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Heat Transfer: Definitions, Formulas, Sizing, Products and the Future

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Overview

- What is heat transfer and how does it apply to the plastics industry
- Heat transfer terms
- Heat transfer formulas commonly used
- Heat transfer products
- Future of heat transfer products

What is heat transfer?

- A method where different “bodies” seek a temperature equilibrium
- **Heat (Energy) is not created or destroyed only transferred**
- Final destination of a heat transfer cycle is the ambient air

Heat transfer and the Plastics Industry

- Heat needs to be added or removed from material being processed
- Heat needs to be removed from hydraulics pumps, recirculating pumps
- Heat needs to be added or removed from barrels
- Heat or cool other applications such as air compressors
- Heat needs to be removed as quickly as possible

Heat transfer terms

- It is important to get a handle on the terms used for describing heat transfer
- **Heat transfer is a balancing act between your process and mother nature**

BTU – British Thermal Unit

- Energy required to “raise one pound of water one degree Fahrenheit”
- BTU benchmark for heat transfer formulas
- Ton
  - Refrigeration > 12,000 BTU = 1 ton
  - Tower > 15,000 BTU = 1 ton

Heat transfer terms

- Turbulent flow
  - A flow of fluid in which the velocity at a given point varies erratically in magnitude and direction
  - Reynolds number: a resulting value from a formula to assure turbulent flow
  - $R = \frac{3160 * GPM}{V * D} \Rightarrow 5,000$
    - V = Kinematic viscosity (Centistokes)
    - D = diameter of channel in inches

Heat transfer terms

- Laminar flow
  - Streamline flow of a fluid near a solid boundary
  - Reynolds number < 2000

Heat transfer terms

- Specific heat
  - The ratio of the quantity of heat required to raise the temperature of a body one degree compared to raising the temperature of an equal mass of water one degree
  - Specific heat of water is 1 BTU/lb degree F

Heat transfer terms

- Latent heat
  - Heat given off or absorbed in a process (as fusion or vaporization) other than a change in temperature
  - Latent heat of water is 72 BTU/#

Heat transfer formulas

- Material BTUs

BTU/hr = lbs of material per hour X specific heat of the material X Δ T of material

- Since one ton equals 12,000 BTUs then,
  - Tons = $\frac{\text{\#/hour X sp heat X } \Delta \text{ T}}{12{,}000}$

- Fluid BTUs

BTU/hr = GPM X 60 min/hr X # per gallon X specific heat X Δ T

- Since one ton equals 12,000 BTUs then,
- Tons = $\frac{\text{GPM X 60 X \# X } \Delta \text{ T}}{12{,}000}$

Heat transfer formulas

- Weighted water
  - This formula is a derivative from the Fluid BTUs formula and is solely used if water is the fluid for heat transfer.

$$\text{Tons} = \frac{\text{GPM X 60 min/hr X 8.34\#/g X specific heat X } \Delta \text{ T}}{12{,}000}$$

Since water weighs 8.34#/gallon and there are 60 minutes in an hour the formula can be condensed to

$$\text{Tons} = \frac{\text{GPM X 500 X } \Delta \text{ T}}{12{,}000}$$

Thus,

$$\text{Tons} = \frac{\text{GPM X } \Delta \text{ T}}{24}$$

How important is FLOW?

There is an old saying……

”No flow = No Load” and “Know Flow = Know load”

Without flow there is no way heat transfer can function efficiently

Reynolds says achieve 5000 or greater and you have turbulent flow

Turbulent flow is only one aspect of the equation

In fact, the Reynolds confirms turbulent flow but not heat transfer

How important is FLOW?

