# ELECTRIC TANK HEATING

A GENERAL DISCUSSION
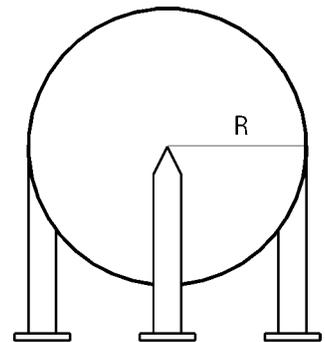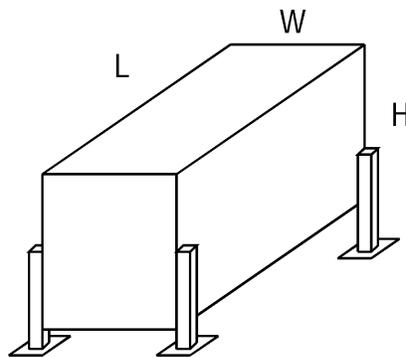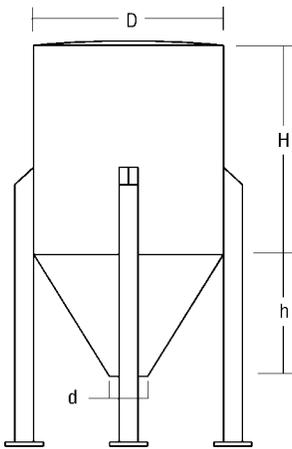
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INTRODUCTION

The heating of tanks is a common industrial practice in many applications. Heating may be required to maintain pumping viscosity of heavy oil or resins, to prevent crystalline precipitation (sodium hydroxide), to facilitate production processes, for freeze protection, and hundreds of other applications. Chromalox offers literally hundreds of ways of heating tanks of all sizes. Included in this guide is an overview of the types of tank heating approaches. The manual is not meant to be a complete guide to each of these heating methods, rather an overview of what is available. Once a specific method is selected, further investigation should be made into the suitability of the heater for the application. Finally, the manual is a detailed guide on sizing heaters for large tanks. This guide includes sizing details that are beyond the scope of the sizing guide presented in the general catalog.

REQUIRED SIZING INFORMATION

For any application it is essential that complete data be obtained and understood before an evaluation and selection of a suitable heating system can be made. Specifically you will need:

- Specific heat
- Heated material specific gravity and/or density
- Temperature rise or temperature to be maintained
- Heat up or temperature recovery times
- Process additions to tank
    - Volume
    - Incoming temperature
- Minimum low ambient temperature exposure
- Tank size, configuration, material of construction, and detail of nozzles and legs
- Insulation
    - Thickness
    - k-factor
- Hazardous/non-hazardous service area
- Location - indoor/outdoor
- Wind conditions - velocity
- Environmental considerations
- Code requirements.

TANK MARKETS AND APPLICATIONS

Nearly every major industrial process requires tank heating in some form or another. The major industries employing extensive tank facilities are:

- Refining and petrochemical operations
- Waste and environmental operations
- Terminal installations loading/unloading
- Pulp and paper operations
- Water storage and fire towers
- Utilities
- Mining operations
- Bulk storage, bins and silos
- Agriculture plants
- Food production plants
- Airports.

COMMON HEATED MATERIALS

A list of some materials commonly stored and heated in tanks is listed as follows:

A. Liquids and aqueous based solutions:
- Liquid carbon dioxide
- Liquid chlorine
- Aqueous ammonia
- Water
  - Process
  - De-ionized
  - De-mineralized
  - Potable
  - Waste
  - Fire towers
- Acids
- Solvents
- Resin and resin coatings.

B. Food items:
- Vegetable cooking oils
- Molasses
- Syrups
- Sucrose (liquid sugar)
- Starch.

C. Petroleum products:
- Benzene
- Naptha
- Paraffin
- Lubricating oils
    Crank case (SAE 5 to SAE 50)
- Gear oils
- ASTM
- Asphalt compound
    Emulsions
    Cut backs
    Penetration
- Fuel oils
    No 1 kerosene
    No 2 (PS-100) Air craft fuels and domestic oil heating
    No 3 (PS-200) Air craft fuels and domestic oil heating
    No 4
    No 5 Heating oils for factory, commercial & mfg. process heating
    No 6
- Bunker C
- Waste oils
- Synthetic and heat transfer oils.

TYPES OF STORAGE TANKS

Storage tanks encountered vary in size depending upon their application. In general, they can be classified as follows:

      A. Medium tanks 500 to 1000 gallons
      B. Large tanks of 1000 to 10 thousand gallons
      C. Very large tanks 10 thousand gallons and over.

There are many approaches to heating tanks of these sizes. The many solutions that Chromalox offers are reviewed in the next section.

In addition to storage tanks, many other tanks are employed in manufacturing processes, such as:

      A. Finishing tanks
      B. Wash and rinse tanks
      C. Cooking vessels

Open top tanks used in these applications typically employ over-the-side heating assemblies as well as screw plug or flanged immersion assemblies. This manual may be used for sizing small open top tanks. Please note, however, that this manual includes much more detail than is typically required for sizing small process tanks. It is recommended that you consult the P120 or the P2000 for some additional examples. Finally, a computer based calculation tool is available that is designed specifically for rectangular open or closed top tanks used in the finishing industry. Contact headquarters for more information.

AN INTRODUCTION TO TANK HEATING DESIGNS
Chromalox offers the broadest range of tank heating solutions in the electric heating industry. There are two main methods to tank heating; **direct and indirect** tank heating.

Direct tank heating consists of placing the heater in direct contact with the heated medium by placing the heater directly in the tank or circulating the fluid directly through the heater.

Indirect tank heating uses a heat transfer medium to apply the heat to the tank. Indirect methods can vary from external heating of the tank using the tank wall as the heating medium to utilizing a heat transfer medium to carry the heat to the tank.

Some heaters or systems can be utilized in **direct** and **indirect** methods and appear in both sections of this manual.

DIRECT TANK HEATING
Direct heating places the heater in direct contact with the heated medium. The heating element is immersed in the process fluid utilizing various mounting styles.

The advantage of heating directly is that the heaters are nearly 100% efficient with this method. This is because all heat that is generated is absorbed directly by the process. This helps to speed heat-up and eliminate thermal lag. There is no intermediate heat transfer medium that could result in heat losses.

The disadvantages of direct heating include the element surface limitation of the heater to deliver the energy. Large surface areas require more space for the heater. If the tank is small there may not be room for a properly sized heater. Additionally, consideration of the heater material must be made to insure that the element is compatible and will not degrade due to corrosion or pitting from the process. Because of the efficient heat transfer with directly immersed heaters, the relative watt density is typically high in these applications. Therefore, the heater must be designed so that it is not exposed to air while operating which could lead to heater failure due to high element temperatures. Finally, the element must be protected from sludge build up in the tank that could limit the elements ability to transfer the heat. Figure 2 is an example of immersion heater mounting and demonstrates installation mounting position above sludge line and below fluid line.

A review of direct heating methods with the application pictures are shown throughout the next pages.

