

SPD0024ERN
PROCESS DESIGN MANUAL
SHELL AND TUBE HEAT EXCHANGER

REV. : 4

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**SAMSUNG
ENGINEERING**

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1. SCOPE

This manual provides information and guidance for the designer of shell and tube type heat exchangers for general petroleum process applications.

2. FORMAT

Design results of shell and tube type heat exchanger shall be summarized in the following blank forms: Data sheet shell and tube type heat exchanger Form No. (Refer to SPD1003KNN)

3. DEFINITIONS

- (1) Exchanger
: One completely assembled vessel (including all internals)
- (2) Exchanger unit
: One or more exchangers for a specified service which may include various conditions.
- (3) Item number
: Purchaser's identification number for an exchanger unit.
- (4) Effective surface
: Outside surface based a length tubes measured between inner faces of the tube sheets. For U-tube bundles, exposed surfaces at U-bends are admissible, provided that the shell nozzle location is beyond the U-bends and the velocity of the flowing fluid makes this surface effective.

4. DESIGN FEATURES

4.1. Standards and Codes

The mechanical design, fabrication, inspection and testing of shell and tube type heat exchangers shall be in accordance with the following sections of the standards of the Tubular Exchanger Manufacturers Association-"TEMA".

Section 5 - The TEMA mechanical standards for Class "R" heat exchangers specify design, fabrication, and materials of unfired shell and tube type heat exchangers for the generally severe requirements of petroleum and related processing applications.

Section 6 - The TEMA mechanical standards for Class "C" heat exchangers specify design, fabrication, and materials of unfired shell and tube type heat exchangers for the generally moderate requirements of commercial and general process applications.

Section 7 - The TEMA mechanical standards for Class B heat exchangers specify design, fabrication, and materials of unfired shell and tube type heat exchangers for chemical Process service.

When TEMA refers to "the code" this should be section VIII of the ASME boiler and pressure vessel code for all exchangers, except unfired waste heat boilers raising steam, which shall conform to Section I of the ASME boiler and pressure vessel code.

Moreover, national standards and codes as specified by the clients shall be adhered to.

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4.2. Basic Relations

(1) Basic heat transfer relation

$$A_o = \frac{Q}{U \Delta T_e} \quad (\text{Eq. 4-1})$$

Where, A_o : Required effective outside heat transfer surface based on length of tubes measured between inner faces of tubesheets, (ft²)
 Q : Total heat to be transferred, (Btu/hr)
 U : Overall heat transfer coefficient, (referred to tube outside surface, Btu/hr ft² °F)
 ΔT_e : Effective temperature difference (Refer to Para. 4.2 (4)), (°F)

(2) Determination of overall heat transfer coefficient.

The overall heat transfer coefficient U , including fouling, shall be calculated as follows:

$$U = \frac{1}{\left[\left(\frac{1}{h_o} + r_o \right) \left(\frac{1}{E_f} \right) + r_w + r_i \left(\frac{A_o}{A_i} \right) + \frac{1}{h_i} \left(\frac{A_o}{A_i} \right) \right]} \quad (\text{Eq. 4-2})$$

Where, U : Overall heat transfer coefficient (fouled) (Btu/hr ft² °F)
 h_o : Film coefficient of fluid outside tubes (Btu/hr ft² °F)
 h_i : Film coefficient of fluid inside tubes (Btu/hr ft² °F)
 r_o : Fouling resistance on outside of tubes (hr ft² °F/Btu)
 r_i : Fouling resistance on inside of tubes (hr ft² °F/Btu)
 r_w : Resistance of tube wall referred to outside surface of tube wall, including extended surface if existing (hr ft² °F/Btu)
 A_o/A_i : Ratio of outside to inside surface tubing
 E_f : Fin efficiency (where applicable)

(3) Tube wall resistance

(a) Bare tubes

$$r_w = \frac{d}{24k} \ln \left(\frac{d}{d - 2t} \right) \quad (\text{Eq. 4-3})$$

(b) Integral circumferentially finned tubes

$$r_w = \frac{t}{12k} \left[\frac{d + 2N\omega(d + \omega)}{(d - t)} \right] \quad (\text{Eq. 4-4})$$

Where, d : OD of bare tube or root diameter of fin (inches)
 ω : Fin height (inches)
 t : Tube wall thickness (inches)
 N : Number of fins per inch
 k : Thermal conductivity (Btu/hr ft °F)

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(4) Effective temperature difference ΔT_e

(a) No change of phase

The driving force of the heat transfer mechanism is the "effective temperature difference" between hot and cold fluids. This difference is called ΔT_e . It can be easily calculated from the actual temperature difference. For exchangers where the flow of hot and cold fluids are truly countercurrent or cocurrent, ΔT_e is equal to the logarithmic mean temperature difference, ΔT_m .

Almost all exchanger designs attempt to achieve countercurrent flow. In most commercial exchangers, however, the use of multiple tube passes or of shell baffles causes the flow of the fluids to be partially countercurrent and partially cocurrent.

Since cocurrent flow gives lower ΔT_m , a correction factor must be applied to the countercurrent ΔT_m . This correction factor, called F, is a function of the particular exchanger design.

Values of F for shell and tube type exchangers can be obtained from reference 9. On these charts, the number of "Shell Passes" refers to the number of shells connected in series.

These charts are valid only when Q is a linear function of temperature.

When Q is not linear, a weighted correction factor may be calculated by dividing the exchanger into zones such that Q is linear with temperature for each zone. (This applies to partial as well as total condensers.)

(b) Change of phase

In the case of condensation or vaporization, the relation between Q and the temperature of both fluids usually deviates appreciably from a straight line. In this case, it is necessary to divide the exchanger into zones so that Q is approximately linear with temperature for each zone. Based on the logarithmic mean temperature differences and heat duties for the individual zones, a weighted ΔT_e is obtained for the entire exchanger.

5. Selection of Type

5.1. General

The shell and tube type exchanger is commonly used in general petroleum processes. It is inexpensive, easy to clean, available in many sizes, and can be designed for moderate to high pressures at reasonable cost.

It consists of a bundle of tubes encased in a shell. There are two basic types of shell and tube exchangers. (Refer to Fig. 5-1). The first is the fixed tube sheet unit, in which both tube sheets are fastened to the shell. In this type of construction, differential expansion of the shell and tubes due to different operating metal temperatures may require the use of an expansion joint or a packed joint.

The second type of shell and tube has only one restrained tube sheet located at the channel end. Differential expansion problems are avoided by using a freely riding floating tube sheet or Unbends at the other end.

There are two variations of floating tube sheet units, the pull-through and the nonpull-

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through. In the pull-through unit, the entire floating tube sheet and cover assembly may be drawn through the shell without disassembly. In the nonpull-through unit, the shell cover and the floating tube sheet cover must be removed before the bundle can be taken out of the shell. This requirement is the greatest disadvantage of the nonpull-through unit. However, due to the smaller diameter tube sheet which is possible if a split ring assembly is used to fasten the floating head cover, the nonpull-through unit requires a smaller shell for the same surface.

Typical configurations of shell and tube type heat exchangers are shown in Fig. 5-2. Listing the above variations in shell and tube units in order of increasing cost would give the following tabulation:

- (1) Simple fixed tube sheet unit
- (2) U-tube unit
- (3) Fixed tube sheet unit with an expansion joint or packed joint
- (4) Floating tube sheet unit (pull-through and nonpull-through)

The designer should choose the least costly type of construction which is applicable. Where there is a choice of pull-through or nonpull-through unit, this decision is made during procurement of the unit although these variations are competitive in price, spot conditions may often favor one over the other.

Shell and tube type exchangers are usually fabricated to conform to Class R of the Standards of the Tubular Exchanger Manufacturers Association. Equipment fabricated in accordance with these standards will adequately meet the heavy duty service requirements of petroleum refinery units.

However, there are numerous applications which do not require this type of construction. Services falling within this category are water-to-water exchangers, air coolers and other such non-hydrocarbon applications as well as some light duty hydrocarbon services such as offsite lube oil heaters and some tank suction heaters. For such services, Class C constructions should be considered. Although units fabricated to either Class R or Class C standards comply with all the requirements of the pertinent codes, Class C units are designed for maximum economy and result in a cost saving of about 5% over Class R.

5.2. Selection of Type

- (1) Fixed tube sheets shall be used under the following conditions:
 For non-corrosive streams with the restriction that any fouling on the shell side can easily be removed by hot water, solvent or other chemical cleaning methods.
 Stress caused by temperature difference between shell and tubes are acceptable. These shall be checked for start-up/shutdown/steam-out as well as for normal operating conditions.
- (2) Preferred head designs are listed below and are to be used, unless otherwise specified:
 Front end
 - Tube side fouling $\leq 0.002 \text{ hr ft}^2 \text{ }^\circ\text{F/Btu}$ ($0.00035 \text{ m}^2\text{-K/W}$) : TEMA type B, bonnet (Integral cover)
 - Tube side fouling $> 0.002 \text{ hr ft}^2 \text{ }^\circ\text{F/Btu}$ ($0.00035 \text{ m}^2\text{-K/W}$) and salt water : TEMA type A, removable cover
 Rear end
 - Shell side fouling $\leq 0.002 \text{ hr ft}^2 \text{ }^\circ\text{F/Btu}$ ($0.00035 \text{ m}^2\text{-K/W}$) and non-corrosive i.e. Shell side CA 1/8 : TEMA type T, with integral cover
 - Shell side fouling $> 0.002 \text{ hr ft}^2 \text{ }^\circ\text{F/Btu}$ ($0.00035 \text{ m}^2\text{-K/W}$) and salt water : TEMA type T or S, with removable cover

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- (3) The use of a removable longitudinal baffle is not permitted except as follows:
For a TEMA shell, Type "G" or "H" when applied to a low pressure drop (2 psi maximum (13.790 kPa)) reboiler or condensing operations.
For a TEMA shell, Type "F", when applied to condensing and subcooling relatively pure substances (benzene, toluene, etc.) and the pressure drop does not exceed 5.0 psi. The shell side differential temperature shall be limited to 250 °F (121.11 °C).

