Pressure Vessel Newsletter

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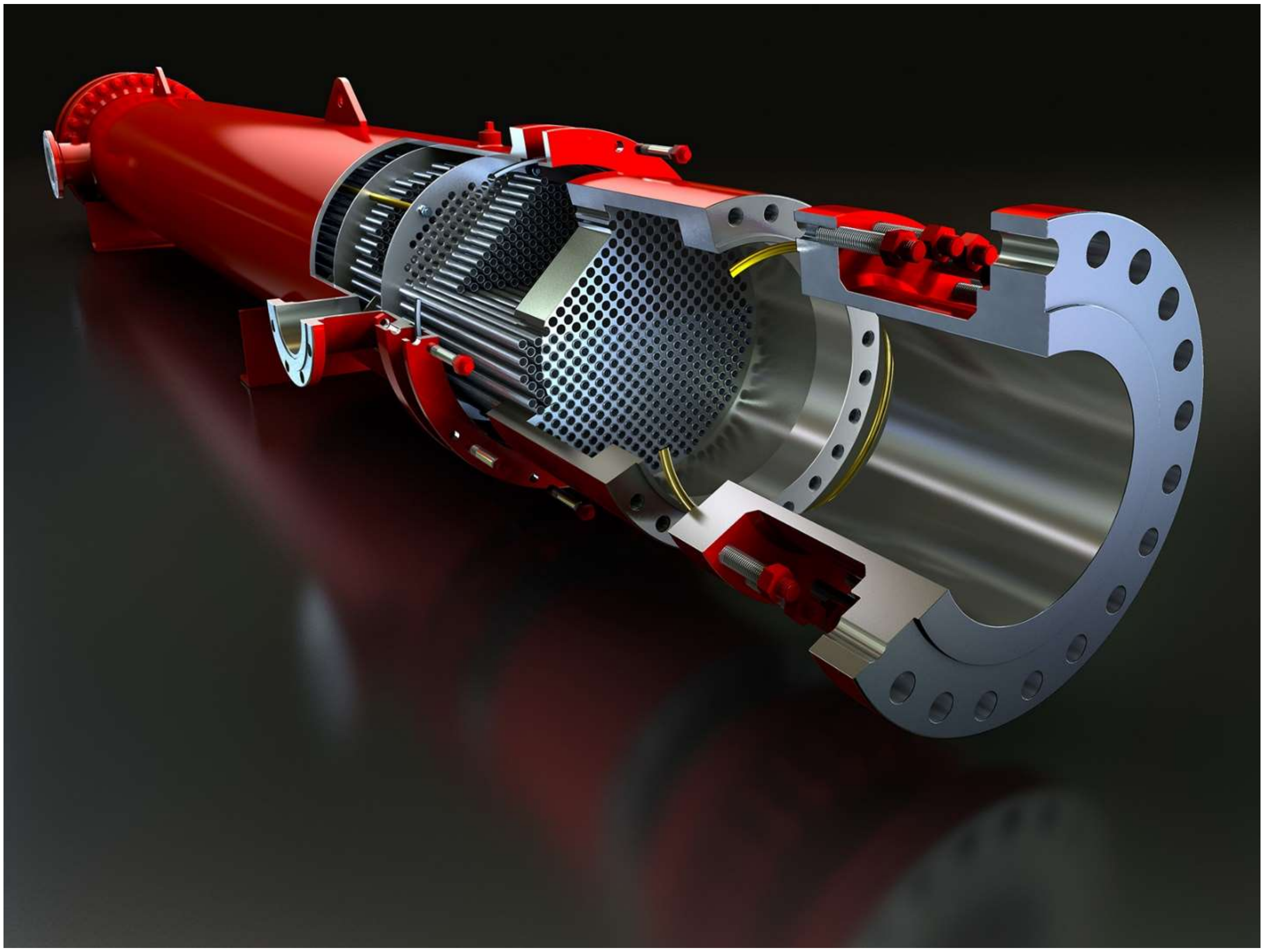

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From The Editor's Desk:

Who hasn't heard of the phrase, "Change is the only constant"; for most of us, change is an unavoidable fact. Embracing change in work and life is essential to growing as an individual and being a better person than we were yesterday.

Here are some ways that you can learn to be comfortable with the discomfort of change, and use change as a success tool:

Take small action steps

If you can start with an end goal, work backward and break your goal into small action steps until you can get to the very first one. This is usually something you can control. Once you can accomplish this milestone, tackle the next one. These small steps make change palatable and easier to embrace.

Be willing to go back in order to move forward

Success is not linear; so expect that when you face change, there will be a time that you will have to move backward. This may be in terms of status, pay or some other factor required to get to next level. It may also include going back to school. If your mind knows that's a part of the process and removes the uncertainty around it, it becomes easier to embrace.

Check your ego

Typically, the biggest roadblock to change is you. Often, there is little downside other than facing your own bruised ego when you evaluate change. To counteract this, quiz yourself about the downside of pursuing change if it doesn't work out. If the downside is primarily a concern about failure, it is time to get over it.

Fail correctly

Most of us were never taught to fail. Our school system is set up so that success is given a gold star and failure is ridiculed. This is unfortunate because failure, when done correctly, is a good thing. It is required for taking on risk and pursuing entrepreneurial endeavors. The right way to fail means doing it quickly, inexpensively, and never the same way twice. And, of course, you need to learn from your failures.

CHANGE IS NECESSARY AND IT IS NOT EVIL. LEARN TO LOVE IT AND YOU WILL BE POISED FOR SUCCESS.

Ramesh K Tiwari

In this issue…

AN OVERVIEW OF HEAT EXCHANGERS

TYPES OF HEAT EXCHANGERS

Heat transfer is an important function of many industrial processes. Heat exchangers are widely used to transfer heat from one process to another. A heat exchanger allows a hot fluid to transfer heat energy to a cooler fluid through conduction and convection. A heat exchanger provides heating or cooling to a process. A wide array of heat exchangers has been designed and manufactured for use in the chemical processing industry.

In pipe coil exchangers, pipe coils are submerged in water or sprayed with water to transfer heat. This type of operation has a low heat transfer coefficient and requires a lot of space. It is best suited for condensing vapors with low heat loads.

The double-pipe heat exchanger incorporates a tube-within-a-tube design. It can be found with plain or externally finned tubes. Double-pipe heat exchangers are typically used in series-flow operations in high-pressure applications up to 500 psig shell side and 5,000 psig tube side.

Figure 1: Fixed Head Heat Exchanger

A shell-and-tube heat exchanger has a cylindrical shell that surrounds a tube bundle. Fluid flow through the exchanger is referred to as tubeside flow or shell-side flow. A series of baffles support the tubes, direct fluid flow, increase velocity, decrease tube vibration, protect tubing, and create pressure drops. Shell-and-tube heat exchangers can be classified as fixed head, single pass; fixed head, multipass; floating head, multipass; or U-tube. On a fixed head heat exchanger (Figure 1), tube sheets are attached to the shell. Fixed head heat exchangers are designed to handle temperature differentials up to 200°F. Thermal expansion prevents a fixed head heat exchanger from exceeding this differential temperature. It is best suited for condenser or heater operations. Floating head heat exchangers are designed for high temperature differentials above 200°F. During operation, one tube sheet is fixed and the other floats" inside the shell. The floating end is not attached to the shell and is free to expand.

Reboilers are heat exchangers that are used to add heat to a liquid that was once boiling until the liquid boils again. Types commonly used in industry are kettle reboilers and thermosyphon reboilers.

Plate-and-frame heat exchangers are composed of thin, alternating metal plates that are designed for hot and cold service. Each plate has an outer gasket that seals each compartment. Plate-and-frame heat exchangers have a cold and hot fluid inlet and outlet. Cold and hot fluid headers are formed inside the plate pack, allowing access from every other plate on the hot and cold sides. This device is best suited for viscous or corrosive fluid slurries. It provides excellent high heat transfer. Plate-and-frame heat exchangers are compact and easy to clean. Operating limits of 350 to 500°F are designed to protect the internal gasket. Because of the design specification, plate-and-frame heat exchangers are not suited for boiling and condensing. Most industrial processes use this design in liquid-liquid service.

Air-cooled heat exchangers do not require the use of a shell in operation. Process tubes are connected to an inlet and a return header box. The tubes can be finned or plain. A fan is used to push or pull outside air over the exposed tubes. Air-cooled heat exchangers are primarily used in condensing operations where a high level of heat transfer is required.

The Tubular Exchanger Manufacturers Association (TEMA) classifies heat exchangers by a variety of design specifications including American Society of Mechanical Engineers (ASME) construction code, tolerances, and mechanical design:

- Class B, Designed for general-purpose operation *(economy and compact design)*
- Class C. Designed for moderate service and general-purpose operation *(economy and compact design)*
- Class R. Designed for severe conditions *(safety and durability)*

HEAT TRANSFER AND FLUID FLOW

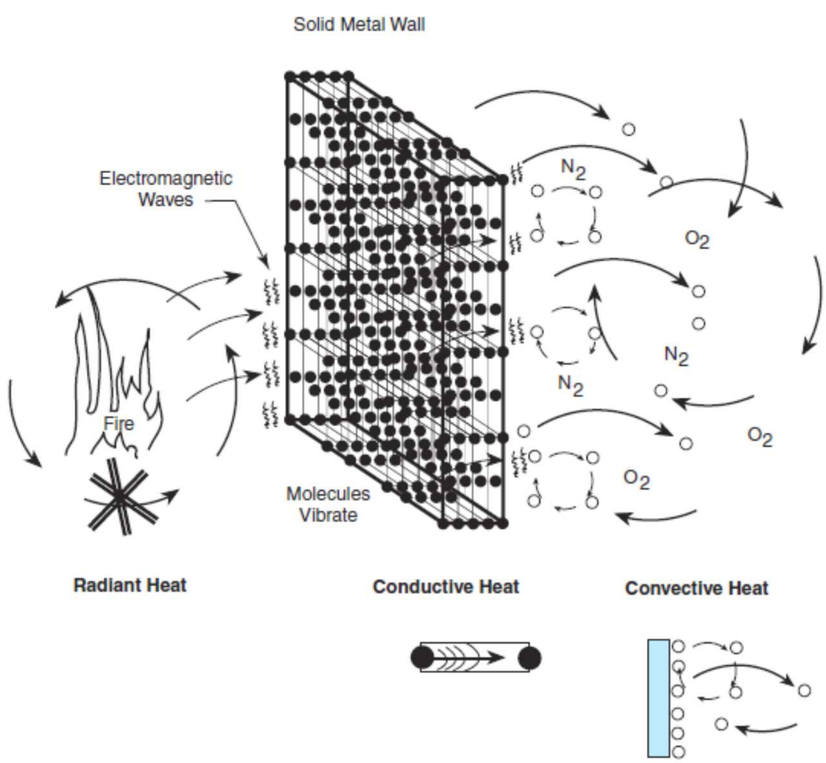

Figure 2: Heat Transfer

The methods of heat transfer are conduction, convection, and radiant heat transfer (Figure 2). In the petrochemical, refinery, and laboratory environments, these methods need to be understood well. A combination of conduction and convection heat transfer processes can be found in all heat exchangers. The best conditions for heat transfer are large temperature differences between the products being heated and cooled (the higher the temperature difference, the greater the heat transfer), high heating or coolant flow rates, and a large cross-sectional area of the exchanger.