*DIRECT HEATING USING SCREW PLUG IMMERSION HEATERS*
Screw plug immersion heaters are typically applied in small tanks or reservoirs requiring relatively small amounts of heat. Many of the tanks are open top style and are used in the finishing industry or industrial process tanks. Many screw plug heaters include a built-in mechanical thermostat, which can often control the heater without any additional equipment. Chromalox, however, typically recommends the use of an over temperature cut out and/or level control.
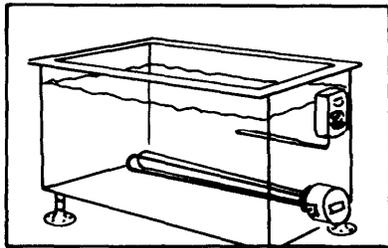
**MT heater** screwed into tank wall parallel to bottom for use as a hot water rinse.
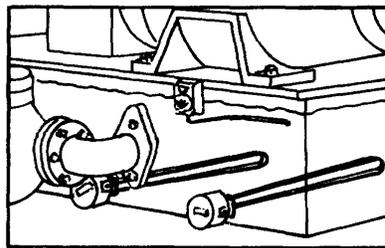
MTO heater used to preheat oil to insure efficient lubrication for heavy motor.
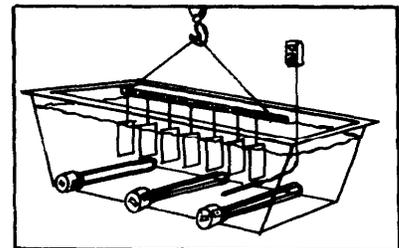
MTO heaters applied to conveyorized degreasing operation of many parts at once.

Figure 1: Typical screw plug immersion heater installations
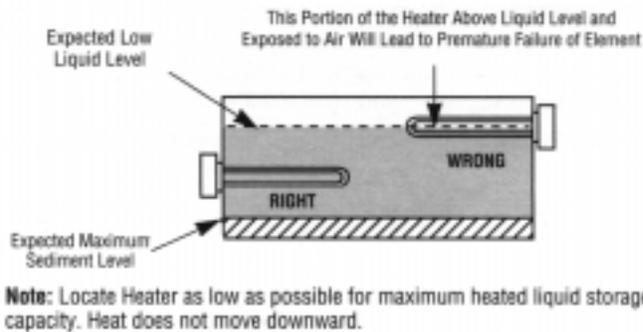
**Figure 2:** Mounting a direct heating style immersion heater
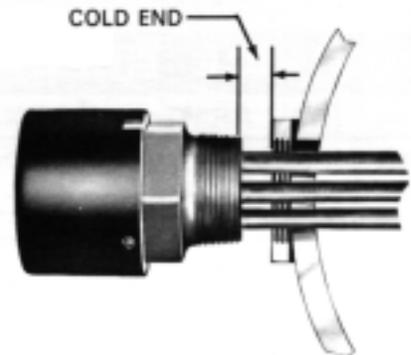
Figure 3:   Mating a screw plug heater to the tank

DIRECT HEATING USING FLANGED IMMERSION HEATERS

Because screw plugs have limited element space flanged heaters are used for larger wattage applications. Flanged immersion heaters are typically applied in large tanks or where process requirements dictate high wattage. Flange heaters provide a high amount of wattage in a relatively small space because of the large amount of heating elements that can fit into the flange. Flanged heaters require an appropriately sized nozzle in the tank and typically cannot be removed without

Figure 4: Mounting a flanged immersion heater

draining the tank. The size of the nozzle will limit how many elements can be put in the tank due to the flange size. A smaller nozzle will require a longer heated length or multiple heaters if the watt density is to be held constant. Nozzle size must always be considered when sizing a flanged immersion heater application.
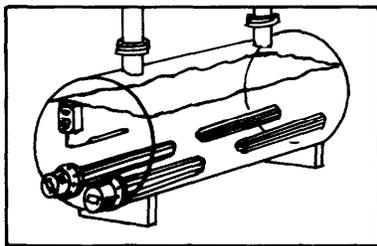

Flange heaters mounted on each end of hot water storage tank for an efficient shower system.
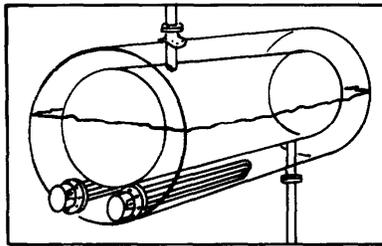
Flange heaters in tank of water to heat inner tank of viscous material.
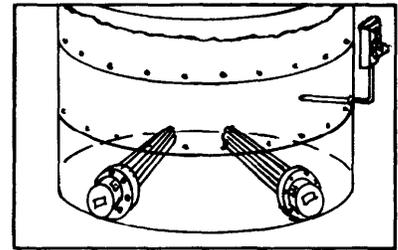
Flange heaters mounted angularly around tank bottom permitting free vertical work area.

Figure 5: Typical flanged immersion heater installations

DIRECT HEATING USING OVER-THE-SIDE IMMERSION HEATERS
Over-The-Side immersion heaters provide heating solutions for tanks without openings
in the side of the tank for insertion of a heater. They also are beneficial in small tanks
or where heater portability is required. They are typically applied as an after market
modification to the tank. Another advantage to the Over-The-Side approach is the
ability to remove or install the heater without draining the tank. Finally, large tanks
where there is only a manhole cover at the top available for heater access are ideal for
Over-The-Side style heaters with manhole construction like the deep tank heaters.
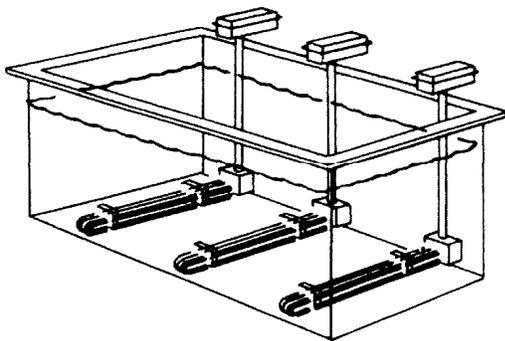

Figure 6: Over-The-Side heater
examples
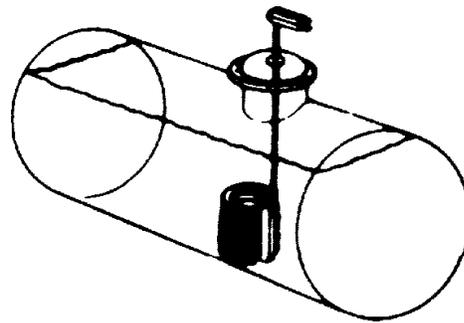
Figure 7:   Deep tank
installations