6. Design Criteria

6.1. Design Manual and Computer Programs

The design manuals of shell and tube type heat exchangers are shown in the following table.

Design Manual

Source	Description
HTRI	HTRI Design manual
	HTRI Technical Reports
	Computer programs support volume
HTFS	Hand book
	Design report
	Research symposium

HTRI : Heat Transfer Research Inc.

HTFS : Heat Transfer & Fluid Flow Service

The design computer programs of shell and tube type heat exchangers are listed in SPD1003KNN.

6.2. General Requirements

(1) Fluid Allocations ³⁾

Fluid allocation shall be made under the following conditions.

- (a) Dirty fluids are passed through the tubes because they can be easily cleaned, particularly if the tube bundle cannot be removed, but through the shell if the tubes cannot be cleaned (hair pin bundles) or if large amounts of coke or debris are present which can be accumulated in the shell and removed by dumping the shell.
- (b) High pressure fluids, corrosive stock, and water are sent through the tubes because the strength of small-diameter (and thin) tube surpasses that of the shell, because corrosion-resistant tubes are relatively cheap, and because corrosion or water scale can be easily removed.
- (c) Large volume fluids (vapors) are passed through the shell because of the availability of adequate space, but small volume fluids are also passed through the shell where

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cross baffles can be used to increase the transfer rates without producing an excessive pressure drop.

- (d) Vapors that contain noncondensable gases are sent through the tubes so that the accumulation of noncondensable will be swept out.
- (e) If the pressure drop must be low the fluids are sent through the shell. The same applies to viscous or low transfer rate fluids because the maximum transfer rates for a fixed pressure drop can be obtained by the use of cross baffles in the shell.
- (f) In fin tube equipment, high-pressure, dirty, or corrosive stock is sent through the fin tube because it is relatively cheap, can be easily cleaned, and has a higher strength than the outside tube.

(2) Installation

(a) Vertical

- Condensate subcooling may be accomplished more easily in a vertical unit.
- For boiling fluids, this is usually a single tube pass type with vaporization occurring in the tubes.

(b) Inclined

- For tube side condensing fluids, this type of heat exchanger is sometimes employed to insure positive drainage of the condensate from the tube. Even a few degrees inclination from the horizontal prevents the accumulation of condensate and possible redistribution, flooding, and surging effects.

(c) Horizontal

- Others

6.3. Geometrical

(1) Tube layout and pitch

(a) Standard tube patterns are shown in Fig. 6-1.

- Triangular pitch:
Most popular, generally suitable for non-fouling or fouling services of chemical treatment processes medium to high pressure drop; gives better coefficients than square pitch.
- Rotated triangular pitch:
Not as popular as the staggered triangular pitch; coefficients not as high, but better than square pitch; pressure drop about medium to high; generally suitable for same fouling conditions as above.
- Square pitch:
Popular for conditions requiring low pressure drop and/or cleaning lanes for mechanical cleaning of outside of tubes; coefficient lower than triangular pitch.
- Rotated square pitch:
Popular arrangement for reasonably low pressure drop (not as low as square), mechanical cleaning requirements, and better coefficient than square pitch.

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(b) Tube pitch

Tubes shall be spaced with a minimum center-to-center distance of 1.25 times the outside diameter of the tube. Where tube diameter is 5/8" (15.875mm) or less and tubes are rolled into tube sheets, minimum center-to-center distance may be reduced to 1.20 times the tube outside diameter.

(2) Baffles

(a) Types

The four types of cross baffles in shell and tube type exchangers are illustrated in Fig.6-2.

- Segmental
This type is probably the most popular.
- Double segmental
Double segmental baffles give one-third to one-half the pressure drop and 60 to 90 percent of the heat transfer for the same total flow rate compared with units with segmental baffles having the same spacing and cut. Therefore, if the pressure drop is a limitation factor at the maximum allowable segmental baffle spacing, the use of a double segmental baffle should be investigated.
- Triple segmental
Triple segmental baffles have proved very effective in low pressure drop applications in both laminar and turbulent flows.
- No-tubes-in-window
Support plates can be used with no-tubes-in-window type baffles. Therefore these type baffles can eliminate flow induced tube vibration.

(b) Cut as percentage of shell ID

The percent baffle cut is determined at position 1 as shown in Fig. 6-3.

- Segmental
Maximum cuts allowed are 49 percent.
- Double, triple segmental
Normally specifies the cut of baffles in a manner which gives equal net flow area for each window.
- No-tubes-in-window
The cut is extremely important because it not only defines the window flow area but also affects the tube count and the height under the window.

(c) Baffle cut orientation

- Vertical
The baffle edge is usually vertical for service in horizontal condensers, reboilers, vaporizers and heat exchangers carrying suspended matter or heavy fouling fluids. With this arrangement non-condensable vapors and inert gases can escape or flow along the top of the unit and thus prevent vapor binding or vapor lock causing a blanking-to-heat transfer of the upper portion of the shell. Also, equally important as the passage of vapor, is the release of liquid from the lower portion of the shell as it is produced.

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- Horizontal
The horizontal cut baffles are good for all gas phase or liquid phase service in the shell. However, if there is dissolved gas in the liquid which may be released in the exchanger, this baffle should not be used, or else notches should be cut at the top for the passage of gas. Notches, will only be effective for small traces of released gas. Liquid should be clean, otherwise sediment will collect at the base of every other baffle segment and blank off part of the lower tubes to the heat transfer.

(3) Spacing of baffles and support plates ¹⁾

(a) Minimum spacing

Segmental baffles normally should not be spaced closer than 1/5 of the shell ID, or 2 inches, whichever is greater. However, special design considerations may dictate a closer spacing.

(b) Maximum spacing

Tube support plates shall be so spaced that the unsupported tube length does not exceed the value indicated in Table 6-1 for the tube material used.

(4) Finned tube

It has been recognized for some time that the use of integral finned tubes in shell and tube type heat exchangers can have significant economic advantages in certain applications. On the other hand, there are also conditions under which these tubes would provide no advantage over plain tubes. In order to make proper use of their potential, therefore, each case should be carefully evaluated.

Some of the factors which limit the use of finned tubes are as follows:

- (a) Low tubeside heat transfer coefficient if the tubeside resistance is a controlling factor, the outside finned surface is almost completely ineffective, and plain tubes should be used instead.
- (b) High tubeside fouling factor
The additional outside area does nothing to decrease the tubeside fouling resistance and, if this factor is controlling, finned tubes should be used.
- (c) High shellside fouling factor
The effect of fouling on the outside of finned tubes has long been a controversial subject. It is obvious that if fin valleys become filled with fouling deposit, heat transfer cannot take place at the finned surface.
- (d) Low fin efficiency
This limitation is seldom a serious problem for low and medium fins, but should always be checked.

(5) Dam baffles

The dam baffle is used to retain a pool of liquid in the bottom of an exchanger. After a vapor has condensed it may be subcooled. Usually condensate is cooled at a natural convection rate of heat transfer which, although low, is the best obtainable if there is no

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positive pressure on the system. otherwise, if the system is under pressure and a loss of 3 - 5 psi (20.684 - 34.474 kPa) is permissible, the condensate can be routed through a segmentally baffled subcooling zone, where a much higher heat-transfer rate will be obtained due to forced convection.

(6) Impingement baffles ⁵⁾

Inlet impingement baffles are used to prevent direct impingement of the fluid from the inlet nozzle into the tube bundle. Without impingement baffles, high velocity bundle penetration can cause erosion and flow-induced tube vibration.

(a) Shell side impingement protection requirements

An impingement plate or other method of protecting the tube bundle against impinging fluid shall be provided when the entrance line values of pV^2 exceed the following, in lb/ft²-s (kg/m²-s):

- Non corrosive, non abrasive, single fluid : 1500 lb/ft²-s (2232 kg/m²-s)
- All other liquid, including a liquid at its boiling point: 500 lb/ft²-s (744 kg/m²-s)
- For all other gases and vapors, including all nominally saturated vapors, and also liquid vapor mixtures, impingement protection is required.

(b) Shell or bundle entrance and exit areas

In no case shall the shell or bundle entrance or exit area produce a value of pV^2 in excess of 4000 lb/ft²-s (5953 kg/m²-s).

6.4. Thermal

(1) Fouling factors

Fouling resistance to heat transfer is caused by dirt, sludge, polymer, and other deposits which form on the inner and outer walls of heat exchanger tubes while in service. The values to be used in design represent the resistance expected during normal operation, assuming reasonable service time between cleanings. Fouling factors are represented by the symbols r_o and r_i .