Flow through the process is the basis for efficient heat transfer

Know flow = Know Load

No flow = No Load

Heat transfer Products

Temperature controllers

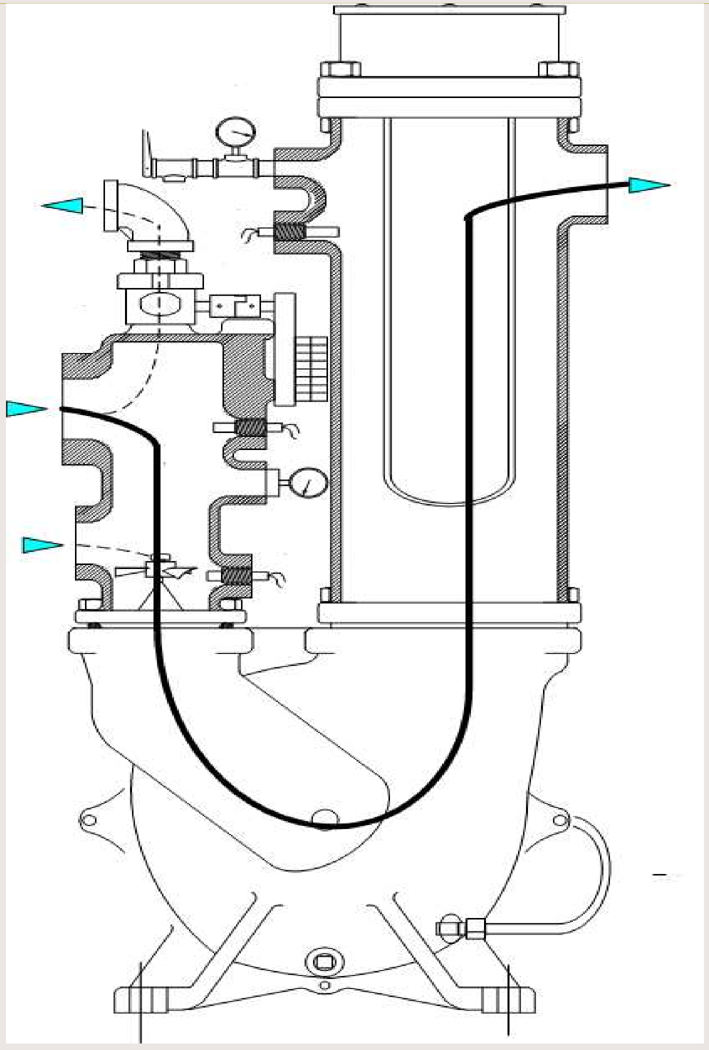
- A device that incorporates:
  - a recirculating pump,
  - a heater,
  - cooling valve,
  - a control device
- Designed to recirculate tempered fluid through a process by allowing a portion of heated fluid to be discharged while the same amount of cold fluid is inserted

Temperature controllers

- Water temperature controllers
- For temperatures up to 250ºF
- Open loop or direct injection
- Closed loop or indirect injection

- Oil temperature controllers
- For temperatures from 200ºF to 500ºF (550ºF for some brands)
- Heating only
- Heating and cooling (via heat exchanger)

Typical schematic



Heat transfer Products

Chillers

- A refrigeration device that incorporates a refrigerant system and a fluid recirculation system that recirculates tempered fluid through a process or to other heat transfer devices.
- For delivery temperatures typically between 20ºF & 70ºF
- Air condensed: refrigerant is condensed via ambient air (plant air or outdoor air)
- Fan driven i.e. propeller fan, not ductable
- Blower driven
  - Ductable air discharge for winter plant heating and discharged outdoor
  - Modulate air flow for low ambient conditions