DIRECT HEATING USING CIRCULATION HEATERS
Circulation heaters are utilized in direct heating applications. The process fluid is circulated directly through the heater. The reason you would choose a circulation heater over an immersion heater directly installed in the tank is either due to space limitations or watt density limitations requiring high fluid velocity over the elements to increase heat transfer. Furthermore, if the circulation heater is piped and valved properly, the heater may be serviced without draining the tank. The circulation of the process fluid is provided by a pump or natural convection. In a pumping design the process fluid is pumped from the bottom of the tank, through a strainer, the pump discharges through the heater, and the fluid is returned to the top of the tank. In convection tank heating applications the natural convection of fluid is used to circulate the fluid through the heater. This approach is often referred to as side-arm heating. This design requires careful consideration of viscosity and watt density to prevent damage to heater or fluid due to low-flow conditions. Another type of tank heating that uses a similar approach to side-arm heating is vaporization. This is applied on low boiling point applications such as ammonia. The heater is mounted side arm style low enough on the tank to remain constantly flooded and the natural convection draws the fluid through the heater. The heater adds the energy consumed by the vaporization of the fluid. Again, careful consideration of watt density must be considered. Additionally, level control should be installed to cut the heater out on fluid low-level conditions. Finally, a circulation heater may be used to heat the fluid on demand as it is drawn from the tank. This method allows for the tank to be maintained at lower temperatures or even remain at ambient temperature.
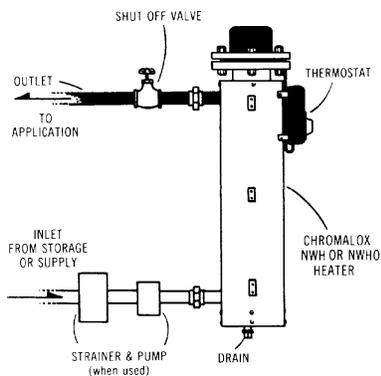
Figure 8: Circulation heater
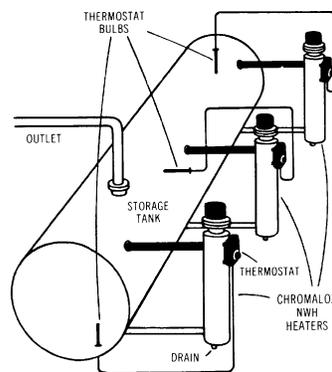
**Figure 9:** Side arm heating
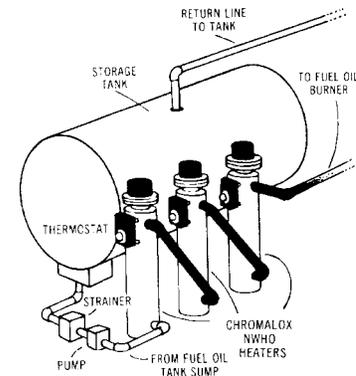
Figure 10: Instantaneous heating

DIRECT HEATING USING HEAT TRANSFER SYSTEMS
Heat transfer systems can be designed to heat tanks directly. The best example of this application is freeze protection or temperature maintenance of large tanks. In this example the fluid is drawn directly from the bottom of the tank, through the heat transfer system and pumped back into the top of the tank. Consideration must be given to the fluid being heated and the process conditions so that the pump and heater may be properly specified for the application. In this approach the process tank must be maintained at levels high enough to provide sufficient static head. Additionally, the depth of the tank must be maintained high enough over the outlet nozzle to prevent vortexing of the fluid and drawing air into the heat transfer system. Two feet of depth in the tank is recommended for every foot per second of velocity in the suction pipe exiting the tank. Finally, the tank should be vented to prevent high pressure from damaging the heat transfer system.
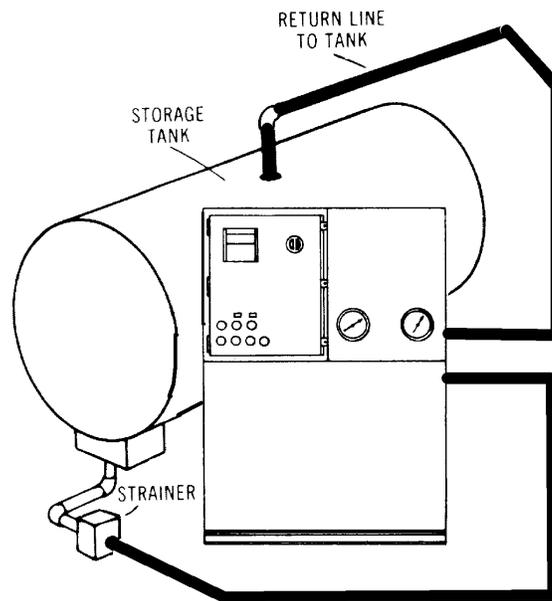
Figure 11: Simplified sketch of heat transfer system direct heating a tank

DIRECT HEATING USING SUCTION HEATERS
Some tank heating applications can benefit from the use of suction heating assemblies. They consist of a flanged immersion heating unit mounted in a heating chamber with one end open so the liquid may be heated as it is pumped from the tank. This eliminates the need to maintain the total storage tank at process or pumping temperature. This simple design results in less piping required and lower installation costs over a circulation heater design. Suction heaters are generally employed for heavy fuel oil and other viscous mediums. Capacity sizing is based on the pumping rate and temperature rise required to obtain proper pumping viscosity. Suction assemblies have the added advantage, through the use of proper valving and valve accessories, of allowing the removal of the flanged immersion heater for maintenance without draining the tank. If the material is highly viscous the piping between the heater and the pump may need to be heat traced to maintain the temperature of the process fluid at pumping temperatures in periods of downtime.
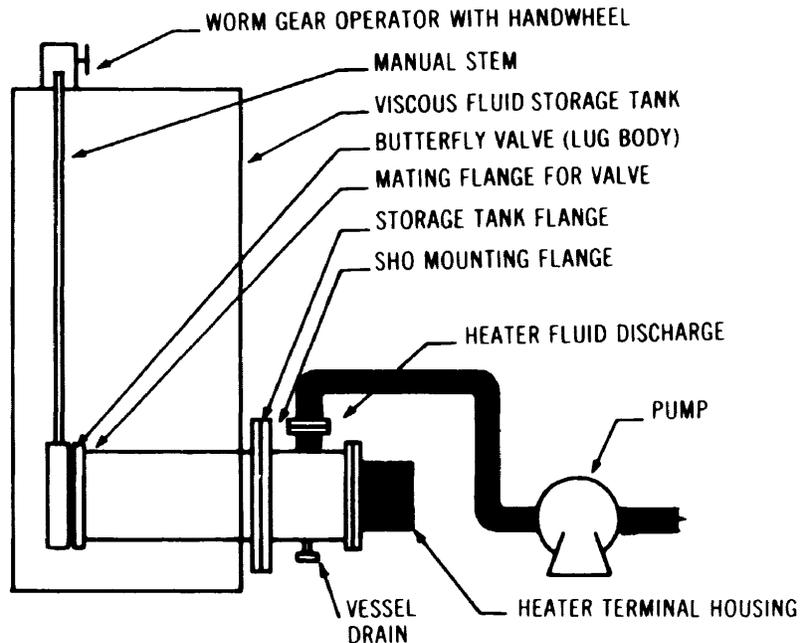

Figure 12: SHO style suction heater piping and installation configuration

INDIRECT TANK HEATING

Indirect heating uses a heat transfer medium to transfer the heat to the tank. Indirect methods can vary from external heating of the tank using the tank wall as the heating medium to utilizing a heat transfer medium to carry the heat to the tank. In addition, pipe insert heaters have been included in this category because they use an air space between the element and the process to convey the heat.

There are various advantages to indirect heating. The biggest advantage is that the heater can typically be serviced without draining the tank. Second, indirect heating often allows watt density exposed to the process fluid to be lowered by spreading the heat over a larger surface. Finally, overheat conditions can be limited in many instances by simply limiting the temperature of the heat transfer medium.

There are a few minor disadvantages to indirect heating that may be critical to your process. The primary disadvantage is the thermal lag caused by using a heat transfer medium to carry the heat. The delay is caused by the fact that the heater must first heat the heat transfer medium before the heat transfer medium can heat the process. If there is a large mass of heat transfer medium, larger heating capacities will be required to raise temperatures.