Table 6-2, gives normal fouling factors for a variety of process services as recommended by TEMA. The tabulated fouling factors are intended to prevent the exchanger from delivering less than the required process heat load for a period of about a year to a year and a half. This table is only a guide, however, and if specific data is available which can be used to determine a more accurate fouling factor for a particular service, that data should be used in preference to Table 6-2.

The actual importance of the fouling factors depends on the value of the clean coefficient U_c , that is the better the coefficient, the more important is the fouling factor. After making a preliminary calculation of U_c , it is easy to determine the effect of doubling (or halving) the assumed fouling factors on the size of the exchanger.

If this effect is small (5 % or less), it is not worthwhile trying to determine a more accurate fouling factor. There are many occasions, however, when U_c is so large that the size of the

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exchanger depends almost entirely on the value of the fouling factor. For these cases, all available plant data should be closely examined

The following general facts on fouling are important in the exchanger design:

(a) Fouling is usually not severe below 250 °F (121.11 °C).

(b) Fouling is more severe when heating hydrocarbons than when cooling them. In the case of pipestills this is due to "Salting out". To minimize this sort of fouling, a crude preheat train sometimes includes a desalter or a flash drum to remove water before the crude reaches the "Salting out" temperature.

(c) Vaporization in an exchanger can cause severe fouling.

(d) High velocities reduce fouling. This is especially true in the case of cooling water that contains salt.

(e) The feed to catalytic reformers and catalytic cracking plants is sometimes severely fouled due to organic reactions with oxygen while the feed is in intermediate tankage. Inert gas blanketing of the tankage is often used to reduce this fouling.

(f) Bottoms from a crude distillation tower, even though heavy and at a high temperature will not normally cause much fouling (provided flash zone temperatures are not excessive).

(2) Water velocity ⁶⁾

The water velocity on the tube side of condensers and coolers shall be established from the following tables:

Material	Most Favorable Velocity, in ft/sec (m/s)	Permissible Range, in Ft/sec (m/s)
*Carbon Steel	5 ft/sec (1.52 m/s)	3 to 10 Ft/sec (0.91 - 3.05 m/s)
Red Brass	5 ft/sec (1.52 m/s)	3 to 10 Ft/sec (0.91 - 3.05 m/s)
Admiralty (Inhibited)	5 ft/sec (1.52 m/s)	3 to 10 Ft/sec (0.91 - 3.05 m/s)
Aluminum Brass	5 ft/sec (1.52 m/s)	3 to 10 Ft/sec (0.91 - 3.05 m/s)
Cupronickel	5 to 8 ft/sec (1.52 - 2.44 m/s)	3 to 10 Ft/sec (0.91 - 3.05 m/s)
Type 316 Stainless Steel	5 to 8 ft/sec (1.52 - 2.44 m/s)	3 to 10 Ft/sec (0.91 - 3.05 m/s)

* Minimum tube side velocity for cooling water shall be 3 ft/sec (0.91 m/s) at mean temperature.

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* Maximum tube side velocity shall be 8 ft/sec (2.44 m/s) when water carries solids and shall not exceed 10 ft/sec (3.05 m/s) when water is clean and without solids.

6.5. Vibration ⁴⁾

There are two primary types of vibration in a shell and tube type exchanger. one involves exciting the natural frequency of the tubes while the other involves exciting the acoustic frequency of the shell. The natural frequency of the tubes depends primarily on the length of span with long spans having low natural frequency. The acoustic frequency depends upon the velocity of sound in the shell side fluid and the shell inside diameter.

The flow phenomena which can excite either of these types of vibration depend upon the velocity of the shell side fluid and the geometry of the flow paths. In general, the frequency of the periodic fluctuations in the flow increases with velocity. As an exciting frequency approaches either the natural frequency of the tubes or the acoustic frequency of the shell, there is an increase in the intensity of vibration. Should they become equal resonance will occur, which can lead to unpleasant noise and failure. Thus, it is desirable to keep exciting frequencies below the natural frequency and the acoustic frequency to prevent resonance taking place.

When a resonance condition occurs, the intensity of tube vibration in terms of the midspan amplitude will be the density of the shell side fluid times the square of the velocity. When the midspan amplitude is large enough for adjacent tubes to hit, tube failure can be expected. Tube failure due to loosening at tube joints and cutting at baffles can occur at lesser amplitudes.

Several criteria which have been proposed to predict the likelihood of tube failure due to vibration include forcing frequency ratios, critical velocity, baffle and collision damage number, and maximum amplitudes of vibration. Each must be considered in the light of the exchanger design as no single criterion can predict the probability of flow-induced vibration.

For a detailed discussion of the various approaches to vibration analysis, see HTRI Report STV-1 Table 6-3 shows a suggested check list for evaluating the probability of flow-induced vibration problems.

6.6. Special Applications

(1) Caustic streams

When an exchanger handles a caustic stream, the caustic gravity must be indicated on the specification sheet. This is necessary in order to determine whether or not stress relieving must be carried out.

(2) Condenser elevation of grade

The location of a condenser at an elevation lower than the distillate drum reduces the amount of structural steel required and simplifies maintenance.

However, for a constant distillate drum pressure, submerging of the condenser causes an increase in system pressure over that when using elevated condensers due to the static head of fluid in the line connecting the condenser with the distillate drum. This pressure increase results in a higher boiling temperature.

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An increased boiling temperature may be significant in low pressure towers , affecting units handling materials subject to temperature degradation and those with reboilers having a close temperature approach.

(a) Total condensers

All total condensers should be located at grade if the increase in temperature due to submerging is not objectionable. Submerged type condensers require a one inch valved vent connection to the vapor-space of the distillate drum.

This vent is used to bleed off any noncondensibles which might otherwise accumulate in the shell of the condenser and adhere to its upper surface, rendering that part of the heat exchanger ineffective.

(b) Partial condensers

Pressure elevation due to submergence is negligible for partial condensers due to their low effluent density. However, the line connecting the condenser and the distillate drum must be designed for "dispersed" two-phase flow. Operation of a condenser under varying conditions resulting in differing outlet vapor rates can produce unstable flow conditions and pressure surges in the effluent line.

In systems where the condenser serves a distillation column, these surges are reflected in tower pressure and can result in poor tower operation, especially with orifice type trays. For this reason, submerging type of partial condensers is recommended only for those cases in- which the condenser effluent rate and composition for all foreseeable operations does not vary to such an extent that the flow in the condenser outlet line becomes unstable.

For all other cases, a partial condenser serving a fractionating tower should be elevated above the distillate drum.

Partial condensers in systems in which the vapors are generated by means other than a distillation tower, such as a reactor, should be located at grade unless pressure surges from unstable flow conditions in the condenser effluent line are detrimental to the process.

(3) Kettle reboilers general

(a) The shell shall be TEMA "K" with a weir plate directly behind the tube bundle. The weir shall be welded firmly to the shell, shall contain no drain holes and shell have sufficient height to flood the top of the tubes with a minimum of two inches of process fluid for normal operation. For amine process fluid, the reboiler tubes should always be covered with 6 inches (152.400 mm) of liquid to prevent drying and overheating.

(b) The general arrangement and connections shall be as shown in Fig. 6-4.

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(4) Kettle reboilers - Steam generator

The general arrangement is similar to the above except that;

- (a) A weir is not required, however the "L" dimension must be minimized (Fig. 6-4).
- (b) The steam outlet shall employ a steam separating device, the lowest part of which is 20" (508.000 mm) above the normal water level.
- (c) A clearance of 2" (50.8000 mm)(minimum) shall be provided between the outside layer of the tubes and the shell.

(5) Slurry handling

- (a) Cycle oil containing catalyst fines (slurry) shall be routed through the tube side of the exchanger. Experience shows that it is necessary to confine slurry oil velocities within the prescribed limits.

The required limits under the specified process flow conditions are.

- Straight tubes - maximum : 7.0 ft/sec. (2.13 m/s)
- Straight tubes - minimum : 3.75 ft/sec. (1.14 m/s)
- U-tubes - maximum : 5.75 ft/sec. (1.75 m/s)
- U-tubes - minimum : 3.75 ft/sec. (1.14 m/s)

In general, the optimum velocity is 5.75 ft/sec (1.75 m/s).

Regarding slurry oil fouling, experience shows that with slurry oil velocities of 4.5 ft/sec (1.37 m/s) and higher, the tube wall surface will develop a dull shine.

A recommended fouling factor of 0.0010 hr-ft²-°F/Btu (0.00018 m²-K/W) will be shown on the item data sheet in the project specifications. Tubing shall be no less than 1" (25.400 mm)OD, to prevent plugging of the tubes with slurry "Chunks", nor less than 12 BWG because of the possibility of erosion that may occur at higher velocities.

A straight tube construction is recommended.

- (b) Horizontal units shall be designed so that the slurry flows either horizontally or downwards through the bundle.
- (c) Vertical units shall be installed with the channel head facing downwards. The channel head shall be TEMA type "C" with support lugs on the channel for shell removal with the bundle in place. The support design shall allow removal of the channel cover. A 1-1/2" (38.100 mm) drain shall be provided for intermediate channel passes.
- (c) A replaceable deflector or impact plate shall be provided at the inlet to divert the flow from the pass partition plate.

