DELTA T HEAT EXCHANGERS
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Elementary Heat Transfer

Heat and Temperature

People often make the mistake of substituting the terms heat and temperature for each other. Actually, there is a distinct difference between the two. ***Temperature*** is a measure of the amount of energy possessed by the molecules of a substance, a relative measurement of how hot or cold a substance is. The difference between two temperatures and can be used to predict the direction of heat transfer.

Heat is energy in transit. The transfer of energy as heat occurs at the molecular level as a result of a temperature difference. Heat is capable of being transmitted through solids and fluids by conduction, through fluids by convection, and through empty space by radiation.

Heat and Work

Distinction should also be made between the energy terms ***heat*** and ***work***. Both represent energy in transition. Work is the transfer of energy resulting from a force acting through a distance. Heat is energy transferred as the result of a temperature difference.

When a temperature difference exists across a boundary, the Second Law of Thermodynamics indicates the natural flow of energy is from the hotter body to the colder body.

If two blocks of metal at different temperatures are thermally insulated from their surroundings and are brought into contact with each other the heat will flow from the hotter to the colder. Eventually the two blocks will reach the same temperature, and heat transfer will cease. Energy has not been lost, but instead some energy has been transferred from one block to another.

Modes of Transferring Heat

Heat is always transferred when a temperature difference exists between two bodies. There are three basic modes of heat transfer:

> ***Conduction*** involves the transfer of heat by the interactions of atoms or molecules of a material through which the heat is being transferred.
>
> ***Convection*** involves the transfer of heat by the mixing and motion of macroscopic portions of a fluid.
>
> ***Radiation*** or radiant heat transfer, involves the transfer of heat by electromagnetic radiation that arises due to the temperature of a body.

Thermal Conductivity

The heat transfer characteristics of a solid material are measured by a property called the ***thermal conductivity*** (k) measured in Btu/hr-ft-°F. It is a measure of a substance's ability to transfer heat through a solid by conduction. The thermal conductivity of most liquids and solids varies with temperature. For vapours, it depends on pressure.

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Log Mean Temperature Difference

In heat exchanger applications, the inlet and outlet temperatures are commonly specified based on the fluid in the tubes. The temperature change that takes place across the heat exchanger from the entrance to the exit is not linear. A precise temperature change between two fluids across the heat exchanger is best represented by the ***log mean temperature difference*** (LMTD or ΔT_{lm}), defined in Equation 1.1.

$$\Delta T_{lm} = \frac{\Delta T_2 - \Delta T_1}{\ln(\Delta T_2 / \Delta T_1)} \qquad (1.1)$$

Where:

ΔT_2 = the larger temperature difference between the two fluid streams at either the entrance or the exit to the heat exchanger

ΔT_1 = the smaller temperature difference between the two fluid streams at either the entrance or the exit to the heat exchanger.

Convective Heat Transfer Coefficient

The convective heat transfer coefficient (h), defines, in part, the heat transfer due to convection. The ***convective heat transfer coefficient*** is sometimes referred to as a film coefficient and represents the thermal resistance of a relatively stagnant layer of fluid between a heat transfer surface and the fluid medium. Common units used to measure the convective heat transfer coefficient are Btu/hr – ft^2 - °F.

Overall Heat Transfer Coefficient

In the case of combined heat transfer, it is common practice to relate the total rate of heat transfer ($\dot{Q}$), the overall cross sectional area of heat transfer (A_0), and the overall temperature difference (ΔT_0) using the overall heat transfer coefficient (U_0). The ***overall heat transfer coefficient*** combines the heat transfer coefficient of the two heat exchanger fluids and the thermal conductivity of the heat exchangers tubes. U_0 is specific to the heat exchanger and the fluids that are used in the heat exchanger.

$$\dot{Q} = U A (LMTD)$$

Where;

$\dot{Q}$ = the rate heat of transfer (Btu/hr)

U = the overall heat transfer coefficient (Btu/hr – ft^2 - °F)

A = the overall cross-sectional area for heat transfer (ft^2)

LMTD = Log Mean Temperature Difference.

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Bulk Temperature

The fluid temperature (T_b), referred to as the ***bulk temperature****,* varies according to the details of the situation. For flow adjacent to a hot or cold surface, T_b is the temperature of the fluid that is "far" from the surface, for instance, the centre of the flow channel. For boiling or condensation, T_b is equal to the saturation temperature.

Practical Heat Transfer Information

From a physics approach, in a system where steady state heat transfer occurs (such as a heat exchanger) a heat balance will take place. That is in a case such as a heat exchanger, the heat given up by one fluid must equal the heat received by the other fluid. The equation that represents the heat given off or received by a fluid in a steady state flow system is;

$$\dot{Q} = \dot{m} C_p \Delta T$$

Where;

$\dot{Q}$ = the rate heat of transfer (Btu/hr)

$\dot{m}$ = mass flow rate of the fluid (lbs_m/hr)

C_p = Specific Heat of the fluid (BTU/ lb_m - ºF)

ΔT = Actual Temperature Difference of the fluid (i.e. $T_{out} - T_{in}$)

"Quick" Heat Transfer Calculation Formulae for Estimates

For Liquids; Btu/hr = GPM x Temp Rise x K

K water = 500
K 30% glycol = 470
K 40% glycol = 450
K 50% glycol = 433
K hydraulic oil = 243

For Air; Btu/hr = SCFM x Temp Rise x 1.085

Btu/hr = Tons of Refrigeration x 12000

Btu/hr = Evaporative Cooling Tower Tons x 15000