INDIRECT HEATING USING HEAT TRANSFER SYSTEMS

Heat transfer systems are utilized in indirect heating by using a heat exchanger near or in the tank. The heat transfer fluid is circulated to the tank by the heat transfer system where the heat exchanger transfers the heat from the fluid to the process. The heat exchanger may consist of a jacketed vessel or a heat exchanger immersed directly into the process fluid. The main advantage to this heating approach is the process fluid is never exposed to temperatures higher than the heat transfer fluid temperature. This is important in fluids that could be damaged by high temperatures. A common

Figure 13: An example of a packaged heat transfer system

jacketed vessel application is the heating of chocolate. Chocolate, when melted, is very viscous and susceptible to damage from even moderately high temperatures. Melting and heating chocolate indirectly through the use of a water bath or jacketed vessel is normally recommended. The water bath allows for the use of a higher watt density heater to heat the water and subsequently a smaller heater without subjecting the

chocolate to the relatively high element temperatures normally associated with high watt densities in a viscous liquid. Therefore, by using a double boiler or jacketed vessel approach the process is protected from high temperatures. Finally, this approach is useful when the process may not be compatible with a standard heater. Instead of designing a custom heater that will withstand the harsh process a heat transfer fluid is used to transfer the heat from a standard heat transfer system.
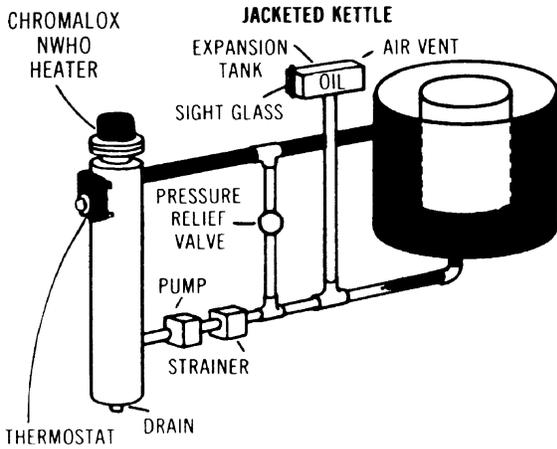
Figure 14: A simplified heat transfer system utilizing a jacketed vessel as the heat exchanger
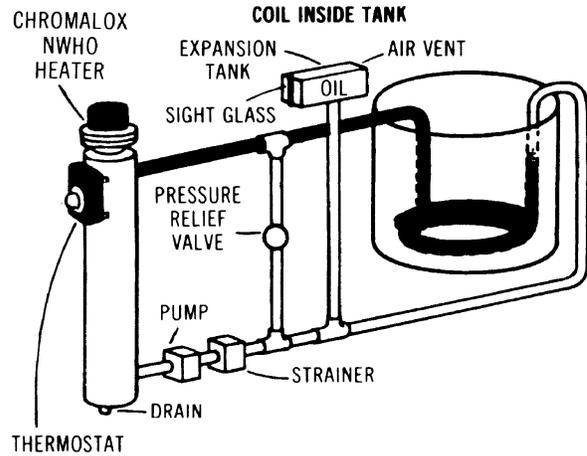
Figure 15: A simplified heat transfer system utilizing a coil in the tank as the heat exchanger
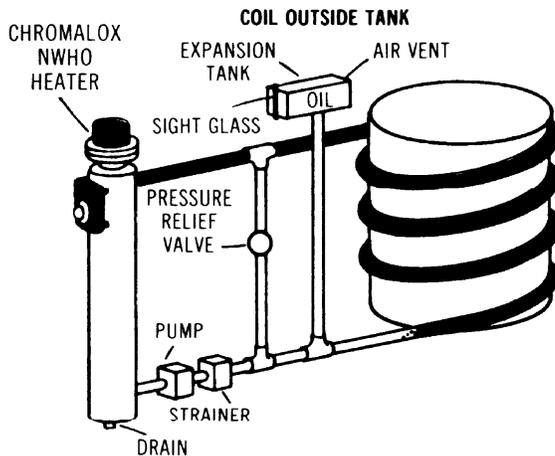
Figure 16: A simplified heat transfer system utilizing a coil external to the tank as the heat exchanger

INDIRECT HEATING USING BOILERS

Boilers are used as heat transfer systems for indirect heating. Instead of a liquid, steam is used to transfer the energy to the process. Again a heat exchanger is used in the process to transfer the energy from the steam to the process. This may be in the form of a jacketed vessel or a heat exchanger directly in the tank (see Figures 14-16). The advantage of steam is it can transfer large amounts of energy to the process efficiently. The disadvantage of steam is the higher cost of piping materials required by the high pressure associated with
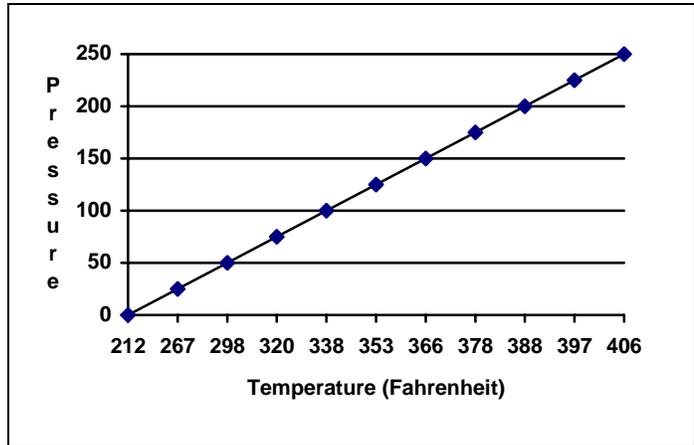
Graph 1: Temperature vs. pressure. Note the high pressure required to achieve 400F
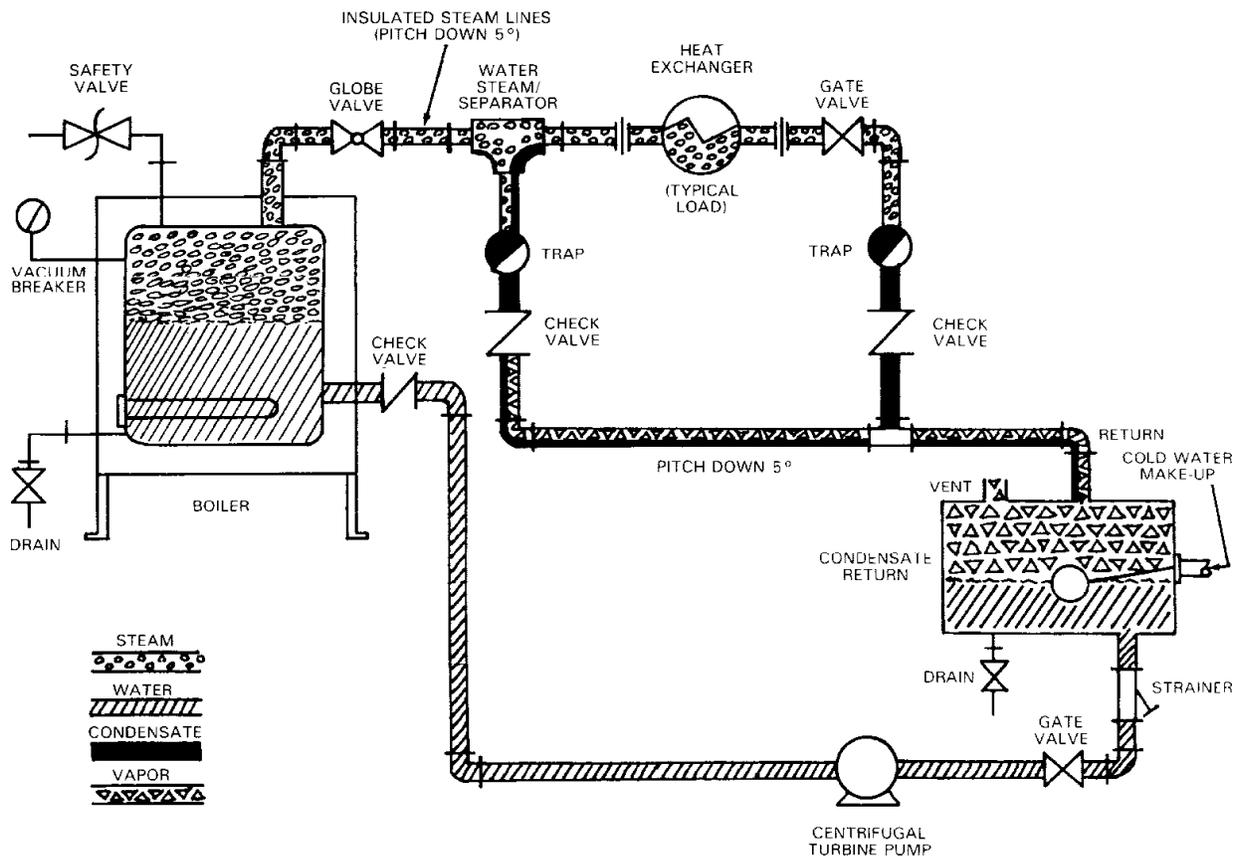
Figure 17: Typical boiler installation showing required accessories for a complete boiler heat transfer system