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Table 6-1. Maximum Unsupported Straight Tube Length in Inches (mm)

Tube O.D.	Maximum Unsupported Span	
	Tube Materials and Temperature Limits □(°C)	
	Carbon and high alloy steel 750 °F (399 °C) Low alloy steel 850 °F (454 °C) Nickel-copper 600 °F (316 °C) Nickel 850 °F (454 °C) Nickel-chromium-iron 1000 °F (538 °C)	Aluminum and aluminum alloys, Copper and copper alloys, Titanium and zirconium at code maximum allowable temperature
3/4inch (19.1mm)	60inch (1524mm)	52inch (1321mm)
1inch (25.4mm)	74inch (1880mm)	64inch (1626mm)
1-1/4inch (31.8mm)	88inch (2235mm)	76inch (1930mm)
1-1/2inch (38.1mm)	100inch (2540mm)	87inch (2210mm)
2inch (50.8mm)	125inch (3175mm)	110inch (2794mm)

Note : Above the metal temperature limits shown, maximum spans shall be reduced in direct proportion to the fourth root of the ratio of elastic modulus at temperature to elastic modulus at tabulated limit temperature. In the case of circumferentially finned tubes, the tube O.D. shall be the diameter at the root of the fins and the corresponding tabulated or interpolated span shall be reduced in direct proportion to the fourth root of the ratio of the weight per unit length of the tube, if stripped of fins to that of the actual finned tube. (All dimensions in inches)

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Table 6-2. Fouling Factor

FOULING RESISTANCE FOR WATER

Temperature of Heating Medium	Up to 240 °F (115.56 °C)		240 °F - 400 °F* (115.56 °C - 204.44 °C)	
Temperature of water	125 °F (51.67 °C) or Less		Over 125 °F (51.67 °C)	
Type of Water	Water Velocity Ft/Sec (m/s)		Water Velocity Ft/Sec (m/s)	
	3 ft/sec (0.91 m/s) and Less	Over 3 ft/sec (0.91m/s)	3 ft/sec (0.91 m/s) and Less	Over 3 ft/sec (0.91m/s)
Sea Water	0.0005 hr-ft ² -°F/Btu (0.00009 m ² -K/W)	0.0005 hr-ft ² -°F/Btu (0.00009 m ² -K/W)	0.001 hr-ft ² -°F/Btu (0.00018 m ² -K/W)	0.001 hr-ft ² -°F/Btu (0.00018 m ² -K/W)
Brackish Water	0.002 hr-ft ² -°F/Btu (0.00035 m ² -K/W)	0.001 hr-ft ² -°F/Btu (0.00018 m ² -K/W)	0.003 hr-ft ² -°F/Btu (0.00053 m ² -K/W)	0.002 hr-ft ² -°F/Btu (0.00035 m ² -K/W)
Cooling Tower and Artificial Spray Pond:				
Treated Makeup	0.001 hr-ft ² -°F/Btu (0.00018 m ² -K/W)	0.001 hr-ft ² -°F/Btu (0.00018 m ² -K/W)	0.002 hr-ft ² -°F/Btu (0.00035 m ² -K/W)	0.002 hr-ft ² -°F/Btu (0.00035 m ² -K/W)
Untreated	0.003 hr-ft ² -°F/Btu (0.00053 m ² -K/W)	0.003 hr-ft ² -°F/Btu (0.00053 m ² -K/W)	0.005 hr-ft ² -°F/Btu (0.00088 m ² -K/W)	0.004 hr-ft ² -°F/Btu (0.00070 m ² -K/W)
City or Well Water(Such as Great Lakes)	0.001 hr-ft ² -°F/Btu (0.00018 m ² -K/W)	0.001 hr-ft ² -°F/Btu (0.00018 m ² -K/W)	0.002 hr-ft ² -°F/Btu (0.00035 m ² -K/W)	0.002 hr-ft ² -°F/Btu (0.00035 m ² -K/W)

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River Water				
Minimum	0.002 hr-ft ² - °F/Btu (0.00035 m ² - K/W)	0.001 hr-ft ² - °F/Btu (0.00018 m ² - K/W)	0.003 hr-ft ² - °F/Btu (0.00053 m ² - K/W)	0.002 hr-ft ² - °F/Btu (0.00035 m ² -K/W)
Average	0.003 hr-ft ² - °F/Btu (0.00053 m ² - K/W)	0.002 hr-ft ² - °F/Btu (0.00035 m ² - K/W)	0.004 hr-ft ² - °F/Btu (0.00070 m ² - K/W)	0.003 hr-ft ² - °F/Btu (0.00053 m ² -K/W)
Muddy or Silty	0.003 hr-ft ² - °F/Btu (0.00053 m ² - K/W)	0.002 hr-ft ² - °F/Btu (0.00035 m ² - K/W)	0.004 hr-ft ² - °F/Btu (0.00070 m ² - K/W)	0.003 hr-ft ² - °F/Btu (0.00053 m ² -K/W)
Hard(Over 15 grains/gal.)	0.003 hr-ft ² - °F/Btu (0.00053 m ² - K/W)	0.003 hr-ft ² - °F/Btu (0.00053 m ² - K/W)	0.005 hr-ft ² - °F/Btu (0.00088 m ² - K/W)	0.005 hr-ft ² - °F/Btu (0.00088 m ² -K/W)
Engine Jacket	0.001 hr-ft ² - °F/Btu (0.00018 m ² - K/W)	0.001 hr-ft ² - °F/Btu (0.00018 m ² - K/W)	0.001 hr-ft ² - °F/Btu (0.00018 m ² - K/W)	0.001 hr-ft ² - °F/Btu (0.00018 m ² -K/W)
Distilled or Closed Cycle Condensate	0.0005 hr-ft ² - °F/Btu (0.00009 m ² - K/W)	0.0005 hr-ft ² - °F/Btu (0.00009 m ² - K/W)	0.0005 hr-ft ² - °F/Btu (0.00009 m ² - K/W)	0.0005 hr-ft ² - °F/Btu (0.00009 m ² -K/W)
Treated Boiler Feedwater	0.001 hr-ft ² - °F/Btu (0.00018 m ² - K/W)	0.0005 hr-ft ² - °F/Btu (0.00009 m ² - K/W)	0.001 hr-ft ² - °F/Btu (0.00018 m ² - K/W)	0.001 hr-ft ² - °F/Btu (0.00018 m ² -K/W)
Boiler Blowdown	0.002 hr-ft ² - °F/Btu (0.00035 m ² - K/W)	0.002 hr-ft ² - °F/Btu (0.00035 m ² - K/W)	0.002 hr-ft ² - °F/Btu (0.00035 m ² - K/W)	0.002 hr-ft ² - °F/Btu (0.00035 m ² -K/W)

* Ratings in columns 3 and 4 are based on a temperature of the heating medium of 240-400° (115.56 - 204.44 °C). If the heating medium temperature is over 400° (204.44 °C). And the cooling medium is known to scale, these ratings should be modified accordingly

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Table 6-2. Fouling Factor (continued)

FOULING RESISTANCES FOR INDUSTRIAL FLUIDS

OILS

Fuel Oil	0.005 hr-ft ² -°F/Btu (0.00088 m ² -K/W)
Transformer Oil	0.001 hr-ft ² -°F/Btu (0.00018 m ² -K/W)
Engine Lube	0.001 hr-ft ² -°F/Btu (0.00018 m ² -K/W)
Quench Oil	0.004 hr-ft ² -°F/Btu (0.00070 m ² -K/W)

GASES AND VAPORS

Manufactured Gas	0.010 hr-ft ² -°F/Btu (0.00176 m ² -K/W)
Engine Exhaust Gas	0.010 hr-ft ² -°F/Btu (0.00176 m ² -K/W)
Steam(non-oil bearing)	0.0005 hr-ft ² -°F/Btu (0.00009 m ² -K/W)
Exhaust Steam(oil bearing)	0.0015-0.002 hr-ft ² -°F/Btu (0.00026 – 0.00035 m ² -K/W)
Refrigerant Vapors(oil bearing)	0.002 hr-ft ² -°F/Btu (0.00035 m ² -K/W)
Compressed Air	0.001 hr-ft ² -°F/Btu (0.00018 m ² -K/W)

LIQUIDS

Refrigerant Liquids	0.001 hr-ft ² -°F/Btu (0.00018 m ² -K/W)
Hydraulic Fluid	0.001 hr-ft ² -°F/Btu (0.00018 m ² -K/W)
Industrial Organic Heat Transfer Media	0.002 hr-ft ² -°F/Btu (0.00035 m ² -K/W)
Molten Heat Transfer Salts	0.0005 hr-ft ² -°F/Btu (0.00009 m ² -K/W)

FOULING RESISTANCES FOR CHEMICAL PROCESSING STREAMS

GASES AND VAPORS

Acid Gas	0.002-0.003 hr-ft ² -°F/Btu (0.00035 – 0.00053 m ² -K/W)
Solvent Vapors	0.001 hr-ft ² -°F/Btu (0.00018 m ² -K/W)
Stable Overhead Products	0.001 hr-ft ² -°F/Btu (0.00018 m ² -K/W)
LIQUIDS MEA & DEA Solutions	0.002 hr-ft ² -°F/Btu (0.00035 m ² -K/W)
DEG & TEG Solutions	0.002 hr-ft ² -°F/Btu (0.00035 m ² -K/W)
Stable Side Draw and Bottom Product	0.001-0.002 hr-ft ² -°F/Btu (0.00018 – 0.00035 m ² -K/W)
Caustic Solutions	0.002 hr-ft ² -°F/Btu (0.00035 m ² -K/W)
Vegetable Oils	0.003 hr-ft ² -°F/Btu (0.00053 m ² -K/W)

