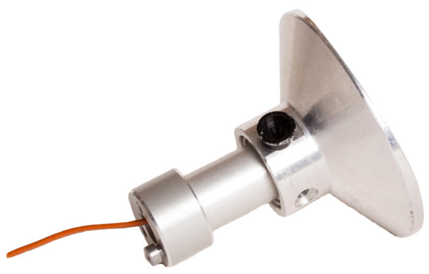
WHITEPAPER ON APPLYING REFLECTIVE CONES TO IR TEMPERATURE SENSORS FOR MOVING TARGETS

1. Reflective cones are a very useful addition to IR sensors when high accuracy and reliability are important for moving process measurements whose a) surface emissivities are likely to vary, and b) ambient temperatures in the measurement areas are somewhat variable.

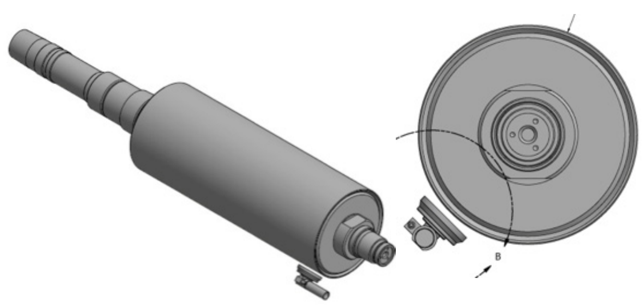


2. For background into the underlying physics of reflective cones providing emissivity corrections, see “THROUGH THE LOOKING GLASS: the Story of Alice’s Quest for Emissivity” attached to this Tutorial, and also available at https://www.exergenglobal.com/white-papers/through-the-looking-glass.

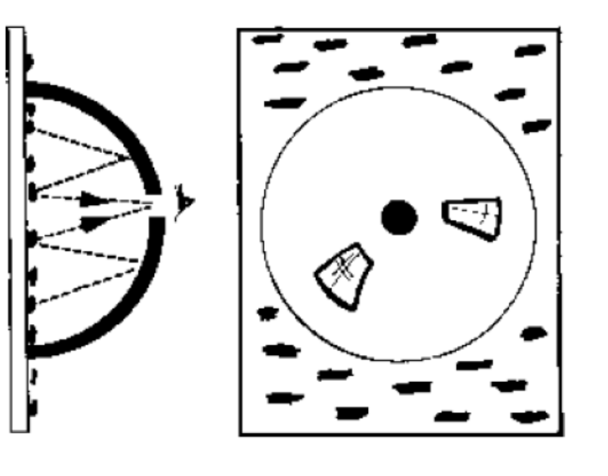
3. Basic analytics for determining the performance of the reflective cone system in a given application is illustrated below. The radiation which reaches the IR sensor is composed of the emitted radiation from the target area at T_T with emissivity e_T plus the ambient radiation at T_A entering the target area and reflecting from the target area, and the radiation reflected from the inside cone reflective surface (which adds no new radiation, but reflects back to the target surface). The radiation entering the sensor has an effective emissivity e_T' which is greater than e_T due to the cone effect.

4. For a drum with emissivity 0.82, average gap between the drum surface and cone of 6 mm, cone radius of 20 mm, the effective emissivity

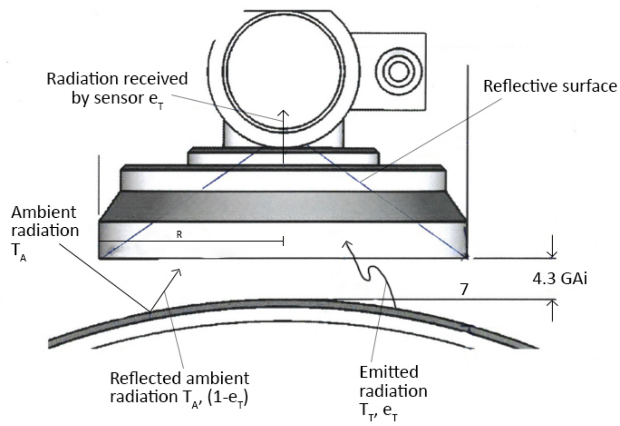
$$e_T' = 0.82 + (1 - 0.82)(1 - 1/1.7) = 0.89$$



The sensitivity of errors caused by emissivity changes is Leak/Signal = 1/1.7 = 0.59. This means that if the emissivity of the target changes by +/-0.05, the temperature measurement



error will be +/- 5% of the difference between target and ambient temperatures, times 0.59. For example, if the target is 100C and ambient is 30C, the shift in emissivity will cause an error of approximately 70*0.05, or +/-3.5°C. The cone will reduce the error to +/-3.5 * 0.59 = 2.1°C. This is a significant improvement, but may not be optimal for a high accuracy system.



Signal area = πR^2 R = 20mm

Leak area = $2\pi RG$ Average G = 6

$$\frac{\text{Signal area}}{\text{Leak area}} = \frac{\pi R^2}{2\pi RG} = \frac{R}{2G} = \frac{20}{12} = 1.7$$

Effective emissivity of radiation received by sensor

$$e_T' = e_T + (1-e_T)\left(1- \frac{\text{Leak}}{\text{Signal}}\right)$$

Sensivity of error caused by emissivity change

$$\frac{de_T'}{de_T} = \frac{\text{Leak}}{\text{Signal}}$$

5. The cone system accuracy can be substantially improved if the gap G is reduced and the cone radius R is increased. For example if G = 2.5 mm (by curving the cone to match the drum radius) and R = 40 mm, then Signal/Leak = R/2G = 40/5 = 8. Then the effective emissivity

$e_T' = 0.82 + (1 - 0.82)(1 - 1/8) = 0.978$

When the effective emissivity approaches 1, that limits the possible error on the high side, so the simple derivative method of assessing the sensitivity to emissivity change may not be accurate. Calculating the values of e_T' directly is the best way to assess the error due to emissivity change of +/- 0.05

High: $e_T' = 0.87 + (1 - 0.87)(1 - 1/8) = 0.984$
Low: $e_T' = 0.77 + (1 - 0.77)(1 - 1/8) = 0.971$

Accordingly, the error due to 0.05 emissivity change for this higher performing cone system is from +0.006 * (100°C – 30C) = +0.42°C, to -0.007 * (100°C – 30°C) = -0.49°C. Accordingly this improved cone system reduces the emissivity error by approximately a factor 7 compared to no cone.

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