higher temperatures. Operation above 350°F can become costly due to the associated piping materials required to operate at high pressure (125PSIG). Higher temperatures and pressures may require using 300# construction of pipes and flanges instead of 150# construction materials resulting in higher installation costs. However, when operating below these temperatures the boiler may be the most cost effective approach. The steam heat exchanger can typically be sized smaller than an equivalent liquid heat exchanger due to the higher efficiency of condensing steam to transfer energy to the process.

PIPE INSERT HEATERS

There are many approaches to pipe insert heaters utilizing various heaters. A pipe insert heater uses an element inserted into a sealed pipe. The advantage to the pipe insert heater is that the element is isolated from the process. This allows the element to be removed without draining the tank, isolates hazardous or corrosive materials from deteriorating the element, and if sized properly may allow for the heat to be distributed over a larger surface area reducing the watt density exposed to the process. Consideration of element expansion both in length and the element supports on the inner diameter must be considered when designing a pipe insert heater. The internal heaters of pipe insert heaters consist of screw plugs, flanged heaters, or open coil elements (OCE) inserted into a pipe. Turnkey examples of these heaters with the pipe included are the RSTO and FXTH. Pipe insert heaters must have a separate temperature controller mounted outside of the pipe to regulate the process temperature. An overtemperature device should be installed and attached to the top of the pipe at the highest point. Packaged Systems offer a control panel with the necessary switch gear and temperature controls along with the heaters.
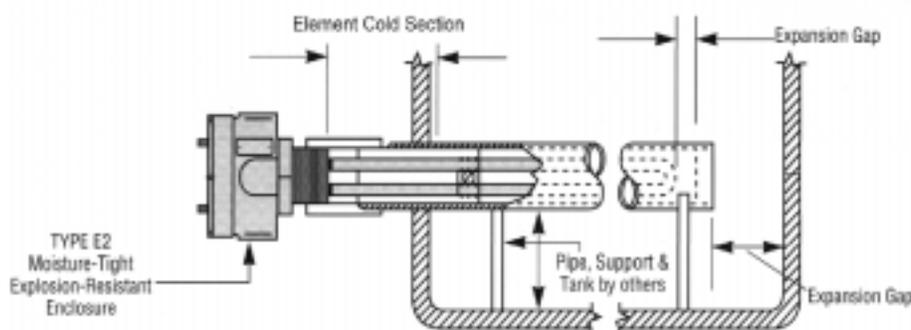

Figure 18: Pipe insert heater utilizing a screw plug heater (MTO-LT). Flanged heaters are often used.
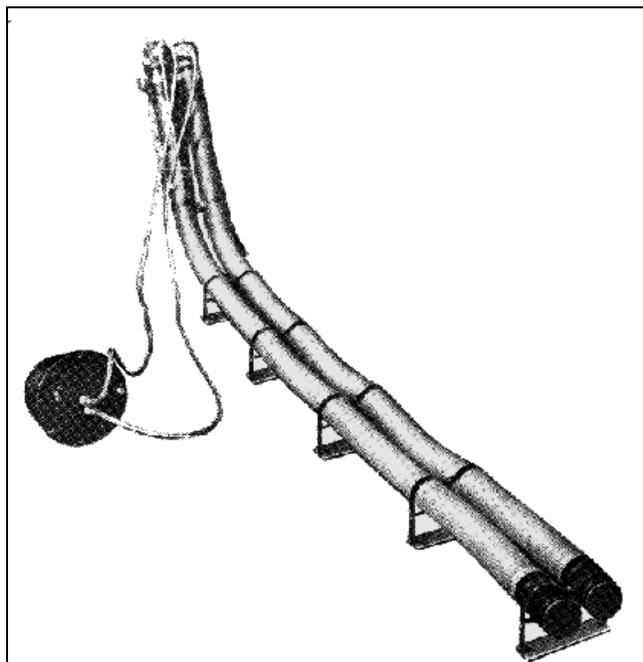
Figure 19: FXTH heater assembly
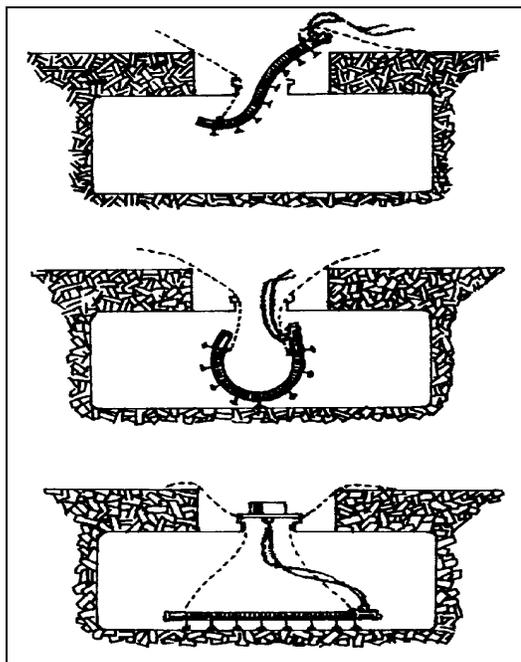
Figure 20: Installing an FXTH heater in an underground tank
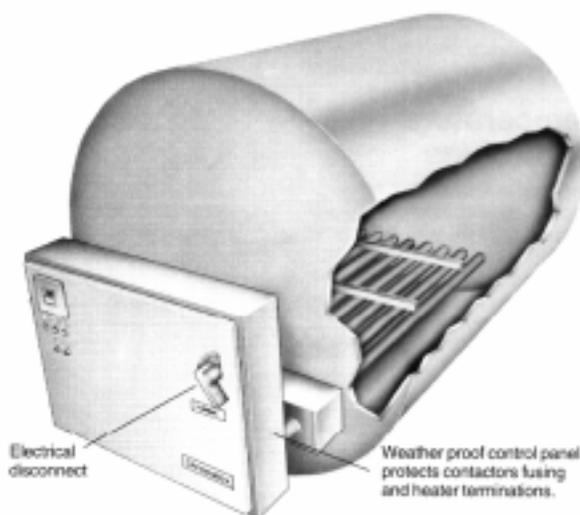
Figure 21: RSTO heater shown installed in a tank. The RSTO ships complete with a panel

ESTIMATING HEATING REQUIREMENTS

A procedure for estimating a large tank heating requirement with calculations is detailed below. The first step in any application is to gather information on the application.