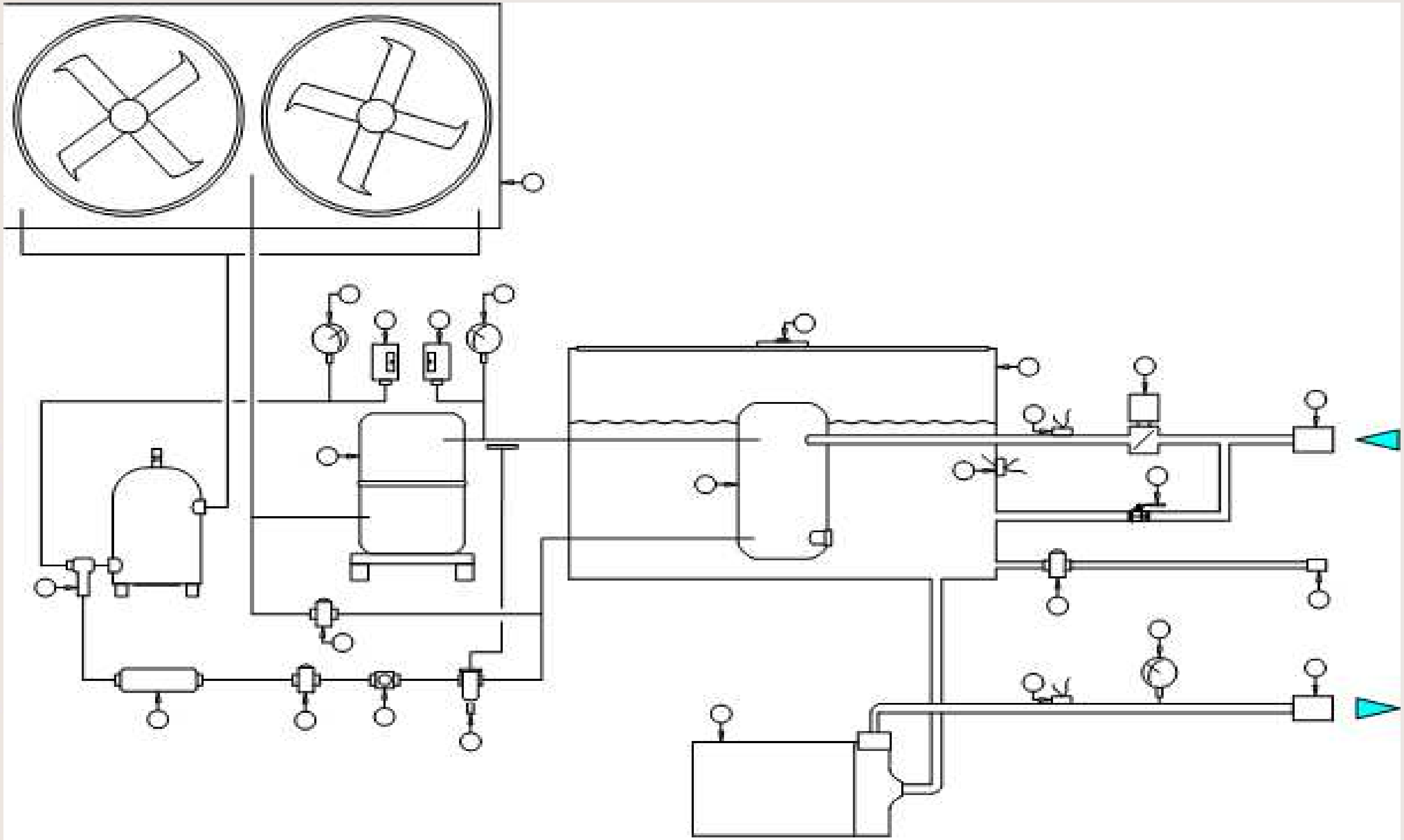
Chillers

- Water condensed
  - Uses a separate source of water (i.e. tower water)
  - Typically less expensive than air condensed, less energy consumption, less maintenance

Chillers

- Portable
  - Typically up to:
  - 30 tons air condensed
  - 40 tons water condensed
  - Designed for “spot” cooling
  - “small” recirculation pump and reservoir

