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Heat load caused by Centurion

The heat load caused by a Centurion is the total of the Radiation Heat Transfer and the Convective Heat Transfer.

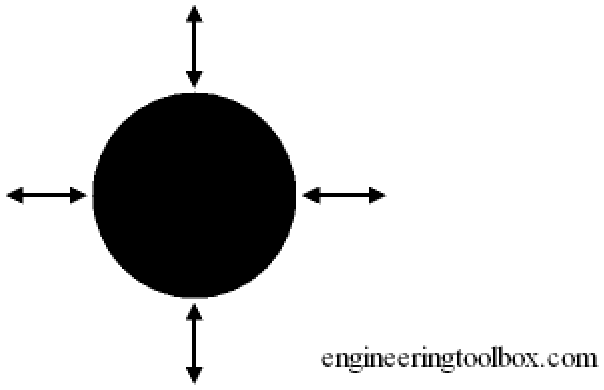
The theory written below is a section of the website:
http://www.engineeringtoolbox.com/radiation-heat-transfer-d_431.html

Radiation Heat Transfer:

Heat transfer due to emission of electromagnetic waves is known as thermal radiation

Heat transfer through radiation takes place in form of electromagnetic waves mainly in the infrared region. Radiation emitted by a body is a consequence of thermal agitation of its composing molecules. Radiation heat transfer can be described by reference to the **'black body'**.

The Black Body



The black body is defined as a body that absorbs all radiation that falls on its surface. Actual black bodies don't exist in nature - though its characteristics are approximated by a hole in a box filled with highly absorptive material. The emission spectrum of such a black body was first fully described by Max Planck.

A black body is a hypothetical body that completely absorbs all wavelengths of thermal radiation incident on it. Such bodies do not reflect light, and therefore appear black if their temperatures are low enough so as not to be self-luminous. All blackbodies heated to a given temperature emit thermal radiation.

The radiation energy per unit time from a **blackbody** is proportional to the fourth power of the absolute temperature and can be expressed with **Stefan-Boltzmann Law** as

$q = \sigma T^4 A$ (1)

where

q = heat transfer per unit time (W)

*$\sigma = 5.6703\ 10^{-8}\ (W/m^2K^4)$ - **The Stefan-Boltzmann Constant***

T = absolute temperature in Kelvin (K)

A = area of the emitting body (m^2)

For objects other than ideal blackbodies ('gray bodies') the **Stefan-Boltzmann Law** can be expressed as

$q = \varepsilon \sigma T^4 A$ (2)

where

ε = emissivity coefficient of the object (one - 1 - for a black body)

Emissivity Coefficients of some common Materials are mentioned on website:
http://www.engineeringtoolbox.com/emissivity-coefficients-d_447.html

From this list is chosen for paint as the Surface Material with the coefficient:
ε = 0.96

Net Radiation Loss Rate

If a hot object is radiating energy to its cooler surroundings the net radiation heat loss rate can be expressed as

$q = \varepsilon \sigma (T_h^4 - T_c^4) A_c$ (3)

where

T_h = hot body absolute temperature (K)

T_c = cold surroundings absolute temperature (K)

A_c = area of the object (m^2)

The next theory is a section of the website:
http://www.engineeringtoolbox.com/convective-heat-transfer-d_430.html

Convective Heat Transfer:

Heat transfer between a solid and a moving fluid is called convection. This is a short tutorial about convective heat transfer

Heat energy transferred between a surface and a moving fluid at different temperatures is known as convection.

In reality this is a combination of diffusion and bulk motion of molecules. Near the surface the fluid velocity is low, and diffusion dominates. Away from the surface, bulk motion increase the influence and dominates.

Convective heat transfer may take the form of either

- **forced** or **assisted** convection
- **natural** or **free** convection

Forced or Assisted Convection

Forced convection occurs when a fluid flow is induced by an external force, such as a pump, fan or a mixer.

Natural or Free Convection

Natural convection is caused by buoyancy forces due to density differences caused by temperature variations in the fluid. At heating the density change in the boundary layer will cause the fluid to rise and be replaced by cooler fluid that also will heat and rise. This continues phenomena is called free or natural convection.

The equation for convection can be expressed as:

$$q = h_c A \, dT \qquad (4)$$

where

q = heat transferred per unit time (W)

A = heat transfer area of the surface (m^2)

h_c= convective heat transfer coefficient of the process ($W/(m^2K)$)

dT = temperature difference between the surface and the bulk fluid (K or ^oC)

The value of heat transfer coefficient was found on the website:
http://www.engineersedge.com/heat_transfer/convective_heat_transfer_coefficients__13378.htm

From this list of flow types is chosen for free convection vertical plate in air with 30 degrees Celsius temperature difference:
h_c= 5 W/(m^2 K)

For 2 machines the cover temperatures have been measured:

Centurion 820N
The surface temperature of the covers has been measured and gave an average temperature of 33 degrees Celsius, is 306 K.
The surroundings temperature is 23 degrees Celsius, is 296 K.

The outside dimensions of the machine are:
Length = 4.85 m. Width = 1.60 m. Height = 1.32 m.
So total surface area is:
(4.85*1.32 + 4.85*1.60 + 1.32*1.60) * 2 = 32.55 m^2
And the vertical surface area is:
(4.85*1.32 + 1.32*1.60) * 2 = 17.02 m^2

Netto Radiation loss: $q = \varepsilon \sigma (T_h^4 - T_c^4) A_c$ (formula 3)

$q = 0.96 * 5.6703*10^{-8} (306^4 - 296^4) * 32.55 = 1933$ W = 1.93 kW

Convection loss: $q = h_c A dT$ (formula 4)

q = 5 * 17.02 * 10 = 851 W = 0.85 kW

Total heat load is 1.93 + 0.85 = 2.78 kW

If average cover temperature is 35 degrees Celsius the total heat load will be 2.34 + 1.02 = 3.36 kW.

Centurion 1240A
The surface temperature of the covers has been measured and gave an average temperature of 35 degrees Celsius, is 308 K.
The surroundings temperature is 23 degrees Celsius, is 296 K.

The outside dimensions of the machine are:
Length = 6.27 m. Width = 1.60 m. Height = 1.32 m.
So total surface area is:
(6.27*1.32 + 6.27*1.60 + 1.32*1.60) * 2 = 40.84 m^2
And the vertical surface area is:
(6.27*1.32 + 1.32*1.60) * 2 = 20.78 m^2

Netto Radiation loss: $q = \varepsilon\ \sigma\ (T_h^4 - T_c^4)\ A_c$ (formula 3)

$q = 0.96 * 5.6703*10^{-8} (308^4 - 296^4) * 40.84 = 2940$ W = 2.94 kW

Convection loss: $q = h_c\ A\ dT$ (formula 4)

q = 5 * 20.78 * 12 = 1247 W = 1.25 kW

Total heat load is 2.94 + 1.25 = 4.19 kW