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Table 6-2. Fouling Factor (continued)

FOULING RESISTANCES FOR NATURAL GAS-GASOLINE PROCESSING STREAMS

GASES AND VAPORS

Natural Gas 0.001-0.002 hr-ft²-°F/Btu (0.00018 – 0.00035 m²-K/W)

Overhead Products 0.001-0.002 hr-ft²-°F/Btu (0.00018 – 0.00035 m²-K/W)

LIQUIDS

Lean Oil 0.002 hr-ft²-°F/Btu (0.00035 m²-K/W)

Rich Oil 0.001-0.002 hr-ft²-°F/Btu (0.00018 – 0.00035 m²-K/W)

Natural Gasoline & Liquefied Petroleum Gases 0.001-0.002 hr-ft²-°F/Btu (0.00018 – 0.00035 m²-K/W)

FOULING RESISTANCES FOR OIL REFINERY STREAMS

CRUDE & VACUUM UNIT GASES AND VAPORS

Atmospheric Tower Overhead Vapors 0.001 hr-ft²-°F/Btu (0.00018 m²-K/W)

Light Naphthas 0.001 hr-ft²-°F/Btu (0.00018 m²-K/W)

Vacuum Overhead Vapors 0.002 hr-ft²-°F/Btu (0.00035 m²-K/W)

CRUDE & VACUUM LIQUIDS

Crude Oil

	0-250 °F (-17.78 to 121.11 °C)			250 - 350 °F (121.11 - 176.67 °C)		
	Velocity ft./sec (m/s)			Velocity ft./sec (m/s)		
	Under 2 ft./sec (< 0.61 m/s)	From 2 to 4 ft./sec (0.61 – 1.22 m/s)	4 and Over ft./sec (> 1.22 m/s)	Under 2 ft./sec (< 0.61 m/s)	From 2 to 4 ft./sec (0.61 – 1.22 m/s)	4 and Over ft./sec (> 1.22 m/s)
Dry	0.003 hr- ft ² -°F/Btu (0.00053 m ² -K/W)	0.002 hr-ft ² - °F/Btu (0.00035 m ² -K/W)	0.002 hr-ft ² - °F/Btu (0.00035 m ² - K/W)	0.003 hr- ft ² -°F/Btu (0.00053 m ² -K/W)	0.002 hr-ft ² - °F/Btu (0.00035 m ² -K/W)	0.002 hr-ft ² - °F/Btu (0.00035 m ² - K/W)
Salt	0.003 hr- ft ² -°F/Btu (0.00053 m ² -K/W)	0.002 hr-ft ² - °F/Btu (0.00035 m ² -K/W)	0.002 hr-ft ² - °F/Btu (0.00035 m ² - K/W)	0.005 hr- ft ² -°F/Btu (0.00088 m ² -K/W)	0.004 hr-ft ² - °F/Btu (0.00070 m ² -K/W)	0.004 hr-ft ² - °F/Btu (0.00070 m ² - K/W)
	350 to 450 °F (176.67 – 232.22 °C)			450 °F and over (> 232.22 °C)		
	Velocity ft./sec			Velocity ft./sec		

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	Under 2 ft./sec (< 0.61 m/s)	From 2 to 4 ft./sec (0.61 – 1.22 m/s)	4 and Over ft./sec (> 1.22 m/s)	Under 2 ft./sec (< 0.61 m/s)	From 2 to 4 ft./sec (0.61 – 1.22 m/s)	4 and Over ft./sec (> 1.22 m/s)
Dry	0.004 hr- ft ² -°F/Btu (0.00070 m ² -K/W)	0.003 hr-ft ² - °F/Btu (0.00053 m ² -K/W)	0.003 hr-ft ² - °F/Btu (0.00053 m ² - K/W)	0.005 hr- ft ² -°F/Btu (0.00088 m ² -K/W)	0.004 hr-ft ² - °F/Btu (0.00070 m ² -K/W)	0.004 hr-ft ² - °F/Btu (0.00070 m ² - K/W)
Salt♣	0.006 hr- ft ² -°F/Btu (0.00106 m ² -K/W)	0.005 hr-ft ² - °F/Btu (0.00088 m ² -K/W)	0.005 hr-ft ² - °F/Btu (0.00088 m ² - K/W)	0.007 hr- ft ² -°F/Btu (0.00123 m ² -K/W)	0.006 hr-ft ² - °F/Btu (0.00106 m ² -K/W)	0.006 hr-ft ² - °F/Btu (0.00106 m ² - K/W)

♣ Normally desalted below this temperature range. (♣ to apply to 250-350 ° (121.11 – 176.67 °C), 350-450 ° (176.67 – 232.22 °C), 450 ° (232.22 °C) and over.)

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Table 6-2. Fouling Factor (continued)

Gasoline	0.002 hr-ft ² -°F/Btu (0.00035 m ² -K/W)
Naphtha & Light Distillates	0.002-0.003 hr-ft ² -°F/Btu (0.00035 – 0.00053 m ² -K/W)
Kerosene	0.002-0.003 hr-ft ² -°F/Btu (0.00035 – 0.00053 m ² -K/W)
Light Gas Oil	0.002-0.003 hr-ft ² -°F/Btu (0.00035 – 0.00053 m ² -K/W)
Heavy Gas Oil	0.003-0.005 hr-ft ² -°F/Btu (0.00053 – 0.00088 m ² -K/W)
Heavy Fuel Oils	0.005-0.007 hr-ft ² -°F/Btu (0.00088 – 0.00123 m ² -K/W)
Asphalt & Residuum	0.010 hr-ft ² -°F/Btu (0.00176 m ² -K/W)
CRACKING & COKING UNIT STREAMS	
Overhead Vapors	0.002 hr-ft ² -°F/Btu (0.00035 m ² -K/W)
Light Cycle Oil	0.002-0.003 hr-ft ² -°F/Btu (0.00035 – 0.00053 m ² -K/W)
Heavy Cycle Oil	0.003-0.004 hr-ft ² -°F/Btu (0.00053 – 0.00070 m ² -K/W)
Light Coker Gas Oil	0.003-0.004 hr-ft ² -°F/Btu (0.00053 – 0.00070 m ² -K/W)
Heavy Coker Gas Oil	0.004-0.005 hr-ft ² -°F/Btu (0.00070 – 0.00088 m ² -K/W)
Bottoms Slurry Oil(4½ft./sec.minimum)	0.003 hr-ft ² -°F/Btu (0.00053 m ² -K/W)
Light Liquid Products	0.002 hr-ft ² -°F/Btu (0.00035 m ² -K/W)
CATALYTIC REFORMING, HYDROCRACKING, & HYDRODESULFURIZATION STREAMS	
Reformer Charge	0.0015 hr-ft ² -°F/Btu (0.00026 m ² -K/W)
Reformer Effluent	0.0015 hr-ft ² -°F/Btu (0.00026 m ² -K/W)
Hydrocracker Charge & Effluent**	0.002 hr-ft ² -°F/Btu (0.00035 m ² -K/W)

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Recycle Gas	0.001 hr-ft ² -°F/Btu
(0.00018 m ² -K/W)	
Hydrodesulfurization Charge & Effluent**	0.002 hr-ft ² -°F/Btu
(0.00035 m ² -K/W)	
Overhead Vapors	0.001 hr-ft ² -°F/Btu
(0.00018 m ² -K/W)	
Liquid Product over 50° A.P.I.	0.001 hr-ft ² -°F/Btu
(0.00018 m ² -K/W)	
Liquid Product 30° - 50° A.P.I.	0.002 hr-ft ² -°F/Btu
(0.00035 m ² -K/W)	

** Depending on charge characteristics and storage history, charge resistance may be many times this value

LIGHT ENDS PROCESSING STREAMS

Overhead Vapors & Gases	0.001 hr-ft ² -°F/Btu
(0.00018 m ² -K/W)	
Liquid Products	0.001 hr-ft ² -°F/Btu
(0.00018 m ² -K/W)	
Absorption Oils	0.002-0.003 hr-ft ² -
°F/Btu (0.00035 – 0.00053 m ² -K/W)	
Alkylation Trace Acid Streams	0.002 hr-ft ² -°F/Btu
(0.00035 m ² -K/W)	
Reboiler Streams	0.002-0.003 hr-ft ² -
°F/Btu (0.00035 – 0.00053 m ² -K/W)	

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Table 6-2. Fouling Factor (continued)

LUBE OIL PROCESSING STREAMS

Feed Stock	0.002 hr-ft ² -°F/Btu
(0.00035 m ² -K/W)	
Solvent Feed Mix	0.002 hr-ft ² -°F/Btu
(0.00035 m ² -K/W)	
Solvent♣	0.001 hr-ft ² -°F/Btu
(0.00018 m ² -K/W)	
Extract♣	0.003 hr-ft ² -°F/Btu
(0.00053 m ² -K/W)	
Raffinate	0.001 hr-ft ² -°F/Btu
(0.00018 m ² -K/W)	
Asphalt	0.005 hr-ft ² -°F/Btu
(0.00088 m ² -K/W)	
Wax Slurries	0.003 hr-ft ² -°F/Btu
(0.00053 m ² -K/W)	
Refined Lube Oil	0.001 hr-ft ² -°F/Btu
(0.00018 m ² -K/W)	

♣ Precautions must be taken to prevent wax deposition on cold tube walls.

