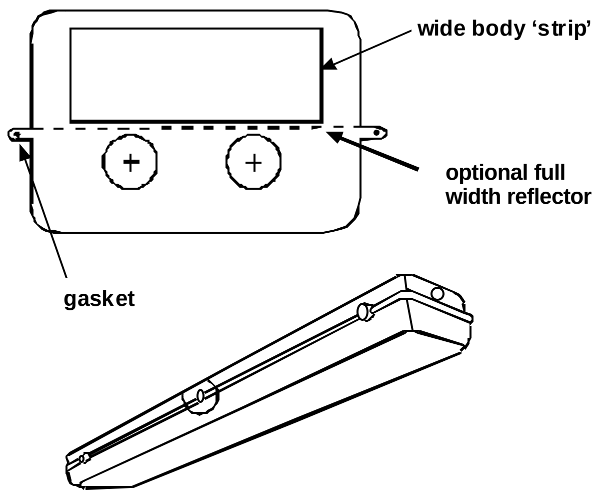


**Figure 10. Fluorescent Fixtures**

**Metal Halide/High Pressure Sodium[4]:** Cast aluminum housing, integral ballast (all components replaceable), totally enclosed and gasketted for wet locations, either glass lens or sturdy acrylic lens, preferably BASE-UP lamp position, and optional hook/cord feature. Avoid polycarbonate lenses due to premature "yellowing". In general, the larger the ballast housing, the cooler is ballast operation, and the larger the reflector and lens, the more efficient is the fixture.

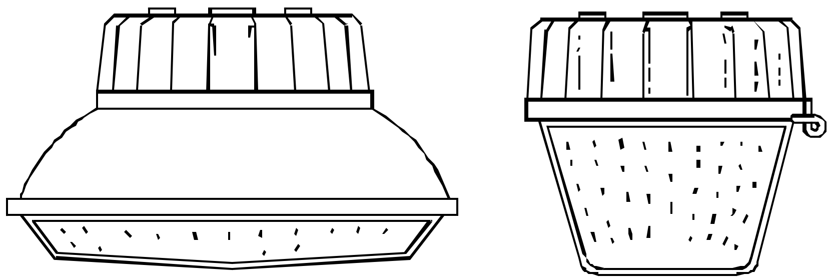

**Figure 11. Metal Halide/High Pressure Sodium Fixtures**

## ■ Some Application and Design Tips

1. Lighting design levels normally at 0.75 – 0.90 meters (2.5 – 3.0 feet) above floor, which is approximately cow eye level.
2. Use of multi-zone or multi-level switching for "sun-rise/sun-set" effect.
3. Use of some night lights (compact fluorescent or incandescent on dimmers).
4. Fluorescent fixtures have a slightly "off-round" or oval light distribution pattern. Locate fixtures to design advantage.
5. Higher surface reflectances are very, very important i.e. walls in tie stall applications.
6. Try to locate fixtures in between windows for best effectiveness.
7. For critical locations, consider the impact of one fixture being OUT.
8. Ensure lighting electrical loads are balanced between phases to minimize voltage drop in the electrical neutral. This will minimize effect of tingle voltage problems.
9. There can be a long term effect of humidity on fluorescent lamps in terms of poor starting. Lamps can simply be wiped clean (also metal reflecting surface) to correct this problem.
10. Preference should be given to pulse start metal halide, over standard metal halide.

11. Fixture reflectors and lenses should be washed and rinsed on an annual basis, and gasketting checked and replaced when necessary.
12. Replace lamps promptly when they fail or flicker.
13. Confirm condition of any existing wiring prior to re-use.
14. Existing T12 fluorescent vapor tight fixture should be checked for direct conversion to T8 fluorescent. Only a ballast and lamps normally required, but the fixture channel can be conveniently replaced. Check on electrical permit.
15. Advantageous to mix some fluorescent with either metal halide or high pressure sodium systems in the event of a power or voltage "dip".
16. Fluorescent (T8) lamps should be operated at least 1 hour per start, but preferably 3 hours or more per start for normal lamp life.
17. Metal halide or high pressure sodium lamps should be operated at least 2 hours per start, but preferably 10 hours or more per start for normal lamp life.
18. Compact fluorescent systems are available but are more costly than T8 fluorescent, both on first-cost basis and as well as normal operating costs.
19. For T8 fluorescent, select the PREMIUM lamps rather than the STANDARD, because of slightly higher light output and better color. Cost premium about 104 extra per lamp. Same rated life.
20. Stay with clear metal halide or high pressure sodium lamps (rather than coated or "frosted") for cost and performance reasons, unless glare is an issue.

## ■ References

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3. "Metalux Fluorescent VT-2 Series Luminaires", Brochure ADF 000079, Cooper Lighting, 400 Busse Rd; Elkgrove IL 60007
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5. Richard Hiatt, President – USA Food & Energy Council. Tom Droppo. ((204) 945-7670) Personal Communication