Conduction

Heat energy is transferred through solid objects such as tubes, heads, baffles, plates, fins, and shell, by conduction. This process occurs when the molecules that make up the solid matrix begin to absorb heat energy from a hotter source. Since the molecules are in a fixed matrix and cannot move, they begin to vibrate and, in so doing, transfer the energy from the hot side to the cooler side.

Convection

Convection occurs in fluids when warmer molecules move toward cooler molecules. The movement of the molecules sets up currents in the fluid that redistribute heat energy. This process will continue until the energy is distributed equally. In a heat exchanger, this process occurs in the moving fluid media as they pass by each other in the exchanger. Baffle arrangements and flow direction will determine how this convective process will occur in the various sections of the exchanger.

Radiant Heat Transfer

The best example of radiant heat is the sun's warming of the earth. The sun's heat is conveyed by electromagnetic waves. Radiant heat transfer is a line-of-sight process, so the position of the source and that of the receiver are important. Radiant heat transfer is not used in a heat exchanger.

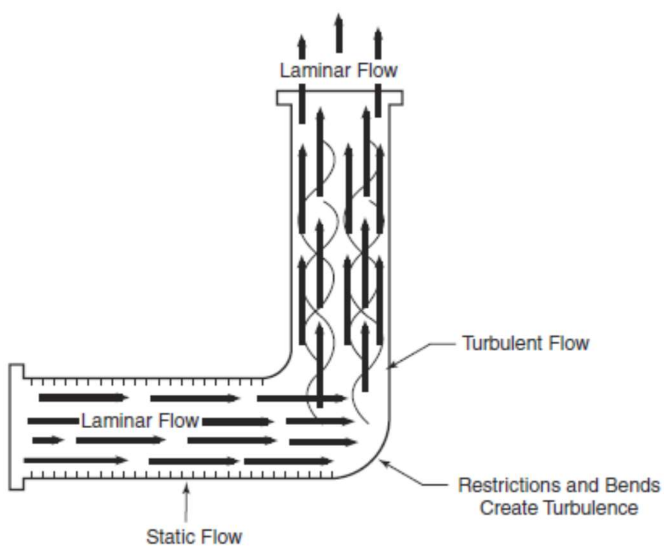

Figure 3: Laminar and Turbulent Flow

Laminar and Turbulent Flow

Two major classifications of fluid flow are laminar and turbulent (Figure 3). Laminar flow moves through a system in thin cylindrical layers of liquid flowing in parallel fashion. This type of flow will have little if any turbulence (swirling or eddying) in it. Laminar flow usually exists at low flow rates. As flow rates increase, the laminar flow pattern changes into a turbulent flow pattern. Turbulent flow is the random movement or mixing of fluids. Once the turbulent flow is initiated, molecular activity speeds up until the fluid is uniformly turbulent. Turbulent flow allows molecules of fluid to mix and absorb heat more readily than does laminar flow.

<u>Parallel and Series Flow</u>

Heat exchangers can be connected in a variety of ways. The two most common are series and parallel (Figure 4). In series flow, the tube-side flow in a multipass heat exchanger is discharged into the tubeside flow of the second exchanger. This discharge route could be switched to shell side or tube side depending on how the exchanger is in service. The guiding principle is that the flow passes through one exchanger before it goes to another. In parallel flow, the process flow goes through multiple exchangers at the same time.

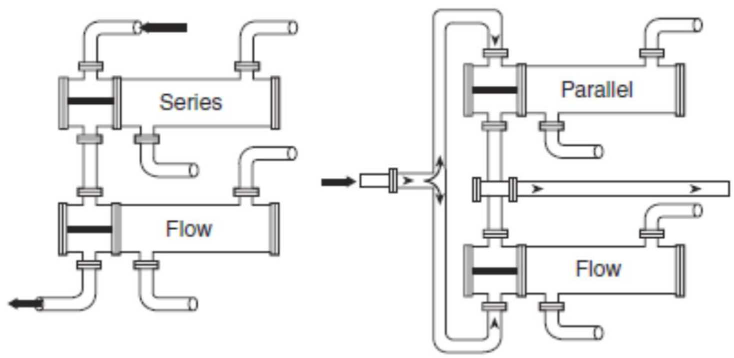

Figure 4: Parallel and Series Flow

<u>Heat Exchanger Effectiveness</u>

The design of an exchanger usually dictates how effectively it can transfer heat energy. Fouling is one problem that stops an exchanger's ability to transfer heat. During continual service, heat exchangers do not remain clean. Dirt, scale, and process deposits combine with heat to form restrictions inside an exchanger. These deposits on the walls of the exchanger resist the flow that tends to remove heat and stop heat conduction by insulating the inner walls. An exchanger's fouling resistance depends on the type of fluid being handled, the amount and type of suspended solids in the system, the exchanger's susceptibility to thermal decomposition, and the velocity and temperature of the fluid stream. Fouling can be reduced by increasing fluid velocity and lowering the temperature. Fouling is often tracked and identified using check-lists that collect tube inlet and outlet pressures, and shell inlet and outlet pressures. This data can be used to calculate the pressure differential or Δp. Differential pressure is the difference between inlet and outlet pressures; represented as ΔP, or delta p.

Corrosion and erosion are other problems found in exchangers. Chemical products, heat, fluid flow, and time tend to wear down the inner components of an exchanger. Chemical inhibitors are added to avoid corrosion and fouling. These inhibitors are designed to minimize corrosion, algae growth, and mineral deposits.

DOUBLE PIPE HEAT EXCHANGER

A simple design for heat transfer is found in a double-pipe heat exchanger. A double-pipe exchanger has a pipe inside a pipe (Figure 5). The outside pipe provides the shell, and the inner pipe provides the tube. The warm and cool fluids can run in the same direction (parallel flow) or in opposite directions (counterflow or countercurrent).

Flow direction is usually countercurrent because it is more efficient. This efficiency comes from the turbulent, against-the-grain, stripping effect of the opposing currents. Even though the two liquid streams never come into physical contact with each other, the two heat energy streams (cold and hot) do encounter each other. Energy-laced, convective currents mix within each pipe, distributing the heat.

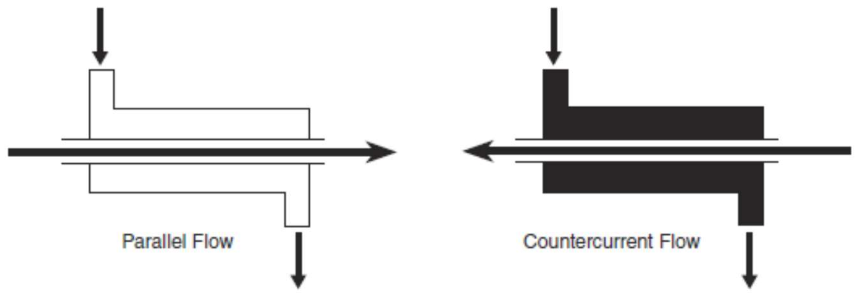

Figure 5: Double-Pipe Heat Exchanger

In a parallel flow exchanger, the exit temperature of one fluid can only approach the exit temperature of the other fluid. In a countercurrent flow exchanger, the exit temperature of one fluid can approach the inlet temperature of the other fluid. Less heat will be transferred in a parallel flow exchanger because of this reduction in temperature difference.

One of the system limitations of double-pipe heat exchangers is the flow rate they can handle. Typically, flow rates are very low in a double-pipe heat exchanger, and low flow rates are conducive to laminar flow.

Hairpin Heat Exchangers

The chemical processing industry commonly uses hairpin heat exchangers (Figure 6). Hairpin exchangers use two basic modes: double-pipe and multi-pipe design. Hairpins are typically rated at 500 psig shell side and 5,000 psig tube side. The exchanger takes its name from its unusual hairpin shape. The double-pipe design consists of a pipe within a pipe. Fins can be added to the internal tube's external wall to increase heat transfer. The multi-pipe hairpin resembles a typical shell-and-tube heat exchanger, stretched and bent into a hairpin.