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Table 6-3. Check List for Flow-Induced Vibration

Step	Item	Low Probability of Vibration Problems	High Probability of Vibration Problems
1	Ratio of cross flow to critical velocity	< 0.8	> 1.0
2	Ratio of vortex shedding to tube natural frequency	< 0.3	> 0.5
3	Ratio of turbulent buffering to tube natural frequency	< 0.3	> 0.5
4	Cross flow amplitude	< 0.01(PT-DRO)	> 0.5(PT-DTO)
5	Ratio of vortex shedding to acoustic frequency	< 0.8	> 0.8 and < 1.2
6	Ratio of turbulent buffering to acoustic frequency	< 0.8	> 0.8 and < 1.2
7	Ratio of tube natural to acoustic frequency	< 0.8	> 0.8 and < 1.2
8	Span length/TEMA max.	< 0.8	> 1.0
9	Parallel flow amplitude	< 0.0075	> 0.5(PT-DTO)
10	Baffle damage number	See HTRI Report STV-1 ⁽¹⁰⁾	> 1.0
11	Collision damage number	See HTRI Report STV-1 ⁽¹⁰⁾	> 1.0
12	C-stream velocity	< Cross flow	»Cross flow
13	E-stream velocity	< Window	»Window

Fig. 5-1. TEMA Type

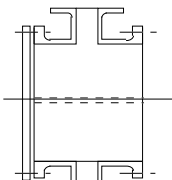
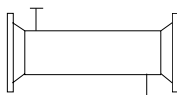
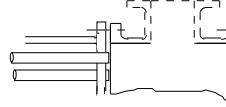
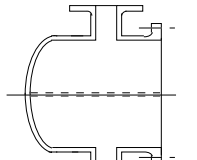
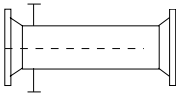
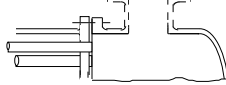
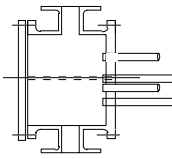
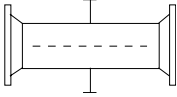
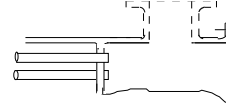
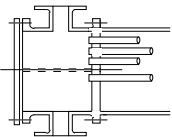
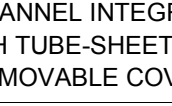
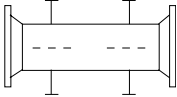
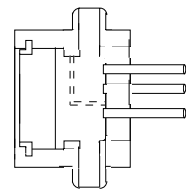
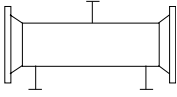
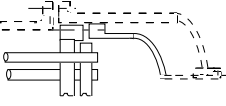
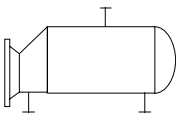
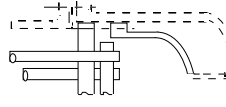
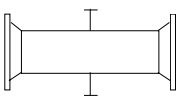
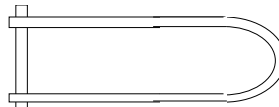
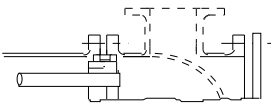
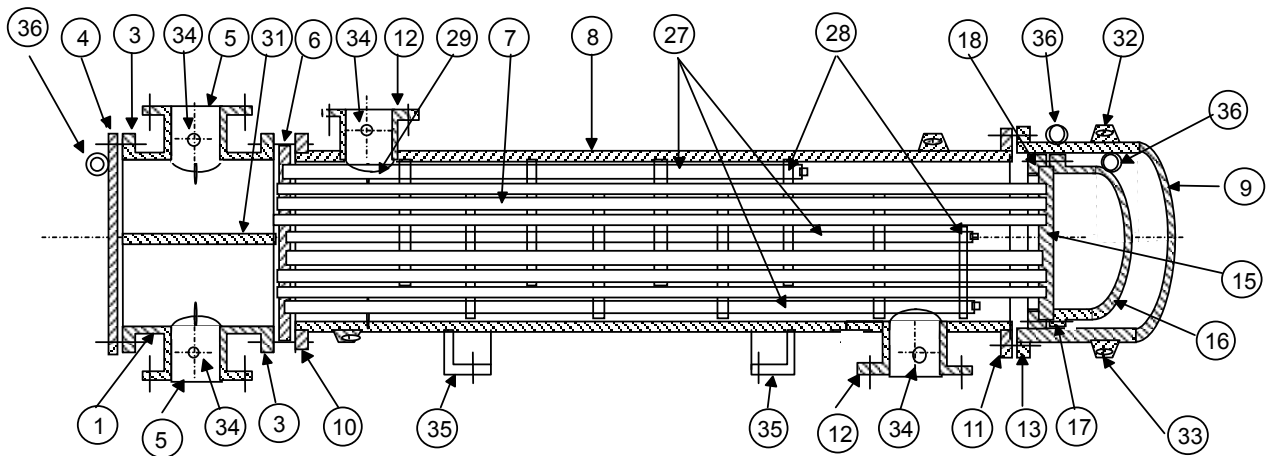
	FRONT END STATIONARY HEAD TYPES	SHELL TYPES	REAR END HEAD TYPES
A		E  ONE PASS SHELL	L  FIXED TUBESHEET LIKE "A" STATIONARY HEAD
	B  BONNET (INTEGRAL COVER)	F  TWO PASS SHELL WITH LONGITUDINAL BAFFLE	M  FIXED TUBESHEET LIKE "B" STATIONARY HEAD
C		G  SPLIT FLOW	N  FIXED TUBESHEET LIKE "N" STATIONARY HEAD
	N  CHANNEL INTEGRAL WITH TUBE-SHEET AND REMOVABLE COVER  CHANNEL INTEGRAL WITH TUBE-SHEET AND REMOVABLE COVER	H  DOUBLE SPLIT FLOW	P  OUTSIDE PACKED FLOATING HEAD
D	 SPECIAL HIGH PRESSURE CLOSURE	J  DIVIDED FLOW	S  FLOATING HEAD WITH BACKING DEVICE
		K  KETTLE TYPE REBOILER	T  PULL THROUGH FLOATING HEAD
		X  CROSS FLOW	U  U-TUBE BUNDLE W  EXTERNALLY SEALED FLOATING TUBESHEET

Fig. 5-2. Typical Configuration of Heat Exchanger

- | | |
|---|--|
| 1. Stationary Head-Channel | 20. Slip-on Backing Flange |
| 2. Stationary Head-Bonnet | 21. Floating Head Cover-External |
| 3. Stationary Head Flange-Channel or Bonnet | 22. Floating Tubesheet Skirt |
| 4. Channel Cover | 23. Packing Box |
| 5. Stationary Head Nozzle | 24. Packing |
| 6. Stationary Tubesheet | 25. Packing Gland |
| 7. Tubes | 26. Lantern Ring |
| 8. Shell | 27. Tierods and Spacers |
| 9. Shell Cover | 28. Transverse Baffles or Support Plates |
| 10. Shell Flange-Stationary Head End | 29. Impingement Plate |
| 11. Shell Flange-Rear Head End | 30. Longitudinal Baffle |
| 12. Shell Nozzle | 31. Pass Partition |
| 13. Shell Cover Flange | 32. Vent Connection |
| 14. Expansion Joint | 33. Drain Connection |
| 15. Floating Tubesheet | 34. Instrument Connection |
| 16. Floating Head Cover | 35. Supports Saddle |
| 17. Floating Head Flange | 36. Lifting Lug |
| 18. Floating Head Backing Device | 37. Support Bracket |
| 19. Split Sheer Ring | 38. Weir |
| | 39. Liquid Level Connection |



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Fig. 5-2. Typical Configuration of Heat Exchanger (continued)