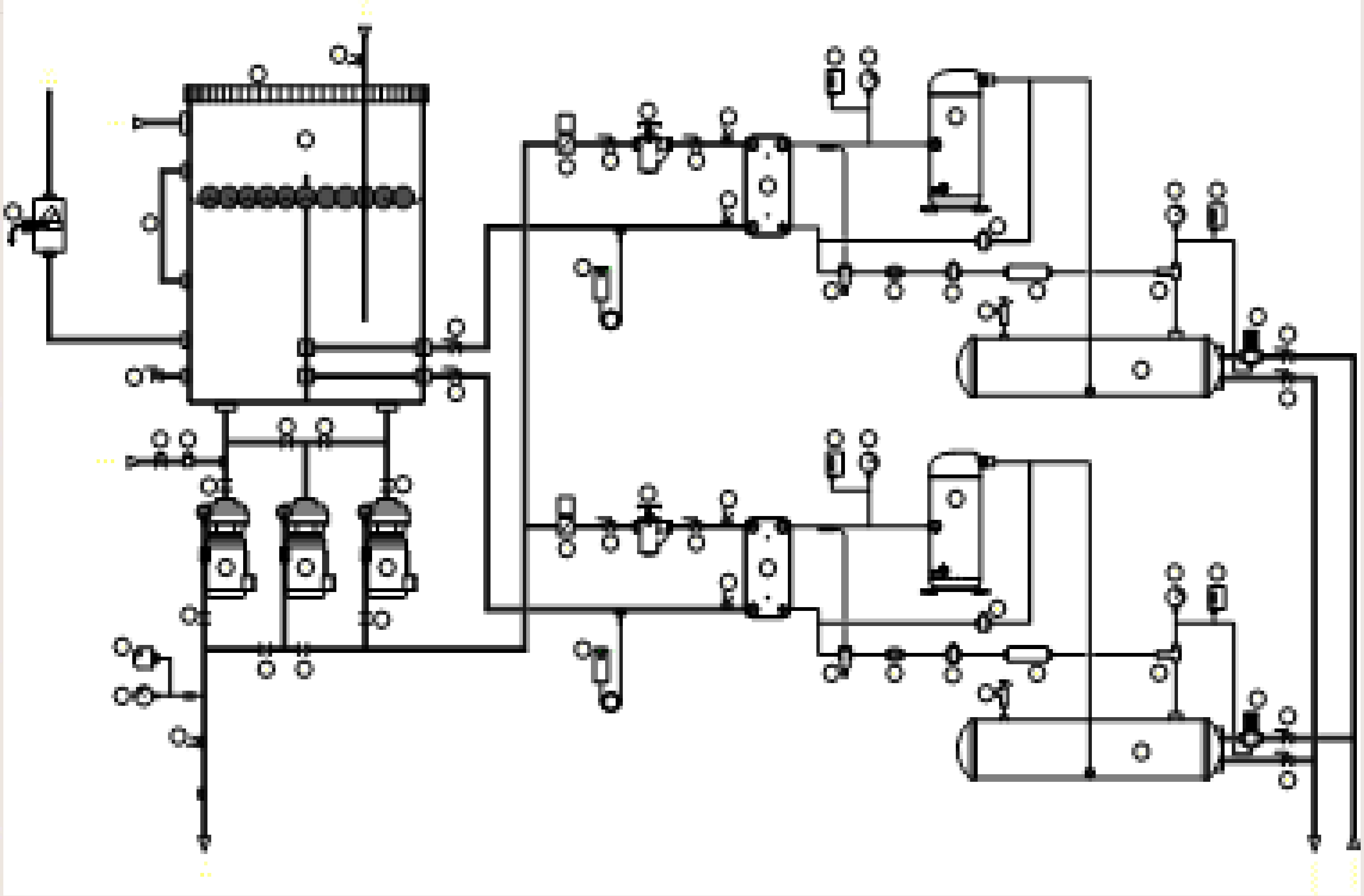
Typical schematic



Chillers

- Central
  - Typically starting at 20 tons regardless of condensing style
  - Designed to deliver same temperature to entire facility use points
  - Typically redundant refrigeration circuits built in
  - “large” reservoir with hot and cold compartments
  - Process pump and evaporator pump
  - Designed to provide adequate flow and pressure to both loops at all times

Typical schematic



Heat transfer Products

- Evaporative cooling tower systems
  - Takes advantage of mother nature and the ambient air's ability to absorb (transfer) heat
  - Based on the wet bulb temperature
  - Combination of ambient temperature and humidity % in the air at any given time
  - Nominal capacity is rated at 78^{o}F WBT (wet bulb temperature)
  - Lower wet bulb temp can mean increased capacity from tower
  - Higher wet bulb temp definitely means lower capacity

Tower systems

- **Equipment**
  - Tower cell
  - Pumping Station
    - Sized typically for 6 gallons/ton
      - 3 GPM to the process
      - 3 GPM to the tower
      - Total 6 gallons/ton