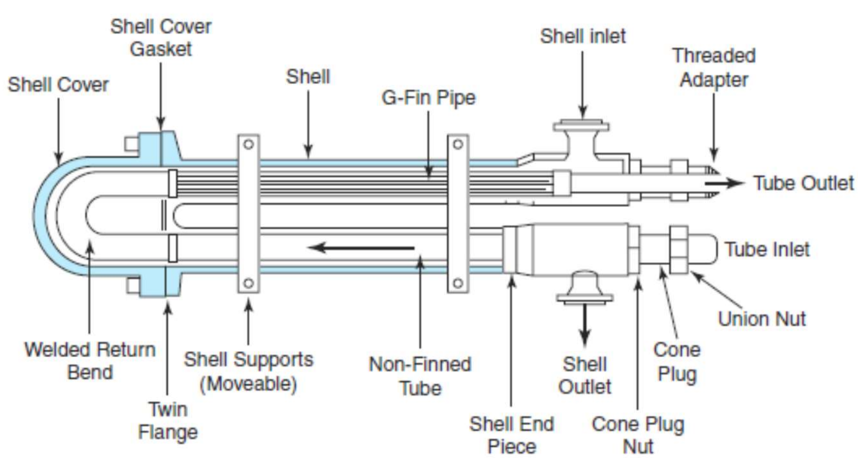

Figure 6: Hairpin Heat Exchanger

The hairpin design has several advantages and disadvantages. Among its advantages are its excellent capacity for thermal expansion because of its U-tube type shape; its finned design, which works well with fluids that have a low heat transfer coefficient; and its high pressure on the tube side. In addition, it is easy to install and clean; its modular design makes it easy to add new sections; and replacement parts are inexpensive and always in supply. Among its disadvantages are the facts that it is not as cost effective as most shell-and-tube exchangers and it requires special gaskets.

SHELL-AND-TUBE HEAT EXCHANGERS

The shell-and-tube heat exchanger is the most common style found in industry. Shell-and-tube heat exchangers are designed to handle high flow rates in continuous operations. Tube arrangement can vary, depending on the process and the amount of heat transfer required. As the tube-side flow enters the exchanger—or “head”—flow is directed into tubes that run parallel to each other. These tubes run through a shell that has a fluid passing through it. Heat energy is transferred through the tube wall into the cooler fluid. Heat transfer occurs primarily through conduction (first) and convection (second). Figure 7 shows a fixed head, single pass heat exchanger.

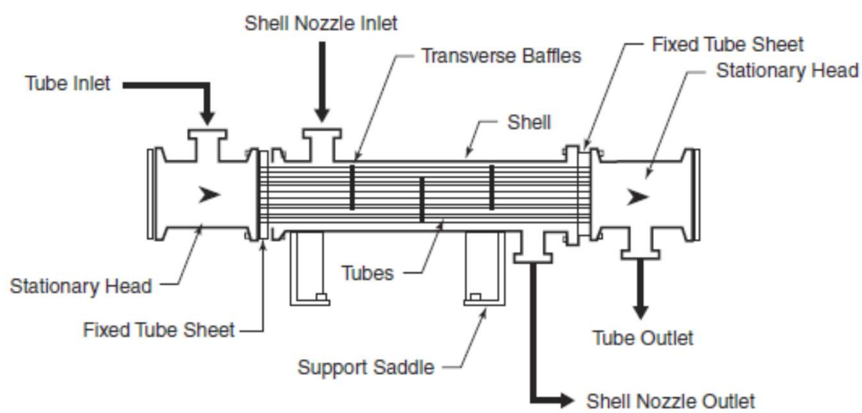

Figure 7: Fixed Head, Single-Pass Heat Exchanger

Fluid flow into and out of the heat exchanger is designed for specific liquid–vapor services. Liquids move from the bottom of the device to the top to remove or reduce trapped vapor in the system. Gases move from top to bottom to remove trapped or accumulated liquids. This standard applies to both tube-side and shell-side flow.

Designs and Components

Exchanger nomenclature uses the terms *front end*, *shell* or *middle section*, and *rear end* to refer to the three parts of shell-and-tube heat exchangers. The front-end design of a heat exchanger varies depending on the type of service in which it will be used. The shell has seven popular designs that are linked to the way flow moves through the shell. The rear-end section of a heat exchanger is linked to the front-end design. Industrial manufacturers are currently using over nine popular designs.

Head

The heads (Figure 8) on a shell-and-tube heat exchanger can be classified as front-end or rear-end types. The front-end head has five primary designs:

1. Channel and removable cover;
2. Bonnet;
3. Channel integral with the tube sheet and removable cover (removable tube bundle);

4. Channel integral with the tube sheet and removable cover (fixed to shell); and
5. Special high-pressure closure.

The rear (or return) header has eight possible designs:

1. Fixed tube sheet with channel and removable cover;
2. Fixed tube sheet with bonnet;
3. Channel integral with the tube sheet and removable cover (fixed to shell);
4. Outside packed floating head;
5. Floating head with backing device;
6. Pull-through floating device;
7. U-tube bundle; and
8. Externally sealed floating tube sheet.

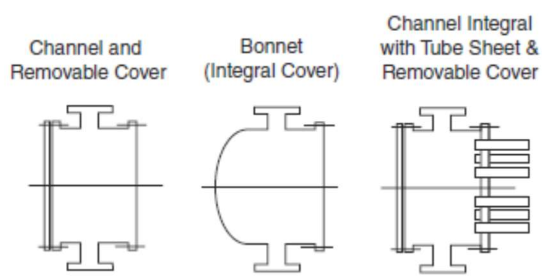

Figure 8: Head Designs

<u>Shell</u>

The shell can be classified as single pass, double pass, split flow, double-split flow, divided flow, kettle, or cross flow (Figure 9). The shell is designed to operate at a specific temperature and pressure, which are clearly marked on the manufacturer's code stamp plate. The shell is the largest single part of the heat exchanger, but if the cross-sectional surface area of the tubes were calculated and compared with the surface area of the shell, the shell would look very small. The shell has inlet and outlet nozzles. The total number and placement of nozzles will depend on the design.

<u>Tubes</u>

Tubes on shell-and-tube heat exchangers can be plain or finned (Figure 10). Fins provide more surface area and allow greater heat transfer to take place. Fins can be located externally or internally. Although plain tubes are more commonly used in fabrication, the enhanced features of the finned tube are starting to make an impact on new design engineers. Tube materials include brass, carbon, carbon steel, copper, cupronickel, glass, stainless steel, specialty alloys, Monel, nickel, and tantalum.

<u>Tube Sheet</u>

Tube sheets are often described as fixed or floating, single or double. A tube sheet is a flat plate to which the ends of the tubes in a heat exchanger are fixed by rolling, welding, or both. Tube sheets have carefully drilled holes designed to admit the end of a tube and secure it to the plate. Double tube sheets are used to prevent tube-side leakage of highly corrosive fluids. The space between the plates provides a void where these hazardous materials can be safely removed from the process stream. Tube sheet connections are identified as plain, rolled, beaded or belled, flared, or welded (Figure 11). Some connections are both rolled and welded. A duplex tube (tube-inside-a-tube) can be beaded or belled, plain or flared. During operation, the tubes will expand. This expansion creates a problem within a fixed head design. Engineering specifications take into account thermal tube expansion. The term *fixed tube sheet* applies to the way the tube sheet is located in the inlet or return head. If the tube sheet is welded or bolted to the shell, it is *fixed*. If the tube sheet is independently secured to the tub head and is allowed to move freely inside the shell, it is *floating*.

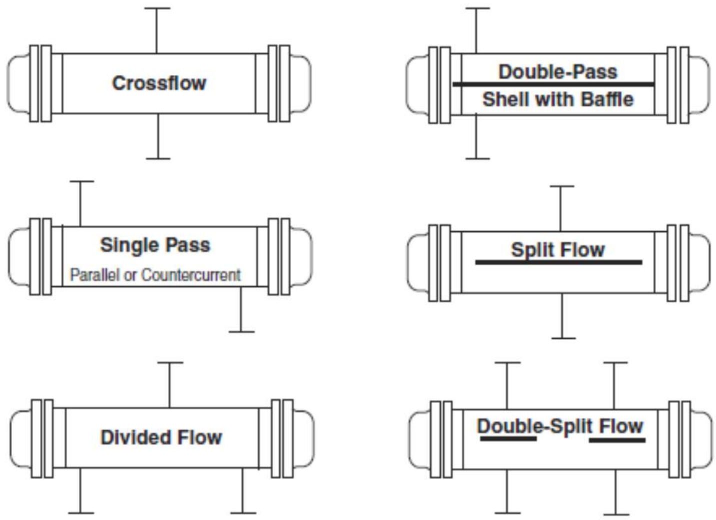

Figure 9: Shell Designs

Baffles

Internal baffles are structurally important to the performance of a shell-and-tube heat exchanger. Baffles provide the framework to support and secure the tubes and prevent vibration. The baffle layout increases or decreases fluid and directs flow at specific points. Tube-side baffles, or pass partitions, are built into the heads to direct tube-side flow. Tube-side baffles may be cast or welded in place. Single-pass exchangers do not need a baffle in the inlet or return head. Multi-pass exchangers requiring two passes will have a single baffle in the inlet channel head. A variety of baffle arrangements are available. Cost goes up with each pass. Additional passes are often needed to provide adequate fluid velocities to prevent fouling (internal buildup of material) and to control heat transfer.

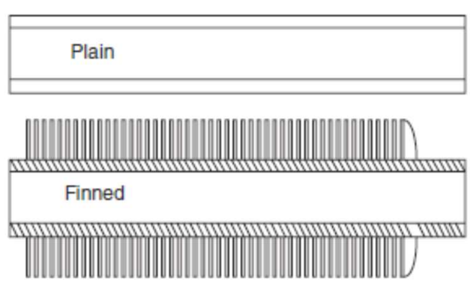

Figure 10: Plain and Finned Tubes

Segmental baffles (Figure 12) are often used in horizontal shell-and-tube heat exchangers. The holes in the baffle are drilled to fit the size of the tube. Without support, tubes will vibrate under pressure. Each segmental baffle supports half of the tubes. Baffles are evenly spaced and alternated from one side to the other to support the tube bundle and direct fluid flow. Segmental baffles may be horizontal or vertical cut. The choice of which arrangement to use is based on the required service. For example, a vertical arrangement is typically used in horizontal exchangers used as condensers, reboilers, or vaporizers.