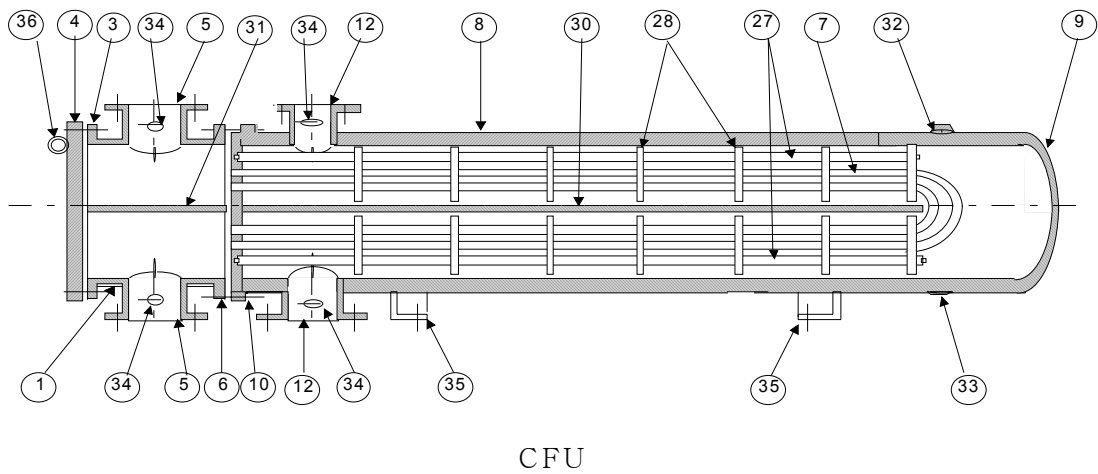
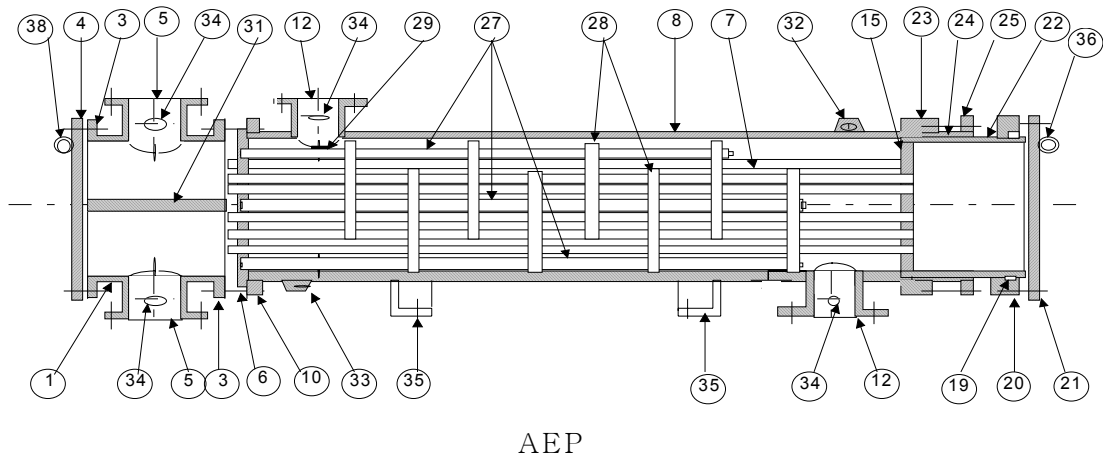
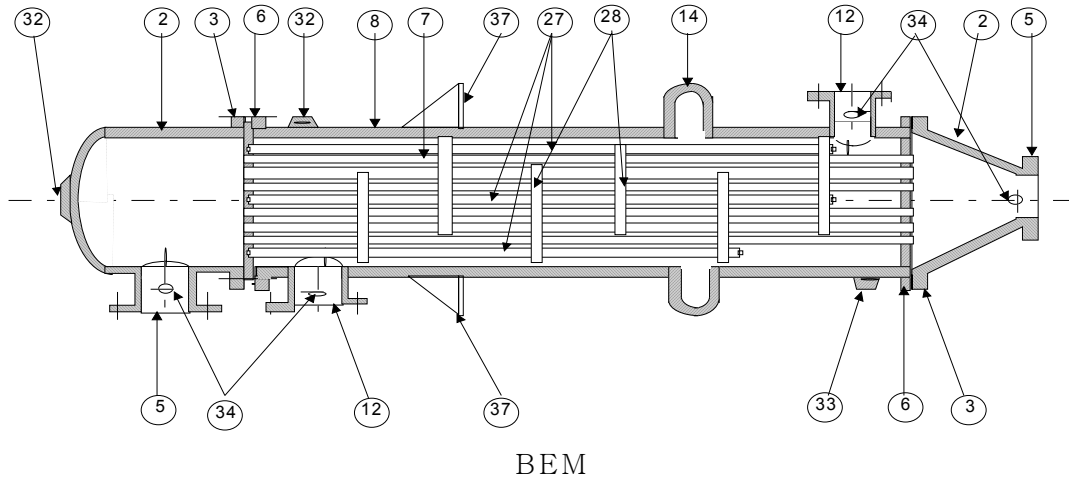


Fig. 5-2. Typical Configuration of Heat Exchanger (concluded)

