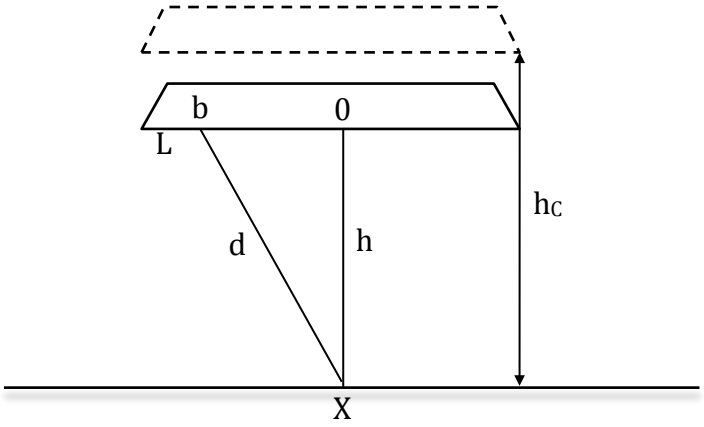
INCORRECTLY-POSITIONED OVERHEAD RADIANT HEATERS

If a radiant heater with manufacturer-specified minimum height h_C above floor level is installed at a lower height h, what will be the degree of overheating on surfaces below?



Overheating will be at its worst case at point X, directly under the heater's centre (point 0). According to the Inverse Square Law, the heat radiation received at point X from point 0 will be too great by a factor of $(h_c / h)^2$. This expression can be used as a first approximation of an overheat factor.

However, point X actually receives heat from every point b along the heated surface (i.e. from point 0 through to point L) proportional to the inverse square of their separation d. From Pythagoras' Theorem:

$$d = \sqrt{h^2 + b^2} \tag{1.0}$$

The heat energy E received at X from any point b is therefore:

$$E \propto \frac{1}{d^2} = \frac{1}{h^2 + b^2} \tag{2.0}$$

The total heat energy E_{total} received at X is:

$$E_{total} \propto \int_0^L \frac{1}{h^2 + b^2}\, db \tag{3.0}$$

$$E_{total} \propto \frac{\tan^{-1}\left(\frac{L}{h}\right)}{h} \tag{3.1}$$

Note: point X obviously receives an equal amount of heat from the right hand side of the heater. This can be ignored because we will be considering the ***ratio*** *of incorrect to correct heat; the doubling of the received heat will cancel when the ratio is taken.*

Using equation (3.1) the **overheat factor F** can be defined as the ratio of the total heat energy received at X from the heater at incorrect height h to the total heat energy received from the heater at correct height h_C:

$$\mathbf{F} = \frac{\mathbf{h_C} \cdot \mathbf{\tan^{-1}}\left(\frac{\mathbf{L}}{\mathbf{h}}\right)}{\mathbf{h} \cdot \mathbf{\tan^{-1}}\left(\frac{\mathbf{L}}{\mathbf{h_C}}\right)} \qquad (4.0)$$

Worked example

A radiant tube of length 1.75 m is installed at a height of 2.1 m. Manufacturer's instructions specify a minimum installation height of 4 m. What will be the degree of overheating?

L will be half the heater length, 1.75 ÷ 2 = 0.875 m.

(4.0)
$$\mathrm{F} = \frac{\mathrm{h_C} \cdot \tan^{-1}\left(\frac{\mathrm{L}}{\mathrm{h}}\right)}{\mathrm{h} \cdot \tan^{-1}\left(\frac{\mathrm{L}}{\mathrm{h_C}}\right)}$$

$$= \frac{4 \times \tan^{-1}\left(\frac{0.875}{2.1}\right)}{2.1 \times \tan^{-1}\left(\frac{0.875}{4}\right)}$$

$$= 3.49$$

Surfaces and persons directly below the heater will be subjected to 3.49 times (349 %) more heat than intended by the manufacturer.

Note: using the first approximation given previously gives a value of (4 / 2.1)^2 = 3.63 (i.e. 363 %) overheating. This simple approximation is accurate for heaters of short length such as radiant plaques but not for longer heaters such as radiant tubes.