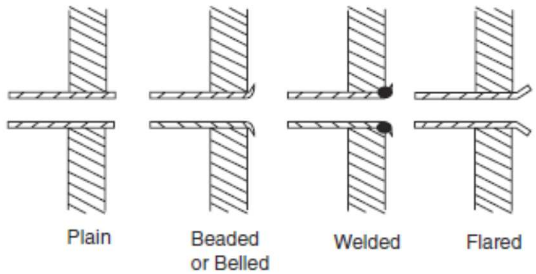

Figure 11: Tube Sheet Construction

Horizontal baffles are used in vapor-phase or all-liquid-phase operations. This type of arrangement is not used where entrained gases are trapped in the liquid unless V-notches are cut in the bottom of the baffle. Horizontal baffles are used in clean service with notches at the bottom to allow liquid drainage on removal from service.

Impingement baffles are used to protect tubing from direct fluid impact. In some systems, high-pressure steam is admitted into the shell side. An impingement baffle, placed over the tubes, will deflect the steam as it enters the exchanger, thereby preventing cutting, pitting, and erosion problems in the tubes.

Longitudinal baffles are used inside the shell to split or divide the flow, increase velocity, and provide superior heat transfer capabilities. This type of baffle can be welded in place, slid into a slot, or situated with special packing. Longitudinal baffles do not extend the entire length of the exchanger because at some point the fluid must flow around it.

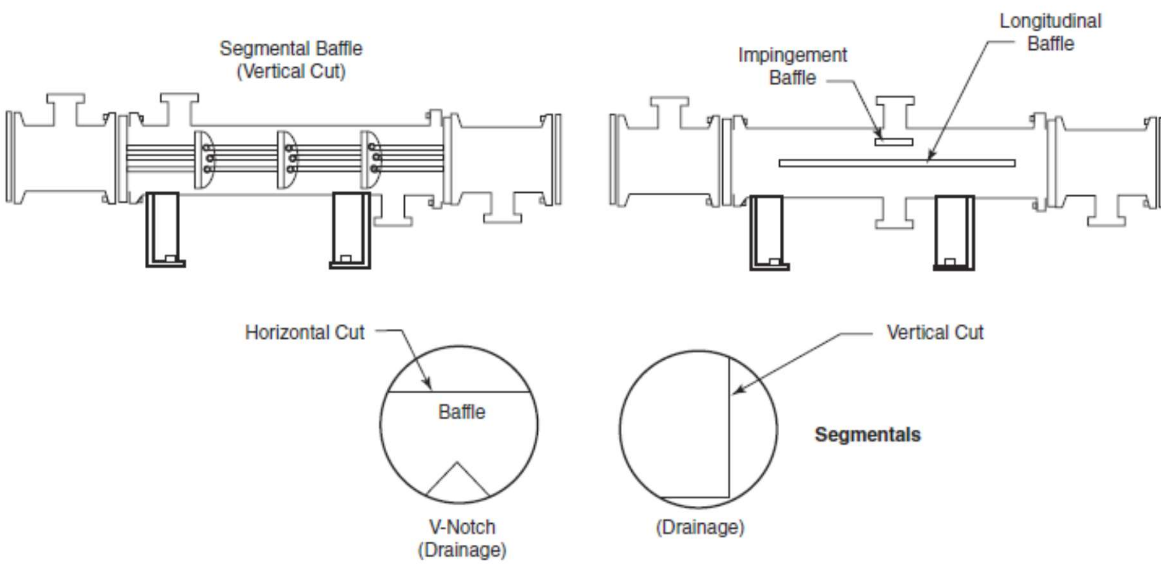

Figure 12: Baffle Arrangements

Tie Rods

Tie rods and concentric tube spacers keep the baffles in place and evenly spaced. Each hole in the baffle plates is 1/64 inch larger than the tube's outside diameter. Tube vibrations on the leading edge of the baffle will eventually damage the tube. Tie rods hold the baffles in place and prevent vibration and excessive tube movement.

Nozzles and Accessory Parts

Shell-and-tube inlet and outlet nozzles are sized for pressure drop and velocity considerations. Nozzle connections frequently have thermowells (a chamber that houses temperature-sensing devices) and pressure indicator connections. Safety and relief valves are located in required areas around the exchanger. Product drains are used to empty the sections between baffles during maintenance. Vents are located on the upper side of the shell to remove gases and vapors. Block valves and control valves are located in the piping entering and leaving the exchanger.

Fixed Head, Single Pass

In a fixed head, single-pass shell-and-tube heat exchanger, the tubes are connected to two tube sheets that are firmly attached to the shell, and two stationary heads (see Figure 7). Process flow (tube inlet) enters the head and is directed toward the fixed tube sheets. Each tube sheet is a flat, metal disc that functions like a collar for the individual tubes. As flow enters the tubes, it experiences maximum heat transfer. Conductive heat transfer is at its highest where the tube sheet, shell, and tubes meet. By the time the tube flow exits the exchanger, very little if any heat transfer is taking place. The term *single pass* indicates that the tube-side flow goes across the exchanger one time.

Fixed Head, Multi-pass

A fixed head, multi-pass shell-and-tube heat exchanger is designed much like the single-pass exchanger. The differences occur with the number of passes the tube-side flow takes across the exchanger, the baffle (pass partition) added to the channel head, and the lack of a tube-side outlet on the discharge head (Figure 13).

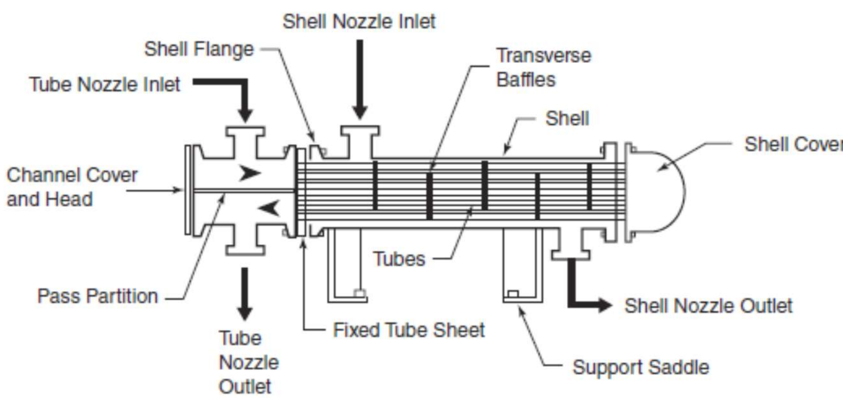

Figure 13: Fixed Head Multi-Pass Heat Exchanger

In a fixed head, multi-pass heat exchanger, flow enters the channel head and is directed into the tubes. A baffle installed in the head limits access to a portion of tubes on the tube sheet. As fluid flows through the exchanger, heat is transferred into or out of the fluid. After completing the first pass, process flow is directed back into another portion of tubes. This second pass across the exchanger allows additional heat transfer to occur.

Floating Head

In a floating head, multi-pass shell-and-tube heat exchanger, one side of the tube bundle is fixed to the channel head, the other side is unsecured, or floating (Figure 14). Flow enters the channel head and is directed into the tubes that are attached to a common, fixed, tube sheet. As flow moves from left to right, it makes one pass before it crosses right to left for the second pass. A network of baffles is established on the tube bundle to enhance heat transfer. Adding fins to the tubes can further enhance heat transfer. An impingement baffle (pass partition) is located between the tubes and shell inlet. This redirects the flow and keeps the tubes from being damaged. This type of heat exchange produces the highest heat transfer efficiency. Floating head exchangers, with their high cross-sectional areas (fins), are designed for high temperature differentials and high flow rates.

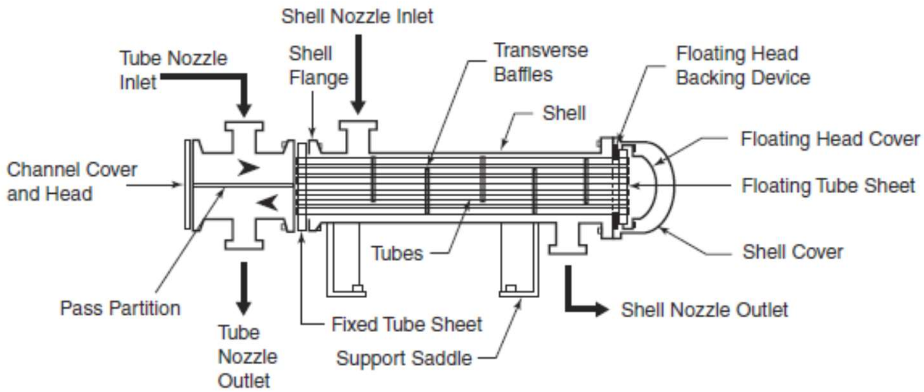

Figure 14: Floating Head, Multi-pass Heat Exchanger

<u>U-Tube</u>

A fixed tube sheet on one end that is typically bolted to the shell characterizes a U-tube exchanger (Figure 15). The tube sheet connects a series of tubes bent in a U-shape (Figure 16). The ends of the tubes are secured to the tube sheet. This design limits the total number of tubes that can be used when compared with a fixed head. A channel head directs tube flow across the body of the exchanger twice. U-tube exchangers are specially designed for large temperature differentials. The U-shaped design allows the head to float and accommodate the thermal expansion of the tubes.

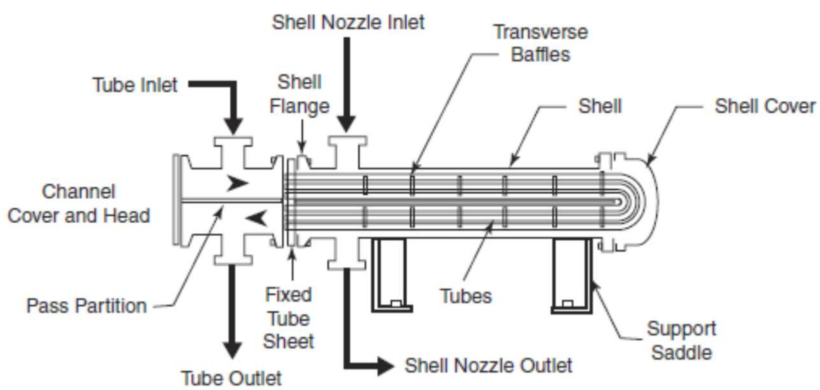

Figure 15: U-tube Heat Exchanger

REBOILERS

Reboilers are used to add heat to a liquid that was once boiling until the liquid boils again. Reboilers are closely associated with the operation of a distillation column. These types of devices are classified by how they produce fluid flow. If a mechanical device, such as a pump, is used, the reboiler is referred to as a forced circulation reboiler. Circulation that does not require a pump is classified as natural circulation.