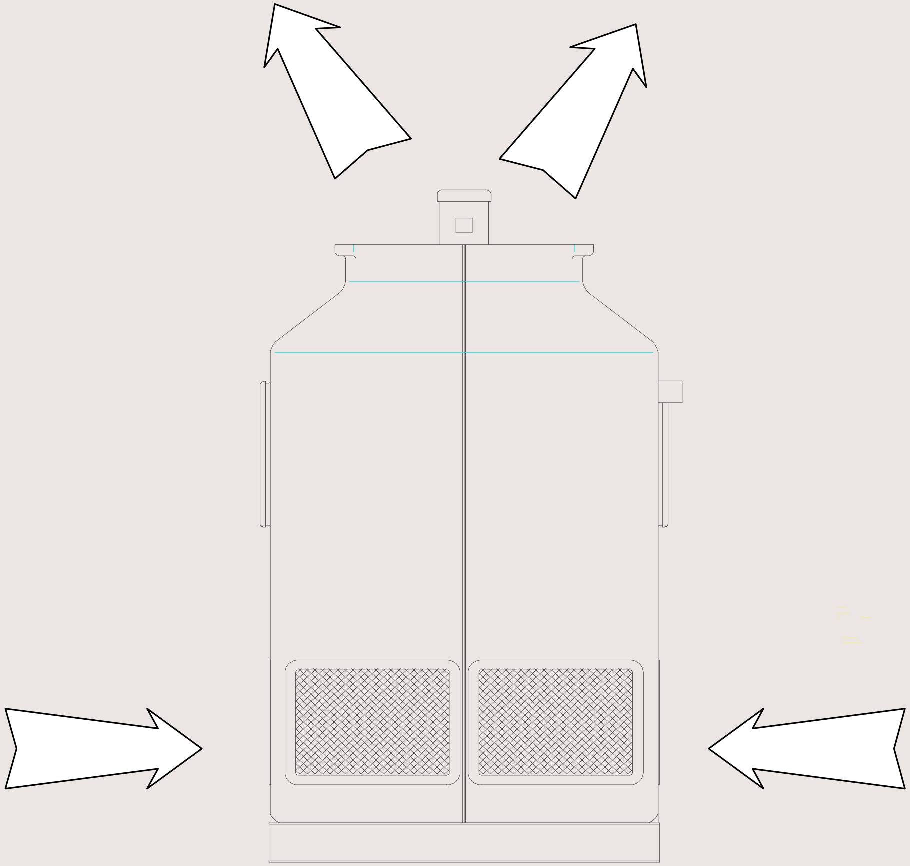
Tower systems

- Pumps
  - Process
    - Typically rated for 60 PSI or more
  - Tower
    - Typically rated for 30 PSI or less
    - Basically need enough feet of head to get water to the top of the tower cell
  - Stand by
    - Typically the same HP as the process pump
    - Manifolded and valved to work as either pump in emergency situations

Tower systems

- Controller
  - Thermostatic to microprocessor
- Water treatment
  - Solids filtration
  - Control of algae, fungus
- Heat exchanger
  - Separates process loop from the tower loop

Typical tower cell



Typical pumping station

Closed loop

- Heat exchanger isolates tower water from the process water
  - Isolates the “dirty” water from the “clean” water
  - Has to have a temperature difference across the heat exchanger in order to transfer the heat
    - If tower water is entering the heat exchanger at 85°F then the best temperature the process water will be is 88°F
    - The tighter the temperature difference the larger the surface area required in the heat exchanger

Plate & frame heat exchanger is the typical heat exchanger of choice

-Made of stainless steel plate

Typical Plate & frame heat exchanger

Water Quality

- Water Quality consists of controlling:
  - Scale build up: minerals (solids) plating heat transfer surfaces
    - 1/64” of scale can reduce heat transfer capabilities by up 25%
    - Filtration: filtering the solids from the water to prevent plating of wetted surfaces
  - Corrosion: typically the result of acidic water (improper PH control)
    - PH level between 7 to 10 is a good target
  - Algae (organism growth)
    - Controlled by proper chemical or non chemical treatment

Water Quality

- Glycol:
  - *Industrial grade* inhibited propylene glycol
    - Not automotive antifreeze
  - Designed to:
    - Lower the freeze point of the fluid
    - Help in controlling corrosion
  - Glycol is a heat transfer deterrent
    - At 30% mix specific heat value is .913
    - At 50% mix specific heat value is .835
  - Typically 30% glycol mix is sufficient. Freeze point is 10°F

The Future

- More efficient components
- Higher efficient motors
- Higher efficient compressors
- Scrolls, screws
- Some electrical companies offer rebates on the purchase of premium motors
- Higher efficient heat exchangers

The Future

- Environmental concerns
- Environmentally friendly refrigerants
  - *Not necessarily more efficient*
- R410A, R134A, R407C

The Future

- Free cooling (not free, but can be a quick payback if parameters are good)
- Tower systems can be designed to operate on lower wet bulb temperatures to produce lower LWT
- Reduce or eliminate the need for operating chillers in the winter
- Reduces operating costs

Conclusions

- Energy is not created or destroyed
  - Only transferred
- Fluid Flow is key to efficient heat transfer
- Formulas for flow and load help us determine the necessary device for transfer heat

Conclusions

- Environmental concerns steering market to new:
  - New Refrigerants
  - Compressors
  - Heat exchangers
- Higher energy costs are steering market to:
  - Higher efficient components
  - Free cooling

- Thank you