INFORMATION REQUIRED FOR SIZING

- Determine tank characteristics and the nature of the material contained in the tank
    - Bulk, liquid or other compound, etc.
    - Acid or alkaline
    - Specific heat
    - Specific gravity or density
    - Viscosity.
- Tank size
    - Diameter
    - Height
    - Capacity (U.S. gallons)
    - Length and width (rectangular tanks)
    - Determine tank surface area, side and roof (sq-ft.) (A_1 and A_2)
    - Determine tank bottom area in contact with ground (sq-ft.) (A_3).
- Temperature
    - Tank temperature contents to be heated from and to, or maintained, ($T_2 °F$)
    - Ambient temperature tank surface is exposed to ($T_1 °F$)
    - Ambient temperature of ground under tank ($T_3 °F$).
- Heat-up or temperature recovery times
- Process
    - Additions to tank
        - Volume
        - Incoming temperatures.
- Insulation
    - Thickness
    - Type
    - k-factors.
- Environmental Conditions
    - Wind velocity
    - Location classification
    - Indoors/outdoors.
- Code requirements

EXAMPLE PROBLEM

Assume a tank of 20 ft. diameter and height of 15 ft. containing 35,000 gallons of No. 6 fuel oil is to be maintained at 100°F, minimum ambient temperature is 10°F, ground temperature averages 40°F, wind velocity is 15 MPH, tank wall and bottom is comprised of 5/16 inch thick carbon steel, roof construction is 12 gauge carbon steel on truss supports. The dome is 4' high. The tank is situated on a concrete donut shaped footing extending below the frost line. Area inside the donut footing is filled with crushed trap rock and sand. The tank has yet to be built, therefore, flanges and nozzle modifications may be added to best meet the heating requirements of this tank.

- Condition (1)
    - Bare tank, uninsulated
    - Calculate steady state heat loss
    - Assume a power brown out of three (3) days duration. Calculate KW required to bring tank and contents back to temperature through a temperature rise of 10°F.
        - NOTE: Large tanks holding viscous materials rarely have temperature drops of more than 2 to 3°F per day. Please see the charts at the end of this text concerning the effects of tank surface conductance and inside tank film build-up on heat loss. Specifically, the following factors come into play:
            - A. Air surface conductance (f_o). This factor is largely influenced by wind velocity and tank surface emissivity. (i.e., tank loss is proportional to wind velocity for given emissivity factor). Please see Table 1 for heat losses versus wind speeds.
            - B. Tank wall inside film build up is also a factor effecting the range of tank losses. This factor is influenced by thickness of film and temperature. Please see Table 2 at the end of this text. Correction factors are employed to reflect this reduction in loss for tanks containing light to heavy oils, asphalt's and other viscous materials. See heat loss data at the end of this text. Correction factors can vary from 10 to 50%.
- Condition (2)
    - Insulated tank with one (1) inch of fiberglass insulation. K = 0.25 at 50°F
    - Calculate steady state heat loss
    - Calculate heat-up kW for same brown out condition as condition (1).

CALCULATIONS
  A. Tank Area's
      • Variables
          ♦ A_1 is the area of the bottom of the tank (ft^2)
          ♦ A_2 is the area of the sides of the tank (ft^2)
          ♦ A_3 is the area of the roof of the tank (ft^2)
          ♦ H_1 is the height in feet of the sides of the tank
          ♦ h is the height of the dome in feet on the top of the tank
          ♦ D is the diameter of the tank in feet.
      • Tank Bottom

$$A_1 = \frac{\Pi D^2}{4}$$

$$= \Pi \times 20^2/4 = 314 \text{ ft}^2$$

      • Tank Side

$$A_2 = \Pi D H_1$$
$$= \Pi \times 20 \times 15 = 942 \text{ ft}^2$$

      • Tank Top

$$A_3 = \frac{\Pi}{4}\left(D^2 + 4h^2\right)$$

$$A_3 = (\Pi/4) \times (400 + 4 \times 16)$$
$$A_3 = 364 \text{ ft}^2$$

      • Total surface area exposed to ambient air
          $A_{TOTAL} = (A_2 + A_3) = 942 + 364 = 1306 \text{ft}^2$

  B. Estimated Uninsulated Heat Losses From Top and Sides of Tank (Condition 1)
      • Variables
          ♦ T_1 is the lowest ambient temperature tank surface is exposed to in °F
          ♦ T_2 is the tank temperature contents to be heated or maintained in °F
          ♦ ΔT is $(T_2 - T_1)$ in °F
          ♦ U_A is the heat loss factor in BTU/HR/SQ-FT/°F (See Table 1)
          ♦ L_S is the total losses $U_A \times \Delta T \times A_{TOTAL}$
      • Heat loss to ambient air condition at 15 M.P.H. and $\Delta T = (T_2 - T_1)°F = 90°F$
          $U_A = 5.1$ BTU/HR/SQ-FT/°F
          $L_S = U_A \times \Delta T \times A_{TOTAL}$
          $L_S = 5.1 \times 90 \times 1306 = 599454$ BTU/HR x correction factor of 0.6 =
                  359672 BTU/HR ÷ 3412 = 105 KW/HR for tank side and roof.

  C. Estimated Heat Loss To Ground
      • Variables
          ♦ T_3 is the lowest temperature the tank bottom is exposed to in °F
          ♦ T_2 is the tank temperature contents to be heated or maintained in °F
          ♦ ΔT_{Ground} is $(T_2 - T_3)$ in °F

- ◆ K is the conductivity of the ground that the tank is supported on in BTU/HR/in/SQ-FT/°F
- ◆ X is the depth of the soil in inches
- ◆ U_G = Overall heat transmit rate in BTU/HR/SQ-FT/°F
- ◆ L_G is the total losses to the tank foundation in BTU/HR

- Heat Loss To Ground

$\Delta T_{Ground} = (T_2 - T_3) = 60°F$

$$U_G = \frac{1}{\left(\dfrac{X}{K}\right)} \qquad\qquad K = \text{Conductivity of foundation}$$

Where, K = 8.5 BTU/HR/in/SQ-FT/°F, sand at 4% moisture
X = 12 inches sand

$$U_G = \frac{1}{\left(\dfrac{X}{K}\right)}$$

Where, U_G = Overall heat transmit rate BTU/HR/SQ-FT/°F

$U_G = \dfrac{1}{1.41} = 0.71$ BTU/HR/SQ-FT/°F

$L_G = U_G \times \Delta T_{Ground} \times A_1$
$L_G = 0.71 \times 60 \times 314 = 13376$ BTU/HR $\div 3412 = 3.9$ KW/HR

- It should be noted here that tank ground loss verse tank ambient loss is small

3.9kW/105kW = .037 or 3.7% of the total losses

- For very large tanks at temperatures under 100°F, ground loss may be ignored for all practical purposes.