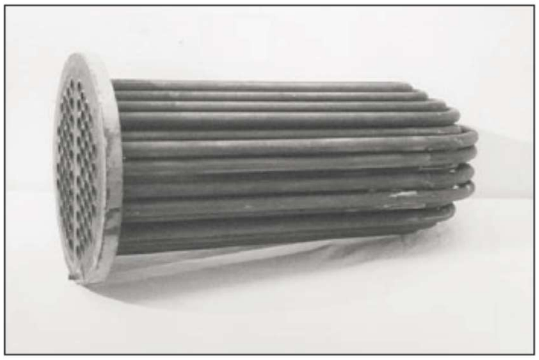

Figure 16: U-tube Bundle

Kettle Reboiler

Kettle reboilers are shell-and-tube heat exchangers designed to produce a two-phase, vapor-liquid mixture that can be returned to a distillation column (Figure 17). Kettle reboilers have a removable tube bundle that uses steam or a high-temperature process medium to boil the fluid. A large vapor cavity above the heated process medium allows vapors to concentrate. Liquid that does not vaporize flows over a weir and into the liquid outlet. Hot vapors are sent back to the distillation column through the reboiler's vapor outlet ports. This process controls the level in the bottom of the distillation column, maintains product purity, strips smaller hydrocarbons from larger ones, and helps maintain the critical energy balance on the column.

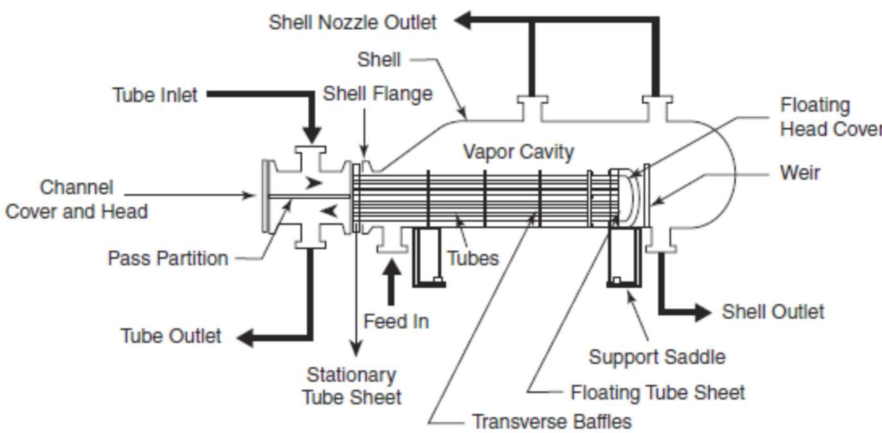

Figure 17: Kettle Reboiler

Kettle reboilers operate with liquid levels from 2 inches above and 2 inches below the upper tubes. Engineering designs typically allow 10 inches to 12 inches of vapor space above the tube bundle. Vapor velocity exiting the reboiler must be low enough to prevent liquid entrainment. Bottom product spills over the weir that fixes the liquid level on the tube bundle.

Vertical and Horizontal Thermosyphon Reboilers

A thermosyphon reboiler is a fixed head, single-pass heat exchanger connected to the side of a distillation column. Thermosyphon heat exchangers can be mounted vertically or horizontally. The critical design factor is providing sufficient liquid head in the column to support vapor or liquid flowback to the column. Natural circulation occurs because of the differences in density between the hotter liquid in the reboiler and the liquid in the distillation tower. One side of the exchanger is used for heating, usually with steam or hot oil; the other side takes suction off the column. When steam is used as the heated medium in a vertical exchanger, it enters from the top shell inlet and flows downward to the shell outlet, to allow for the removal of condensate. The lower tube inlet of the exchanger usually takes suction at a point low enough on the column to provide a liquid level to the exchanger. A pump is not connected to the column and exchanger unless a forced circulation system is required. This system uses buoyancy forces to flash off and pull in liquid. As liquids and vapor circulate back to the column, the inlet line provides fresh liquid to support the circulation.

PLATE-AND-FRAME HEAT EXCHANGERS

Plate-and-frame heat exchangers are high heat transfer and high pressure drop devices. They consist of a series of gasketed plates, sandwiched together by two end plates and compression bolts (Figures 18 and 19). The channels between the plates are designed to create pressure drop and turbulent flow so high heat transfer coefficients can be achieved.

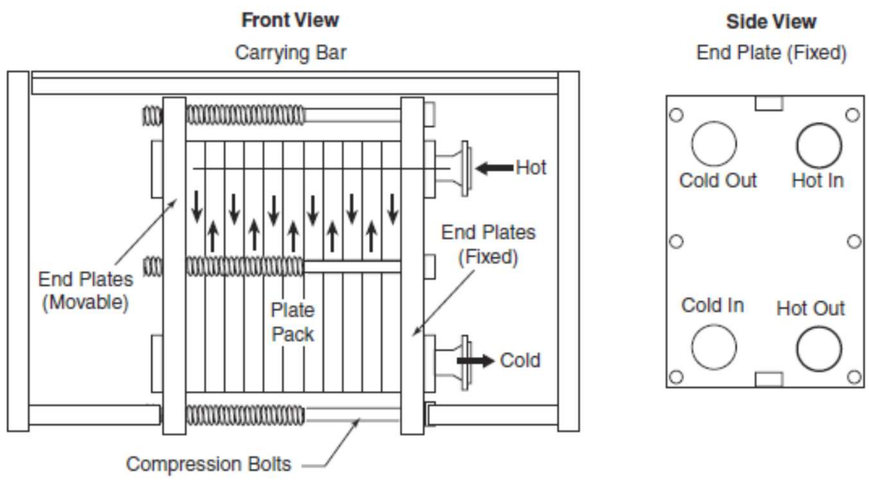

Figure 18: Plate-and-Frame Heat Exchanger

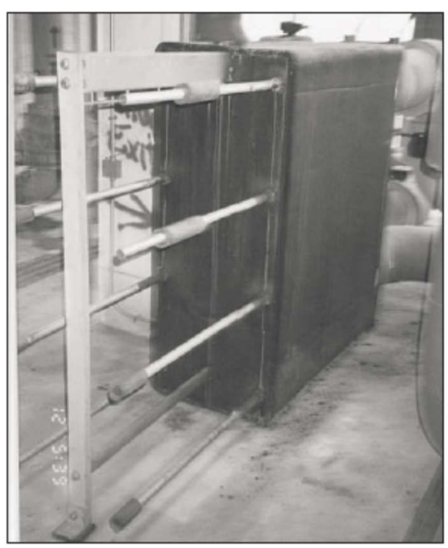

Figure 19: Plate-and-Frame Assembly

Plate-and-frame heat exchangers have several advantages and disadvantages. They are easy to disassemble and clean and distribute heat evenly so there are no hot spots. Plates can easily be added or removed. Other advantages of plate-and-frame heat exchangers are their low fluid resistance time, low fouling, and high heat transfer coefficient. In addition, if gaskets leak, they leak to the outside, and gaskets are easy to replace. The plates prevent cross-contamination of products. Plate-and-frame heat exchangers provide high turbulence and a large pressure drop and are small compared with shell-and-tube heat exchangers.

Disadvantages of plate-and-frame heat exchangers are that they have high-pressure and high-temperature limitations. Gaskets are easily damaged and may not be compatible with process fluids.

AIR-COOLED HEAT EXCHANGERS

A different approach to heat transfer occurs in the fin fan or air-cooled heat exchanger. Air-cooled heat exchangers provide a structured matrix of plain or finned tubes connected to an inlet and return header (Figure 20). Air is used as the outside medium to transfer heat away from the tubes. Fans are used in a variety of arrangements to apply forced convection for heat transfer coefficients. Fans can be mounted above or below the tubes in forced-draft or induced-draft arrangements. Tubes can be installed vertically or horizontally.

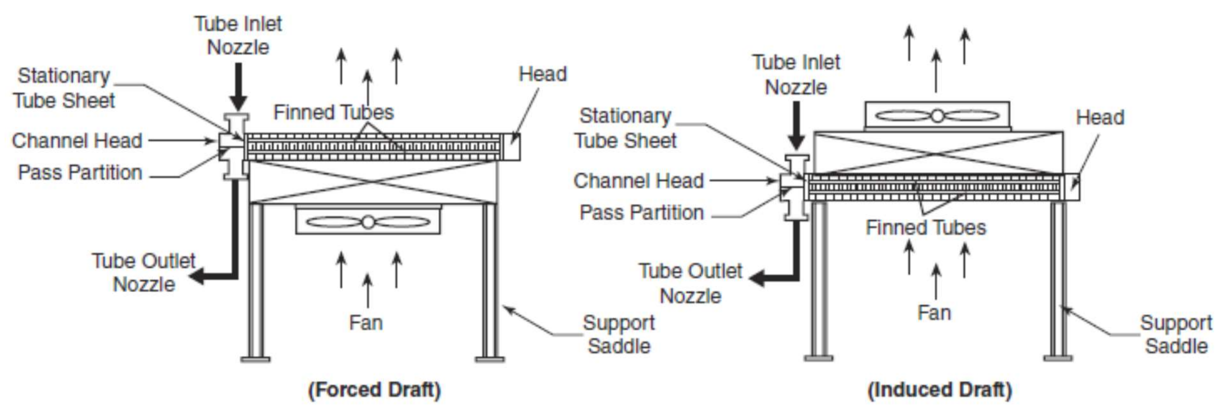

Figure 20: Air-Cooled Heat Exchanger

Air-cooled heat exchangers can be found in service on air compressors, in recirculation systems, and in condensing operations. This type of heat transfer device provides a 40°F temperature differential between the ambient air and the exiting process fluid.

