

$$C = 2\sqrt{200}(95 - 95) = 0 = 0\% \text{ total heat load}$$

$$M = 800 \text{ B.t.u./hr.}$$

$$E_{\text{req.}} = 1040 \text{ B.t.u./hr.}$$

$$E_{\text{max.}} = 10.3 (200)^{0.4} (42 - 28) = 1100 \text{ B.t.u./hr.}$$

$$\text{Heat stress index} = E_{\text{req.}}/E_{\text{max.}} \times 100 = 95$$

Thermal balance will be maintained in this environment. The exposure is just acceptable for a young acclimatized man. In practical mining operations, however, the stress should be lowered. This is a warm-moist environment in which evaporative cooling capacity is limited. An increase in the wet-bulb temperature to 89° F. would reduce $E_{\text{max.}}$ to 700 B.t.u./hr., thus making the environment wholly unacceptable even to young men in the best physical condition.

Example 3. The following measurements were made on a hot summer day in a glass factory: $t_g = 123^\circ \text{ F.}$; $t_a = 103^\circ \text{ F.}$; $t_{wb} = 80^\circ \text{ F.}$; $V = 300 \text{ f.p.m.}$ outside air temperature = 87° F. ; calculated $t_w = 162^\circ \text{ F.}$; M assumed = 960 B.t.u./hr.

Determine: (a) magnitude of stress and (b) magnitude of change required in each of the environmental factors to establish thermal balance.

Solution:

$$R = 22(162 - 95) = 1480 \text{ B.t.u./hr.} = 54\% \text{ total heat load}$$

$$C = 2\sqrt{300}(103 - 95) = 280 \text{ B.t.u./hr.} = 10\% \text{ total heat load}$$

$$M = 960$$

$$E_{\text{req.}} = 2720 \text{ B.t.u./hr.}$$

$$E_{\text{max.}} = 10.3 (300)^{0.4} (42 - 20) = 1930 \text{ B.t.u./hr.}$$

$$\text{Heat stress index} = 140 \text{ (excessive heat exposure)}$$

$E_{\text{req.}}$ must be reduced by 790 B.t.u./hr. to attain thermal balance.

(1) Radiant heat has to be reduced as follows:

$$(1480 - 790) = 22(t_w - 95); t_w = 127^\circ \text{ F.}$$

The mean radiant temperature, t_w , must be reduced by 35° F.

(2) To obtain some improvement by reducing the air temperature, the convective load must be reduced to: $(280 - 790) = -510 \text{ B.t.u./hr.}$ Entering the value of C in the equation for convection exchange:

$$-510 = 2\sqrt{300}(t_a - 95); t_a = 80^\circ \text{ F.}$$

A reduction of 23° F. is therefore required in air temperature.

(3) Air velocity might be increased to bring about thermal balance, indicated by the following equations:

$$E_{\text{req.}} = 960 + 1480 + 2\sqrt{V}(103 - 95)$$

$$E_{\text{max.}} = 10.3 V^{0.4} (42 - 20)$$

Equating $E_{\text{req.}}$ and $E_{\text{max.}}$ and solving for V , we get $V = 900 \text{ f.p.m.}$ Increasing the velocity to 900 f.p.m. raises C to 480 B.t.u./hr. and $E_{\text{req.}}$ goes up to 2920 B.t.u./hr.

Heat stress index = $2920/2400 \times 100 = 120$, which is excessive, even for a fit young man. This illustrates the fallacy in using "man-cooling" fans to combat extreme heat exposures.

(4) The reduction in humidity necessary to establish balance would be:

$$E_{\text{req.}} = E_{\text{max.}} = 2720 = 10.3 (300)^{0.4} (42 - VP_a); VP_a = 10 \text{ mm.}$$

This corresponds to $t_{wb} = 70^\circ \text{ F.}$ and RH (relative humidity) = 20%, compared with original value of $t_{wb} = 80^\circ \text{ F.}$ and RH = 37%. Since $E_{\text{req.}}$ exceeds 2400 B.t.u./hr., this is not a good solution because of the excessive sweating needed to secure thermal balance.

The calculations in Example 3 are of practical interest because they reveal the nature and magnitude of the corrective problem. The logical first step in control is obviously to reduce the radiant heat by more than 50 per cent, which has been shown to be easily attainable (see Table 3). Cooling the air is not economically feasible. Increasing the air velocity to 900 f.p.m. appears to be an easy solution. It is not an acceptable solution, however, since thermal balance can be attained only with an actual increase in heat load and a demand for excessive sweating. Reducing the humidity would be costly and also improper physiologically since $E_{\text{req.}}$ is excessive.

IV. Heat Control

Heat escaping into the environment from hot processes should be thought of as a contaminant, like dust or vapor, and measures for the control of heat fall into the same classes as do the different procedures for control of other atmospheric contaminants.

A. CONTROL AT SOURCE

In the application of local control measures, distinction must be made between the heat losses from hot bodies by radiation and those by convection. Since radiation varies with the fourth power of absolute temperature, it is clear that the larger share of heat loss from furnaces with high surface temperatures will be in the form of radiant heat. With a surface temperature of, say, 500° F. , the radiation coefficient has a value of $K_r = 3.2 \text{ B.t.u./ft.}^2\text{/hr./}^\circ \text{ F.}$ compared with $K_c = 1.6$. Hence, 67 per cent of the heat loss will be by radiation. Only when the hot body is located in a strong forced air stream will the convection exchange equal or exceed the radiation output.

1. Insulation

Insulation of hot surfaces prevents the escape of sensible and radiant heat to the environment. Similarly, enclosing hot water tanks, covering drains carrying hot water, and continuous maintenance of joints and valves in piping to prevent loss of steam constitute direct measures for the control of latent heat in warm-