D. Total Estimated Heat Loss (L) For Tank

$L = L_S + L_G$
    = 105 + 3.9 = 108.9 KW/HR
Safety Factor of 20% = <u>131 KW/HR TOTAL</u>

E. Estimated Heat Loss To Ambient Air For Insulated Tank (Condition 2)
- Variables
    - ◆ T_1 is the lowest ambient temperature tank surface is exposed to in °F

- ♦ T_2 is the tank temperature contents to be heated or maintained in °F
- ♦ ΔT is (T_2-T_1) in °F
- ♦ U_{Insul} is the heat loss factor in BTU/HR/SQ-FT/°F
- ♦ $L_{S(I)}$ is the total losses U_{Insul} x ΔT x A_{TOTAL}

- Heat Loss Calculations
  U_{Insul} = 0.25 BTU/HR/SQ-FT/°F for (1 inch Fiberglass insulation)
  $L_{S(I)}$ = 0.25 x 90°F x 1306 = 29385 BTU/HR ÷ 3412 = 8.6 KW/HR
- Heat Loss to Ground
  L_G = 3.9 KW/HR
- Total estimated heat loss, insulated tank
  $L_{(I)}$ = 8.6 + 3.9 = 12.5 KW/HR
  Safety Factor of 20% = 15 KW/HR installed
- By comparing the kW required to maintain a tank temperature of 100°F (for a ΔT = 90°F) it can be seen that the insulated tank kW is only 11.5% of the KW required for base uninsulated tank. If energy cost per kW*Hr is 0.05 cents, operating cost for insulated tank versus bare tank is:
  - Bare tank loss = 131KW
  Energy cost = 131 x 0.05 x 720 = $4716.00/month
  - Insulated tank = 15KW
  Energy cost = 15 x 0.05 x 720 = $540.00/month
  Savings of $4176.00/month or 89%
  - The cost of insulating a typical tank is $7.50 to $10.00 per sq-ft. Based on this assumption the cost to insulate subject tank can be realized in approximately three (3) months energy savings.

F. Tank heat up, recovery for ΔT = 10°F
- Estimated weight of the tank
  Weight of 1 square foot of 5/16 steel (0.3125" thick)
  $\Rightarrow$ (0.3125/12) ft x 487 lb/ ft³ =   12.7 lb/ft²
  Side (A_2) 942 ft² x 12.7 lb/ft² =   11,963 lb.
  Roof (A_3) 364 ft² x 4.375 lb/ft² =   1,593   lb.
  Bottom (A_1) 314 ft² x 12.7 lb/ft² =   3,988   lb.
                                        17,544 lb.
- Weight of No. 6 fuel oil
  Specific Gravity of No. 6 fuel oil = 0.943
  Tank Volume is 35000 gal.
  35000 x 8.4 x 0.943 =   27,7242 lb.

- Specific heat of tank and oil:
          Specific Heat   - tank = 0.12 BTU/LB/°F
                           - oil   = 0.44 BTU/LB/°F

- Tank heat up
  17544 lb. x 0.12 x 10°F = 21053 BTU

- Oil heat up

  277242 lb. x 0.44 x 10°F = 1219865 BTU
- TOTAL HEAT UP REQUIMENT

  (21053BTU + 1219865BTU)/3412 = 364kW

  Add Safety Factor of 20%   = <u>437kW</u>

- Below is a chart depicting recover time versus required kW. The equation for heat up time is total heat up requirement (wattage) divided by number of hours. Note that this analysis does not include losses. If losses are to be included the equation is:

(Heat Up Requirement / Hours) + (losses@90F + losses@100F)/2.
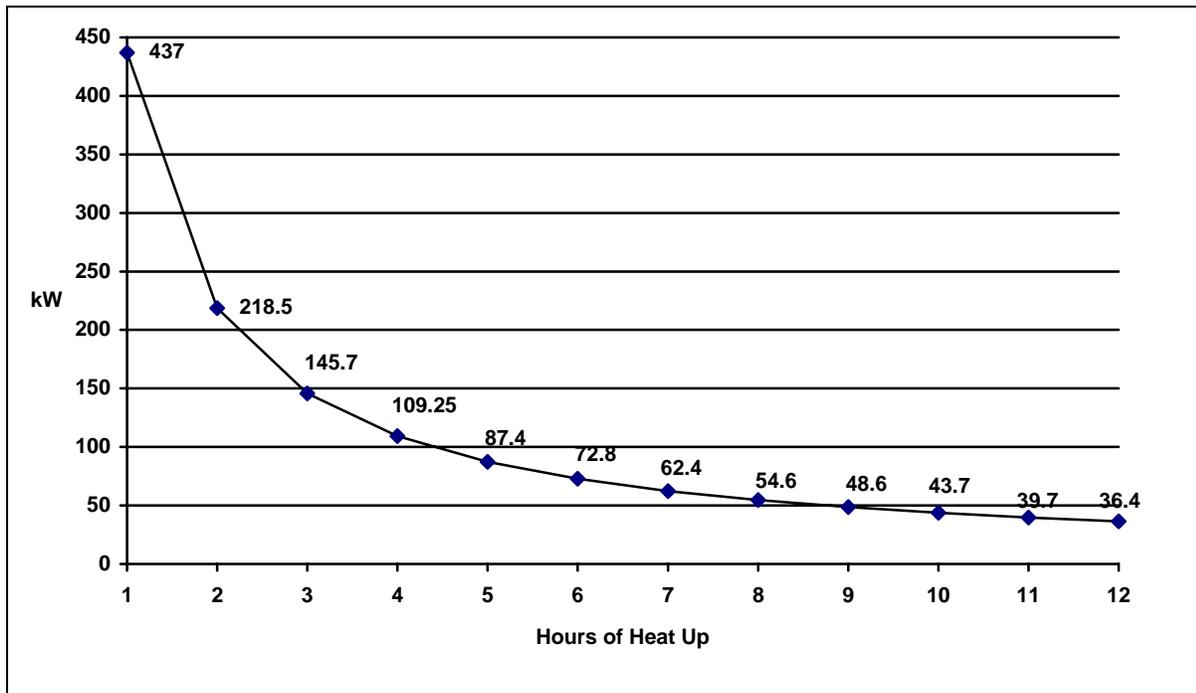
Graph 2:   Heat up versus time allowed