Air-cooled heat exchangers have none of the problems associated with water such as fouling or corrosion. They are simple to construct and cheaper to maintain than water-cooled exchangers. They have low operating costs and superior high temperature removal (above 200°F).

Their disadvantages are that they are limited to liquid or condensing service and have a high outlet fluid temperature and high initial cost of equipment. In addition, they are susceptible to fire or explosion in cases of loss of containment.

SUMMARY

Each type of heat exchanger can be represented by a symbol. Figure 21 illustrates heat exchanger symbols.

A heat exchanger allows a hot fluid to transfer heat energy in the form of heat to a cooler fluid without the two fluids physically coming into contact with each other. Heat exchangers can be categorized as pipe coil, double pipe, shell and tube, reboiler, plate and frame, air cooled, and spiral. The shell-and-tube heat exchanger is the most common in the process industry. Shell-and-tube heat exchangers are designed to handle high flow rates in continuous operations. Reboilers are used to maintain heat balance in distillation columns. Kettle reboilers and thermosyphon reboilers are the types most often used. Condensers are typically tube and shell heat exchangers often used in distillation columns to condense hot vapors into liquid.

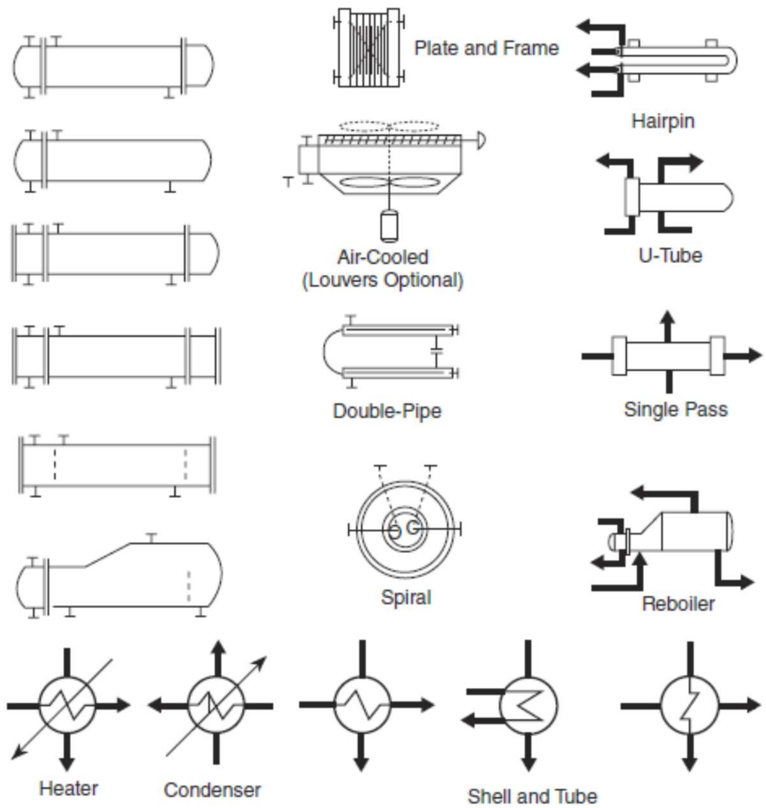

Figure 21: Heat Exchanger Symbols

The three methods of heat transfer are conduction, convection, and radiation. Conduction and convection are used in heat exchangers, but radiation is not used. Heat transfer occurs best when large temperature differences exist between the products, flow rates are high, and cross-sectional area is large.

Laminar flow moves through a system in layers of liquid flowing in parallel. Turbulent flow is the random movement or mixing of fluids. Once turbulent flow is initiated, molecular activity speeds up until the fluid is uniformly turbulent. Laminar flow is not conducive to heat transfer.

Source: Process Technology Equipment and Systems *by* Charles Thomas

Pressure Vessel & Piping Training

Offered by CoDesign Engineering LLC

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DAY 1	Introduction Pressure vessel failures Stresses in pressure vessels General design considerations Codes and standards Material of construction
DAY 2	Fatigue Low temperature operation Design of shells Formed heads Conical heads and sections Flat heads and dished covers
DAY 3	Nozzles, openings and reinforcement Bolted flange joints Welding requirements Heat treatment Non-destructive examination
DAY 4	External load Wind and seismic loads Supports for vertical vessels Horizontal vessels Fabrication, inspection and testing Design by analysis

Instructor Profile

Ramesh Tiwari

Ramesh Tiwari is an ASME member, and a member of ASME Section VIII Subgroup on Heat Transfer Equipment. He holds Bachelor's and Master's degrees in Mechanical Engineering, and is a registered Professional Engineer in the state of Maryland in the United States. Ramesh has over 24 years of experience with design of pressure vessels, heat exchangers and storage tanks used in oil & gas, chemical, petrochemical, fertilizer and power industries. He has worked with engineering organizations and pressure vessel manufacturers, and has provided trainings and in-house workshops in US, Canada, Germany and India. Ramesh is also an approved pressure vessel instructor at several organizations and educational institutions.

REGISTRATION: US$ 1650

Who Should Attend:

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Training Details:

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Please contact Ramesh at ramesh.tiwari@codesignengg.com, or call at +1 713-562-0368 to register for the training

About CoDesign Engineering:

CoDesign Engineering specializes in the core business of providing training and consultancy services for the design and fabrication of pressure vessels and heat exchangers, and the ecosystem that includes piping, welding, valves, geometric dimensioning and tolerancing, process improvement, and engineering management. For more information, please visit www.codesignengg.com.

Air Cooled Heat Exchangers

SUMMARY OF CHANGES - API 661, 7TH EDITION

About The Author:

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API Standard 661 - 7th Edition was published in July 2013 by API. This article will discuss summary of changes along with comments concerning the changes/information provided in the 7th Edition versus the 6th Edition. It is observed that in API-661 it is very hard to understand which para./ sections got added / substituted or deleted as there is no specific marking available for changes done. Also there is no specific change list included by API in API-661. Hence intent of this summary is to list out such changes and made readily available for readers.

These summaries along with comments / interpretations are intended as information to readers. Author does not make any claims on the accuracy of these comments / interpretations. We recommend you to contact API directly for any detailed clarifications.

Summaries are listed in ascending order of para./ sections listed in API-661-7th Edition. We have first listed General changes, and then Specific changes from 7th edition are listed. Author's comment / interpretation or information on these changes is provided in parenthesis in blue.

General Changes / Comments:

1. Title of API-661-7th edition is revised to *"Petroleum, Petrochemical, and Natural Gas Industries—Air-cooled Heat Exchangers"*.

   [Title changed to resemble with ISO 13706-1:2011 edition. 6th edition was just mentioning general refinery service. Substituted title will cover enhanced definition of Oil & Gas service.]

2. ISO 13706-1:2005 which was listed on title page of 6th edition is deleted from 7th edition. Also ISO standard logo deleted from title page of 7th edition. It has been observed that wherever in 6th Edition 'International Standard' has been mentioned is now replaced with mentioning only as 'Standard' in 7th Edition. Also header on each page is representing only 'API 661' and deleted 'ISO 13706' reference from header.

   [As ISO 13706-1:2005 is superseded so same is deleted from title page. However latest edition is not mentioned (ISO 13706-1:2011 edition) specifically on title page. While preparing summary of changes on API 661-7th edition, we have also referred ISO 13706-1:2011 edition & we found that majority of changes (addition, substitution, deletion) done in API 661-7th edition is inline with changes done in ISO 13706-1:2011 edition.]

3. 'Special Note' section added paragraphs mentioning 'Users of this standard should not rely exclusively on the information contained in this document. Sound business, scientific, engineering, and safety judgment should be used in employing the information contained herein. Also, Users are solely responsible for assessing their specific equipment and premises in determining the appropriateness of applying the standard.

[API emphasized more on scientific and engineering judgement, safety precautions, and users (manufacturer) experience in ACHE while interpreting and applying any clause from this standard.]

4. 'API Foreword' section title revised to 'Foreword'. ISO Foreword which usually presented after 'Contents' is deleted from 7th edition. 'Foreword' section introduced below specific terminology.

   Shall: As used in a standard, "shall" denotes a minimum requirement in order to conform to the specification.

   Should: As used in a standard, "should" denotes a recommendation or that which is advised but not required in order to conform to the specification.

   [These terms are introduced in order to ease in interpretation and clear understanding of each para / clause requirement.]

5. 'Content' section. In 7th edition List of Figures and Tables is also listed as part of Content.

   [This will ease in referring through mentioned page number against each listed figure and table while using standard.]

6. Annexure D (informative), Recommended Procedure for Airflow Measurement of Air-cooled Heat Exchangers, has been added. This annex provides standardized guidelines for the measurement, analysis, and reporting of airflow air-cooled heat exchanger fans at the Vendor's site.

   [In this Annexure it has been mentioned that Additional information and procedures may be found in ISO 3744. We presume that this statement is wrongly mentioned here in Annex D because ISO 3744 covers 'Acoustics Determination of sound power levels and sound energy levels of noise sources using sound pressure'. So this statement should be specified in scope of Annexure E (newly added in 7th edition) which is meant for measurement of noise from ACHE.]

7. Annexure E (informative), Measurement of Noise from Air-cooled Heat Exchangers, has been added. This annex gives guidance on standard procedures for measuring and reporting sound-pressure levels (Lp) and sound-power levels (LW) for air-cooled heat exchangers.