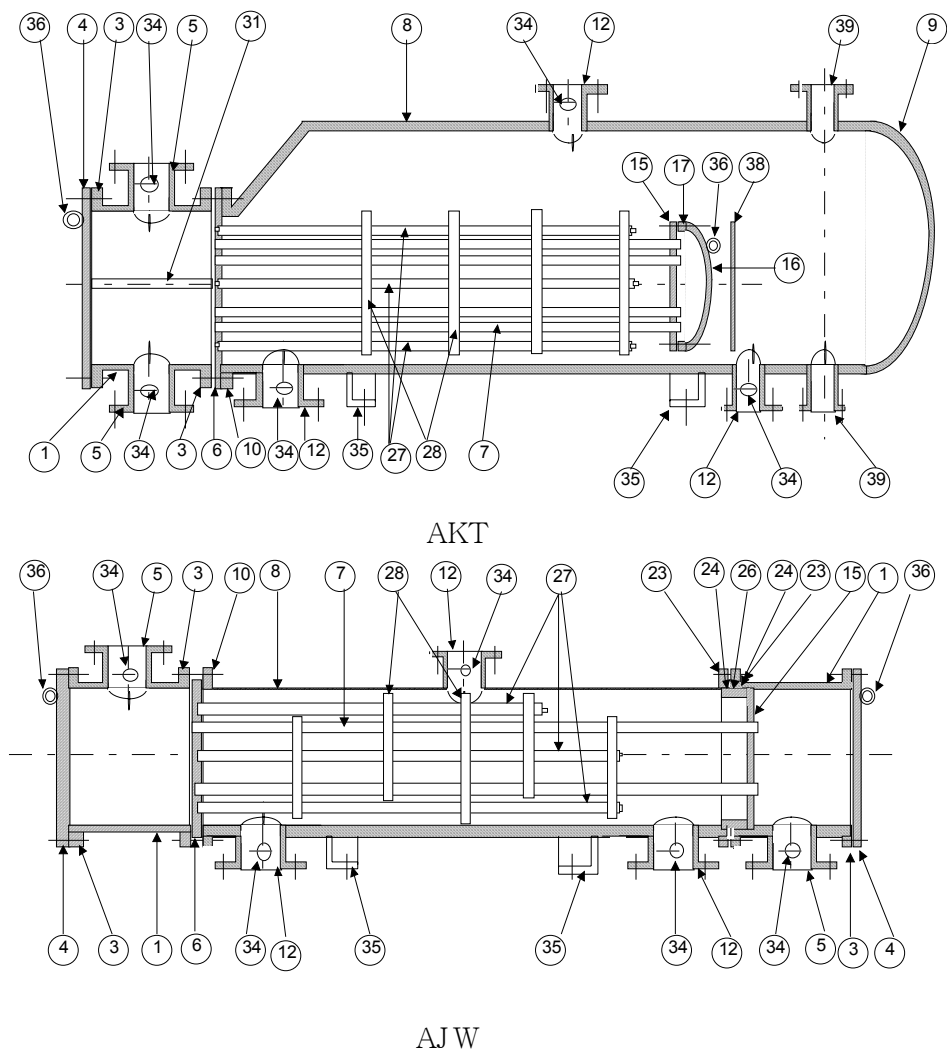


Fig. 6-1. Tube Patterns

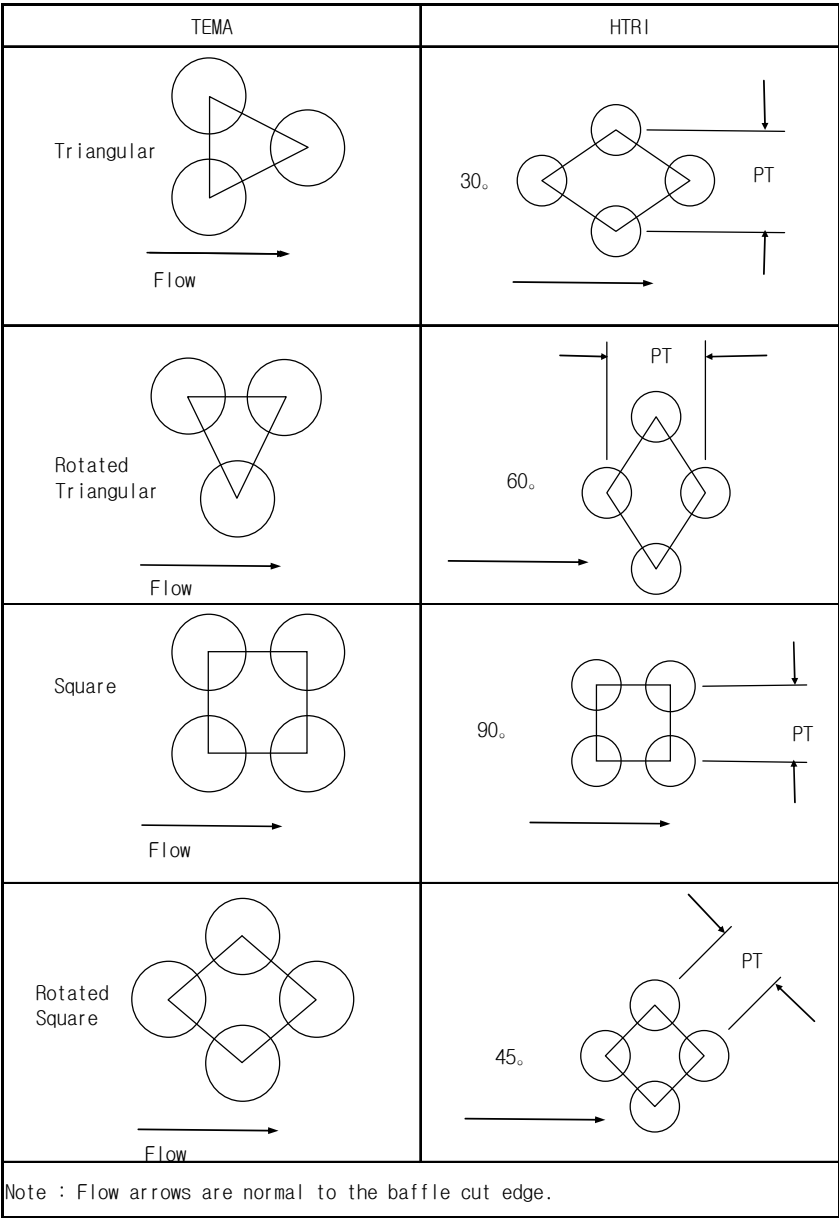
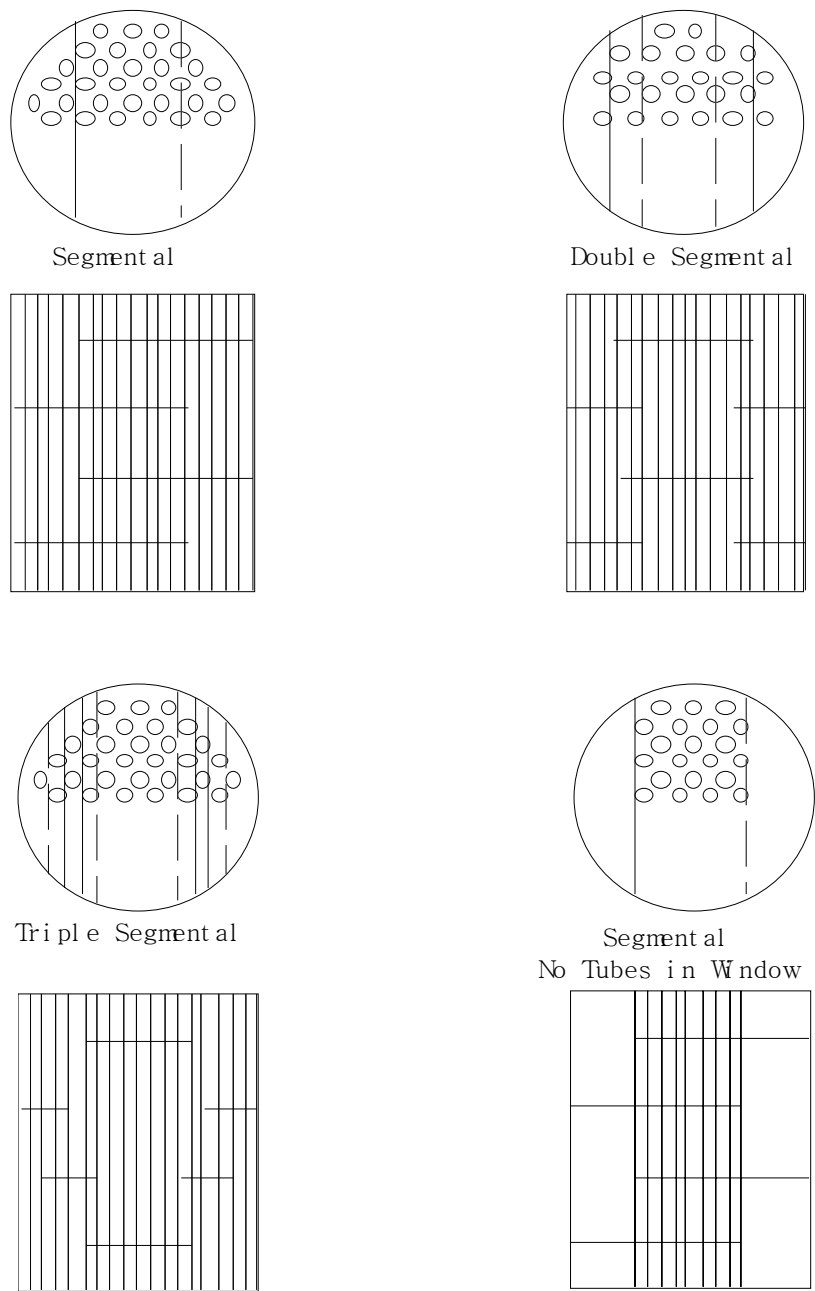
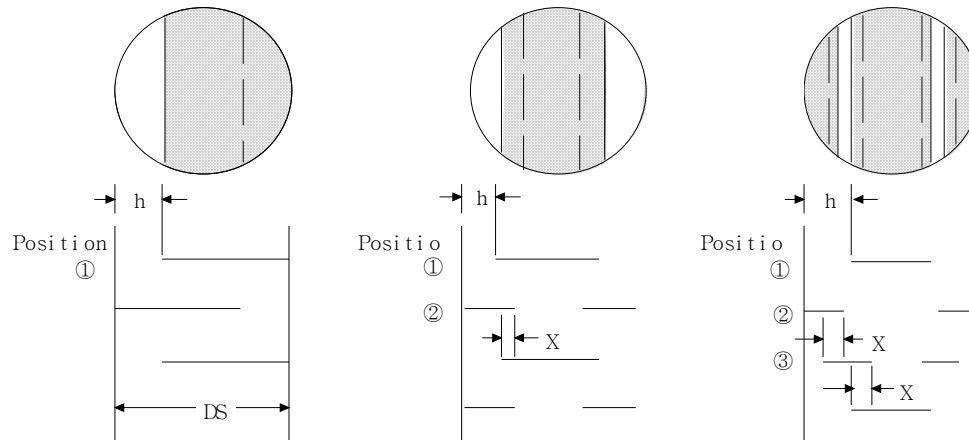


Fig. 6-2. Baffle Types



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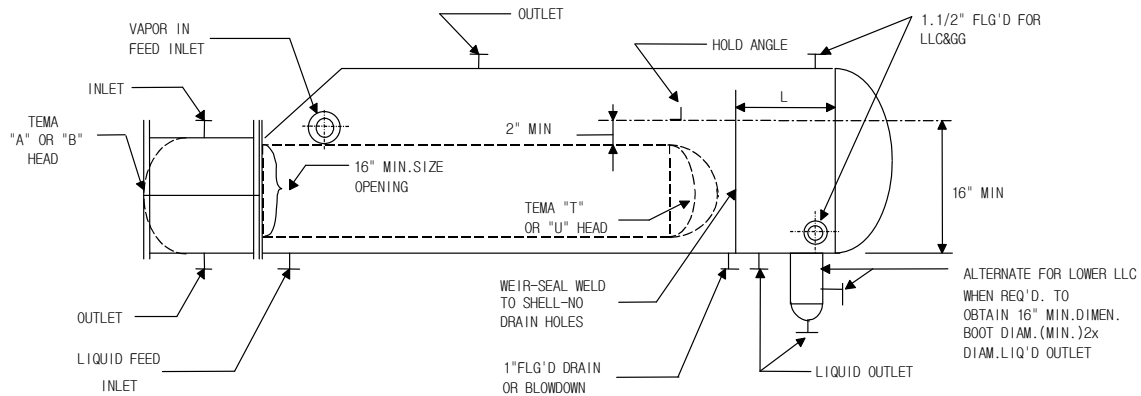
Fig. 6-3. Baffle Cut



Note: %Baffle cut = $h/DS \times 100$

Overlap = X (normally two tube rows overlap)

Fig 6-4. Typical Kettle Type Reboiler



WHEN SURGE CAPACITY IS NOT SPECIFIED ON PROJECT SPECIFICATION
L=4FT. FOR 16FT. OR LONGER TUBES OR L=3FT. FOR SHORTER TUBES

7. Reference

- (1) Standard of Tubular Exchanger Manufacturers Association, Ninth edition
- (2) UOP Standard Specification (4-11-0)
- (3) Petroleum Refinery Engineering (Chapter .17)
- (4) HTRI Computer Programs Support Volume
- (5) Applied Process Design for Chemical and Petrochemical Plants(Volume 2)
- (6) Esso General Specification
- (7) HTRI Design Manual
- (8) Petroleum Processing (March 1956)
- (9) Process Heat Transfer
- (10) HTRI Technical report, STV-1 Tube Vibrations in Shell-and-Tube Heat Exchangers (1974; revised 1978)

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DATE : 2013. 05. 16		

8. Revision History

Rev. No.	Rev. Date	Rev. Page	Description
0	1998.4.17	All Page	- First Edition - Team : Process Eng'g Team - Made by : S.H.Han I.S.Kim - Checked by : B.I.Lee S.B.Jo J.C.Ro - Approved by : S.G.Oh
1	2004.10.30	All Page	- Made by : W.J.Lee - Checked by : J.H.Park J.C.Ro M.H. Oh - E.D. Lee - Approved by : C.S.Jung
2	2009.05.29	-	- Made by : C.H.Yun - Checked by : Henry.Sung J.C.Ro E.D. Lee - Approved by : C.S.Jung
3	2010. 11. 20	All	Document number revision - Prepared by : D.S. Song - Reviewed by : H. Sung, J.C. Ro, H.H. Kwak, M.H. Oh, S.U. Hong - Approved by : E.D. Lee
4	2013.05.16	All pages	Add US Units symbol and SI Units symbol for values. Update Equations, references and tables. - Prepared by : C.H. Park - Reviewed by : J.C. Ro - Approved by : S.B. Lee