ADDITIONAL NOTES ON HEAT LOSS CALCULATIONS FOR STORAGE TANKS

1. Heat loss data is given for uninsulated and insulated tanks, a range of temperature differentials and the effect of wind velocities in MPH is shown. Below is a plot of wind velocity versus heat loss (BTU/HR/SQ-FT°F) and is useful to estimate the effect of wind velocities in excess of 30 MPH that may be experienced in colder climates on bare tank surfaces.
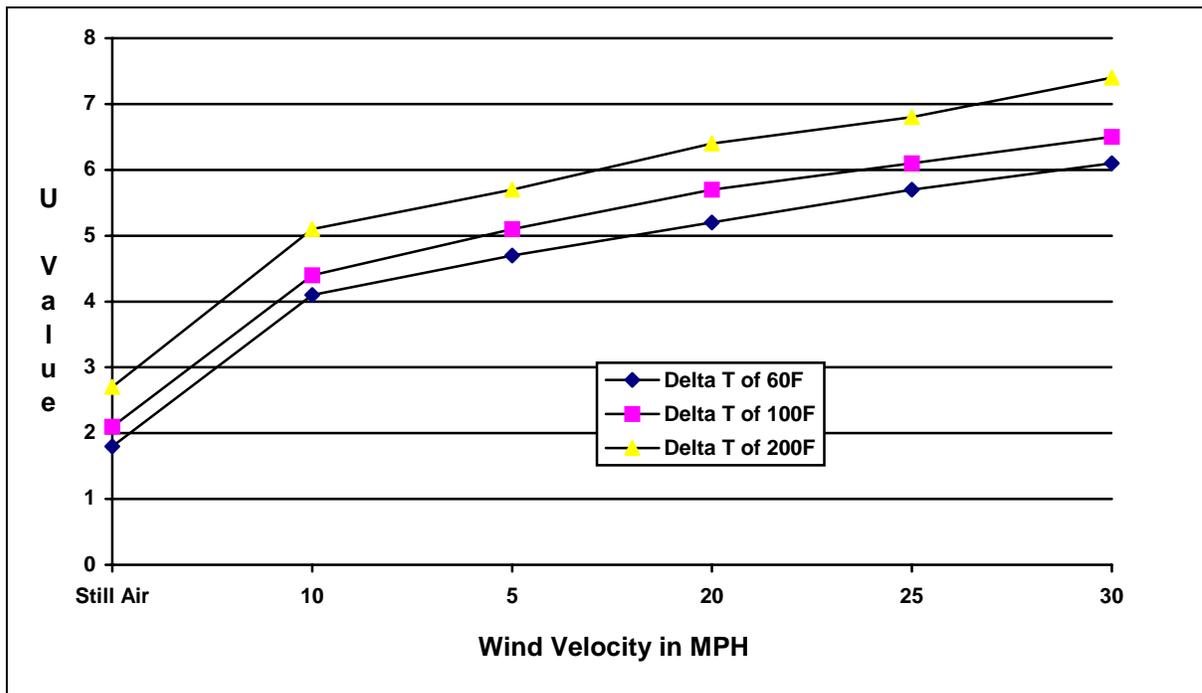
Graph 3: U-values versus wind velocities for various delta T's

2. Heat loss data U for insulated tanks is based on insulation having a k-factor of 0.23. For insulation having a k-factor other than 0.23 multiply data by the ratio of the k-factors.

3. Product correction factors apply to uninsulated tanks for the types of products shown. These products increase the inside film coefficients and thus reduce the overall tank heat loss rate. Corrective factors do not apply to insulated tanks.

4. Apparent thermal conductivity (K) for soils vary considerably based on soil type and moisture content. Table 3 gives some k-factors for various soil types. Tanks should be located in areas with low ground water tables. Fill under the tank bottoms should be well drained and consist of dry crushed trap rock and sand to a depth of two feet or more depending upon natural soil conditions.

HEAT LOSS DATA
Heat Loss for Storage Tanks and Product Correction Factors

Heat loss expressed as U (BTU/hr. sq. ft. F)
▲T = Product temperature minus air temperature

Surface Condition	Still Air	10 mph	15 mph	20 mph	25 mph	30 mph
General Range of ▲t = 60F						
(*) Uninsulated	1.8	4.1	4.7	5.2	5.7	6.1
1" Insulation	0.18	0.20	0.20	0.21	0.21	0.21
1 ½ " Insulation	0.13	0.14	0.14	0.14	0.14	0.14
2" Insulation	0.10	0.11	0.11	0.11	0.11	0.11
General Range of ▲t = 100F						
(*) Uninsulated	2.1	4.4	5.1	5.7	6.1	6.5
1" Insulation	0.18	0.20	0.20	0.21	0.21	0.21
1 ½ " Insulation	0.13	0.14	0.14	0.14	0.14	0.14
2" Insulation	0.10	0.11	0.11	0.11	0.11	0.11
General Range of ▲t = 200F						
(*) Uninsulated	2.7	5.1	5.7	6.4	6.8	7.4
1" Insulation	0.19	0.21	0.21	0.21	0.22	0.22
1 ½ " Insulation	0.13	0.15	0.15	0.15	0.15	0.15
2" Insulation	0.11	0.11	0.11	0.11	0.11	0.11

(*) Product correction factors. Apply to uninsulated U values only.

Product	Approx. Product Temp		
	75F	150F	250F
Watery solutions	1.00	1.00	1.00
Gasoline, Kerosene, etc.	0.90	0.90	0.90
Light oils	0.80	0.85	0.90
Medium oils	0.70	0.75	0.80
Heavy oils	0.60	0.65	0.70
Asphalt's, Tars, etc.	0.50	0.55	0.60
Gases or Vapor spaces	0.50	0.50	0.50
U values as listed for insulated tanks, apply to all products without correction.			

Table 1: Heat loss versus wind speed of uninsulated tanks

Table 2: U-factor correction values for uninsulated tanks*

Notes:
1. Insulation k-factor is 0.23.
2. Table 2 product correction factors apply only to uninsulated tanks
3. Table 2 was calculated from data in Oil and Gas Journal's, "The Refiner's Notebook", No.125 by Prof. W. L. Nelson.

Mean Temperature - 40 F

Soil Designations	Mechanical Analysis % by Weight				Moisture Content - %						
	Gravel	Sand	Silt	Clay	4			10		20	
					Dry Density - lb. Per cu ft.						
	Over 2.0mm	0.5 to 2.00mm	0.005 to 0.05mm	Under 0.005mm	100	110	120	90	110	90	100
Fine Crushed Quartz	0.0	100.0	0.0	0.0	12.0	16.0					
Crushed Quartz	15.5	79.0	5.5		11.6	16.0	22.0				
Graded Ottawa Sand	0.0	99.9	0.1		10.0	14.0					
Fairbanks Sand	27.5	70.0	2.5		8.5±	10.5	13.5		15.0		
Lowell Sand	0.0	100.0	0.0	0.0	8.5	11.0			13.5		
Chesa River Gravel	30.0	19.4	0.6			9.0±	13.0				
Crushed Feldspar	25.5	70.3	4.2		6.0	7.5	9.5				
Crushed Granite	16.2	77.0	6.8		5.5	7.5	10.0				
Dakota Sandy Loams	10.9	57.9	21.2	10.0		6.5	9.5		13±		
Crushed Trap Rock	27.0	63.0	10.0		5.0	6.0	7.0				
Ramsey Sandy Loam	0.4	53.6	27.5	18.5	4.5	6.5			10.0		
Northway Fine Sand	0.0	97.0	3.0	0.0	4.5	5.5			3.5		
Northway Sand	3.0	97.0	0.0	0.0	4.5	6.0			7.5±		
Healy Clay	0.0	1.9	20.1	78.0	4.0±			5.5	9.0±	8.0	10.0
Fairbanks Silt Loan	0.0	7.6	30.9	11.6				5.0	9.0±	7.5	10.0
Fairbanks Silty Clay Loam	0.0	9.2	63.8	27.0				5.0	9.0±	7.5	9.5
Northway Silt Loam	1.0	21.0	64.4	13.6				4.0±	7.0±	6.0±	7.0±

*k = BTU per (square feet) (hour) (Fahrenheit degree per inch).

Table 3: Apparent thermal conductivity k-factors of soils in approximate order of decreasing values

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