   [Annexure on measurement of noise from ACHE was part of 4th edition of API-661, which got deleted in 5th edition and now added in 7th edition]

Specific Changes / Comments:

1. *Para.2:* ISO 15156 (all parts), NACE MR0103 , NACE SP0472, - These Standards listed in Normative references.
2. *Para. 3:* Terms & Definitions: In 7th edition more terminology has been introduced from para. 3.4 to 3.33. Few of them are, Critical process temperature, Geometric center, Hydrogen service, internal/ external recirculation, Minimum design air temperature, MDMT, Specified minimum tube-wall temperature, seal/strength welded joint, Winterization etc. For detailed terminologies go through mentioned para in 7th edition.
3. *Para. 4.6:* In this para. Sour service requirement is added. As per which the purchaser needs to specify if the service is designated as sour in accordance with ISO 15156 (all parts) & NACE MR0103. Identification of the complete set of materials, qualification, fabrication, and testing specifications to prevent in-service environmental cracking is the responsibility of the user (Purchaser).
4. *Para. 4.7:* Added, The requirement for winterization and its type shall be specified by the Purchaser.

5. *Para. 6.1.3:* Added, Calculations shall also be provided for restraint relief in accordance with para. 7.1.6.1.3, and also for the defined external moments and forces on nozzles in accordance with para. 7.1.10.

6. *Para. 7.1.1.7 :* Substituted 'The last pass of tubes in multi-pass condensers shall be sloped downward at least 10 mm/m (1/8 in./ft) towards the outlet header'

   [Earlier API kept no slope requirement for multi-pass condenser. The API/ISO standard earlier editions only require that single pass condenser tubes be sloped. This para is revised as same is not considered adequate arrangement based on few of industry experience.]

7. *Para. 7.1.1.12:* Added, Cyclic service requirement purchaser shall specify. Also it's corresponding design data / information, & its acceptance criteria purchaser needs to specify.

8. *Para. 7.1.2.3:* Substituted 'The tube pitch of the heating coil shall not exceed the smaller of twice the tube pitch of the tube bundle or 4.75 times the nominal heating coil tube diameter.'

   [For cases with larger process tube diameters API/ISO standard earlier editions spacing requirements seems insufficient. So this para is revised.]

9. *Para. 7.1.6.1.5:* Substituted, The lateral velocity in the header inlet compartment shall not exceed the velocity in the inlet nozzle.

   [In 7th edition this para is specifically dedicated to inlet header compartment. This para provides for adequate distribution of fluids to multiple tubes within the inlet tube pass.]

10. *Para. 7.1.6.2.3:* Added 'For hydrogen, sour or wet hydrogen sulfide service, only confined gasket construction shall be used.' (For cover plate header and removable bonet header).

    [As these services are critical in nature in order to avoid any leakage scenario confined gasket is specifically asked. For other services either confined gasket or unconfined full face gasket is permitted.]

11. *Para. 7.1.6.2.11:* Added, for stainless steel alloys and high-nickel alloys flanges and gasketed flat covers design, Allowable stresses that have been established on the basis of short-time tensile strength shall not be used. As these allowable stresses can cause permanent deformation.

    [This addition is as per ASME Sec. II-D, where for stainless steel materials two sets of allowable stress values are given. As per note G5 of table 1A of ASME Section II-D "Due to relatively low yield strength of these (SS) materials, these higher stress values were established at temperatures where the short-time tensile properties govern to permit the use of these alloys where slightly greater deformation is acceptable." As per API added para. allowable stresses established on the basis of short-time tensile strength shall not be used for the design of flanges and gasketed flat covers because these higher stresses do not exceed 90% of the yield strength. At these stresses, small amounts of plastic deformation can be expected. & Permanent deformation in case of flanges results into leakage which is not acceptable. That's why in general while selecting SS flange joint material as per ASME for design, lower allowable stress material shall be selected.]

12. *Para. 7.1.8.1:* Added, 'Plug gasket hardness shall be less than that of the plug and the plug-sheet materials.' & substituted 'Plug gaskets shall be of the solid-metal type.' Earlier double-metal-jacketed gasket was permitted as plug gasket, which is deleted in 7th edition.

13. *Para. 7.1.8.4:* Solid metal with a soft gasket seal facing is added as gasket material for cover plate and bonnet header. Earlier only double-metal-jacketed gasket was permitted for this application.

[As per this addition now kammprofile gasket can also be used for cover plate and bonnet header cooler.]

14. *Para. 7.1.8.8:* Welded gaskets requirement added. In 7th edition requirements added for gasket made up with welds.

15. Deleted *Para. 7.1.9.10* from 6th edition as per which 'Except in hydrogen service, forged carbon steel slip-on flanges may be used on connections to headers that are limited to, (then conditions listed where slip on flanges can be used).

    [Deletion of this para. would result in the standard API/ ISO restrictions on the use of slip-on flanges being enforced.]

16. *Para. 7.1.11.3:* The wall thickness for tubes with an outside diameter of 25.4 mm (1 in.) to 51 mm (2 in.) shall not be less than that specified in Table 5.

    [Earlier Table 5 was applicable upto Tube OD 38.1 mm (1 1/2 in.).OD limit has been increased to cover more tube sizes minimum thickness requirement specified in Table 5.]

17. *Para. 7.1.11.12:* Substituted, Now U bend heat treatment is entirely made purchaser specific.

18. *Para. 7.2.1.2:* Added adequate headroom and approach velocity requirements for forced and induced draft air coolers. It requires adequate clearance below the fan plenum for forced draft units or below the tube bundle for induced draft units for adequate quantity of air to enter the bay. Approach velocity shall not exceed a nominal value of 3.6 m/s (700 ft/min) for forced draft units, or 4 m/s (800 ft/min) for induced draft units. Adequate head clearances shall also be considered for mechanical equipment maintenance.

    [To prevent re-circulation of warm discharge air to the suction side of the cooler proper control of air intake velocity is important. For this earlier mainly relying on vendor standards which are not uniform or consistently applied. This edition of API/ ISO standards introduced requirements for approach velocity for the same.]

19. *Para. 7.2.1.3:* Added, The minimum height above grade for grade-mounted installations shall be calculated in accordance with added Equation (For its nomenclature refers mentioned para.):

$$\boxed{h = \frac{q_v}{l_p \times k}}$$

    [To limit approach velocity of 3.6 m/sec (700 ft/min) for forced draft units and 4 m/sec (800 ft/min) for induced draft units as added in para. 7.2.1.2, minimum height requirement of ground mounted air cooler (both forced and induced draft) is introduced. Here factor k is a constant, and its value is equal to approach velocity as mentioned for both type of air coolers.]

20. Para. 7.2.1.4: Added, for forced draft units, the kinetic energy of the entering air shall be less than that of the discharge air exiting the tube bundle.

    [This addition is also done specially for forced draft units to prevent re-circulation of warm discharge air to the suction side of the cooler.]

21. *Para. 7.2.1.5:* Air will get blocked or obstructed by structures like inlet louvers and bug screens so this para added so the approach velocity shall be calculated based on the effective net free area through the inlet louvers and bug screens provided on the ends or sides of the unit.

22. *Para. 7.2.1.8:* Design exposure temperature calculation for mechanical parts is entirely now vendor's responsibility in case purchaser asks to do so. Earlier guideline has been deleted.

23. *Para. 7.2.3.3:* 1 meter Minimum fan diameter requirement deleted, accordingly radial clearance table 6 fan diameter range modified.

24. *Para. 7.2.7.1.2:* For electric motor drivers, the minimum required driver rated shaft power (Pdr) shall be calculated according to 2 formulas given in this para.

    [Earlier in 6th edition, it was greater of the terms on the right sides of the 2 equations. It has been observed that same requirement didn't modified by ISO in ISO 13706-1:2011. It's still following earlier requirement of 2005 (i.e. identical with API 6th edition).]

25. *Para. 7.2.11.2.3:* Substituted, Insect-Lint Screens mesh size shall be number 8 for galvanized or number 16 for stainless steel.

    [Earlier only galvanized screen mesh was specified. Now Stainless steel is also added and other materials also accepted if agreed with the purchaser. However mesh wire thickness requirement is deleted.]

26. *Para. 8.2:* "Requirements for Carbon Steel in Sour or Wet Hydrogen Sulfide Service" is newly added, other para. accordingly renumbered.

    Para. 8.2.1: Materials shall be supplied in the normalized condition

    Para. 8.2.2: Pressure-retaining components shall be supplied with a certified material test report (CMTR).

    Para. 8.2.3: The maximum allowable carbon equivalent shall be agreed with the Purchaser. Restrictions on other residual elements and micro-alloying elements may also apply depending on the severity of the service.

27. *Para. 9.1.1.2:* Deleted 6th edition requirement of welds (All pressure-containing header welds) shall also be double-side welds except end plate and nozzle welds.

28. *Para. 9.1.1.5:* Added, weld procedure qualifications for carbon steel in sour or wet H2S service shall include a micro-hardness survey performed on a weld cross-section and transverse to the weld centreline (if purchaser specified).

    [Microhardness testing is a method of determining a material's hardness or resistance to penetration when test samples are very small or thin, or when small regions in a composite sample or plating are to be measured. As per ASM international, In microhardness testing, applied loads are 1 kg and below, and material being tested is very thin (down to 0.0125 mm, or 0.0005 in.).]

29. *Para. 9.2.1:* Substituted, PWHT of welded tube to tubesheet joint shall not be performed unless specifically asked by Purchaser or its pressure design code requirement..

    [Earlier PWHT of welded tube to tubesheet joint totally excluded without any code or purchaser specific requirement. Because it requires precautions to protect the aluminium fins from melting during welding & stripping back some part of fins etc. This time purchaser or code specific requirement (e.g. PWHT for LAS application) included in order to decide for the same.]

30. *Para. 9.2.3:* Added, for sour or wet hydrogen sulfide service, the minimum PWHT requirements for header boxes with carbon steel construction shall be in accordance with NACE SP0472.

    [NACE SP0472 covers Methods and Controls to Prevent In-Service Environmental Cracking of Carbon Steel Weldments in Corrosive Petroleum Refining Environments. According to NACE SP0472 the

standard PWHT should be performed at 620 °C ± 15 °C (1150 °F ± 25 °F) for one hour per inch (25 mm) thickness, with a one hour minimum soak time.]

31. *Para. 9.4.3:* Plug gasket contact surface finish tolerance is increased from '0.8 μm - 1.6 μm (32 μin -64 μin)' to '1.6 μm - 3.2 μm (63 μin. -125 μin.)'.

32. *Para. 10.1.7.a:* Duplex SS hardness testing requirement is added. Also heat affected zone hardness testing asked to carry out if required by the pressure design code or specified by purchaser.

33. *Para. 10.1.7.b:* Complete modification of Para is done. Brinell hardness tester (earlier Rockwell hardness measurement) shall be used for hardness reading and other techniques may be employed subject to purchaser approval.

34. *Para. 10.1.7.d:* Table 12 is added. The weld hardness shall not exceed the values listed in this table.

Table 12 — Maximum Weld Hardness

Material	Maximum Weld Hardness
Carbon steel	225 HBW
Chromium steel (up to 3 % Cr)	225 HBW
Chromium steel (5 % Cr to 17 % Cr)	241 HBW
Duplex stainless steel (22 % Cr)	by agreement with Purchaser
Super duplex stainless steel (25 % Cr)	by agreement with Purchaser

NOTE These hardness values are for general services. More stringent hardness testing and acceptance criteria can be required for special services (e.g. sulfide stress cracking or other types of environmental cracking services as specified in NACE standards).

[Instead of rockwell hardness now equivalent brinell hadrness acceptable values are specified in added table (20 HRC in 6th ed. = 226 HBW & 22 HRC in 6th ed.= 237 HBW). BHN is designated by the most commonly used test standards (ASTM E10-14 and ISO 6506–1:2005) as HBW (H from hardness, B from brinell and W from the material of the indenter, tungsten (wolfram) carbide) Also for Duplex SS and Super Duplex SS its clearly specified that max weld hardness shall be agreed with purchaser.].

35. *Para. 10.1.12:* Added, all carbon steel plate in sour or wet hydrogen sulfide service shall be subjected to an ultrasonic lamination check if specified by purchaser.

    [To ensure any inclusion free sub-surface this check is introduced.]

36. *Para. 10.1.13:* Added, for austenitic and duplex stainless steels, the ferrite content of all accessible completed production welds shall be checked using a ferritescope. The acceptance criteria for the minimum and maximum ferrite content shall be agreed between the Purchaser and Vendor.

37. *Para. 10.1.14:* Added, where nozzle pipe and transitions are fabricated from plate, the welds shall be subject to 100 % radiography after final forming or after any required heat treatment.

38. *Para. 12.1:* This is supplemental requirements. This section generally applies additional design, fabrication and non-destructive examination requirements that are necessary to prove the fabrication integrity in services subject to high pressure to prevent a loss of pressure containment. Earlier API/ISO also specified plate thickness and critical service as criteria. However now those criteria are excluded and kept it as purchaser specific.

39. *Para. 12.2.2:* Substituted, All tubes shall be either seal-welded or strength-welded to the tubesheet. Added, Low-alloy chromium steel tubes shall not be used in this application.

[Rewording done for tube to tubesheet joint requirement. Low alloy chrome tubes exempted as some of pressure design codes call for PWHT for this material, which might require PWHT of welded tube to tubesheet joint]

40. *Para. 12.3.1:* UT shall be performed on plates and forgings welded to other components if the thickness exceeds 50 mm.

    [Thickness limit is reduced to perform UT if thickness exceeds 50 mm (earlier 65 mm).Examination of thicker plates/forgings welded to other components ensures strength and integrity of material especially for high pressure and critical services.]

41. *Para. 12.3.13:* Added, if PWHT is required, the tests within Para. 12.3 shall be performed after completion of the PWHT.

42. *Para. 12.3.14:* Added, Prior to use in the fabrication of the bundle, all welded tubes shall be eddy-current tested and pressure tested.

    [For these applications of high pressure and critical services, only pressure (hydrostatic) testing seems inadequate based on few of industry experiences. So both pressure testing and eddy current testing requirement is added.]

43. *Annex A (informative) Recommended Practices: Added A.1 Introduction:* This annex has been prepared to give advice in areas outside the scope of this standard. The advice is not mandatory and is offered for guidance only.

    [Annexure has been revised with change in listed para as compared to 6th edition. Now these practices listed according to ascending sequence of para included in standard.]

44. *Annex A (informative) Recommended Practices: Added A.3.1:* This para included conditions in which each pass of multi-pass condenser shall provide slope.

45. *Annex A (informative) Recommended Practices: Added A.3.2:* This para included conditions for identifying a potential cyclic service application.

46. *Annex A (informative) Recommended Practices: Added A.3.3.3:* the maximum fin density should not exceed 394 fins per meter (10 fins per in.) In areas prone to air-side fouling due to airborne particulates, the minimum gap between the fins on adjacent tubes should be 6.4 mm (1/4 in.) to allow effective cleaning of the fins.

    [Higher fin densities are more prone to airside fouling/plugging. That's why it's limited to 394 fins per meter (10 fins per in.)]

47. *Annex A (informative) Recommended Practices: Added A.3.10:* These added practices covered recommendations to be considered for adequate airflow on pipe rack mounted coolers and hot air recirculation prevention. Few of them are,

    A.3.10.1: if the height of the pipe rack above grade is equal to or greater than one half the length of the air-cooled heat exchanger tubes, the air-cooled heat exchanger has mechanical equipment walkways located beneath the bays, and if the area directly below the mechanical equipment walkways provides a 50 % or greater net free area, then adequate air flow can be expected.

    A.3.10.2: "hot air recirculation" can be controlled by the judicial placement of the units with respect to one another, as well as taking the prevailing winds into consideration. Also CFD programs can help in sighting equipment and can provide an estimate of how much to increase the design air temperature of air entering the air-cooled heat exchangers.

A.3.10.3: Forced draft and induced draft air-cooled heat exchangers should not be located adjacent to each other due to the potential for unwanted hot air recirculation.

48. *Annex A (informative) Recommended Practices: Added A.4.1 & A4.2:* Which covers guidance on Welded Tube Ends and Tube-to-Tubesheet Joint. As per which PWHT of welded tube to tubesheet joint should be avoided. Also for hydrogen service, tube-to-tubesheet joints should be welded and expanded. & a 4.8 mm (3/16 in.) minimum overlay or clad should be provided for cladded /weld overlaid tubesheet.

49. *Annex B (informative) :*

    - Title of Annex revised to ‘Checklist and Data Sheets’.
    - Footnote added in ‘Contents and Usage’. By this footnote API emphasized more on scientific and engineering judgement, safety precautions, and users (manufacturer) experience in ACHE all above the instructions and checkpoints listed in these checklist and datasheet.

      [However footnote as added in API is not part of ISO.]
    - ACHE Checklist is revised with adding checkpoints as per revision/addition done in 7th edition.
    - Cyclic datasheet added which will cover Description of Cyclic Service Operation.

50. *Annex C (informative) : Winterization of Air-cooled Heat Exchangers /C.2.2 :* Para Added in ‘Reasons for Winterization’. In cold climates, where the ambient temperature can vary from −29 °C (−20 °F) or lower during winter months to 30 °C (86 °F) or higher during summer months, airflow control alone can be inadequate to provide control of the process outlet temperature and the tube wall temperature. In such cases, winterization can also be required as a means of providing process control.

51. *Annex C (informative): Winterization of Air-cooled Heat Exchangers / C.3.1.1 System A — Airflow Control:* In 7th edition Variable speed drives (VSD) is also listed as one of the measure for Airflow Control. Para added to signify use of variable speed drives.

    - VSD have become much more prevalent in recent years, especially in cold climates where there is a significant variation in ambient air temperature between summer and winter months.
    - It improves in the areas of process control, electric power reduction and noise reduction.
    - Louvers should always be used in combination with VSD when the airflow requirement for any operating case is less than 20 % of the required design airflow.

    [Capital cost for variable frequency drive controllers is higher. However it is preferred for air flow modulation due to close control of outlet temp., reliability, controllability, reduced noise and power savings]

52. *Annex C (informative): Winterization of Air-cooled Heat Exchangers / C.3.1.5:* This Para Added under ‘Airflow and Air Temperature Control Systems’. It covers ‘Recirculation Ducts — Arrangement and its Location’. This para provides guidelines about arrangement and location of recirculation ducts (louvers) in different scenario like multi-bay units (with and without symmetrical piping manifolds), single bay units, & special services (for high viscous, for vacuum system condenser, in arctic climates). Additional guidelines provided,

- All fans should be equipped with variable speed drives or auto-variable pitch for external over the side recirculation.
- The variable-pitch or variable speed fan should always be located on the outlet (coldest) end of the process bundle to maximize tube wall temperatures at the coldest section of the tube bundle.
- VSD minimum allowable fan speed should not be less than 30% for adequate air recirculation.

[In Para.3 (Terms and Definition) term for recirculated air is added. As per which 'Air that has passed through the process bundle and is redirected to mix with and heat the inlet air is called as recirculated air.'

In Para.5.10 proposal documents requirement for ACHE with recirculation system is added.

In Para.6.1.5 documents requirement for approval for ACHE with recirculation system is added.

In System D (External air recirculation system), hot exhaust air is recirculated through an external recirculation duct being mixed with inlet air when the inlet air temperature is low. For this inlet louvers, exit louvers and bypass louvers are employed in this system. Bypass louver is also termed as recirculation louver as these louvers provided along tube bundle/header sides and control recirculation of warm exit air from tube bundle and direct towards mixing with inlet air.]

References:

- API 661, Petroleum, Petrochemical, and Natural Gas Industries—Air-cooled Heat Exchangers- 7th Edition / 6th Edition.
- ISO 13706, Petroleum, Petrochemical, and Natural Gas Industries—Air-cooled Heat Exchangers- 2011 Edition / 2005 Edition.
- API 661-5th edition Summary of changes by Hudson Products Corp.

  http://www.hudsonproducts.com/media/images/API-661-5th-Edition-ISO-13706.pdf
- API 661-6th edition Summary of changes by Hudson Products Corp.

  http://www.hudsonproducts.com/media/pdfs/API-661-6th-Edition-ISO-13706-Summary.pdf

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