API RP 572 Inspection Practices for Pressure Vessels

Annex A (informative) - Exchangers

This Ballot is limited to Annex A.

- **Accepting comments on all content.**
  - Comments on redlines will be resolved.
  - Comments on non-redline section will be reviewed and incorporated. Where comment resolution requires significant work, comment will be scorecard
- All moves accepted if not commented on during the last ballot 5449 or were the result of ballot 5449 comment resolution
- Non-move redlines accepted if they were not part of Ballot 5449 comment resolution

When voting "Negative" please label the specific comments regarding your negative so we may be able to identify the concern.

Note to balloters: Please ignore formatting and numbering issues and focus on technical/editorial content. Formatting and numbering issues will be cleaned up before re-publication.

To properly organize the ballot resolution spreadsheet please be sure to enter the section numbers under the ballot spot labeled "clause/sub-clause number"; and then under "paragraph/table/figure number" simply indicate which paragraph in the section you are commenting upon.

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- "technical" when a substantive change is being made
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Annex A
(informative)

Exchangers

A.1 Shell and Tube- Exchangers

A.1.1 Types of Shell and Tube Exchangers

There are several types of shell and tube exchangers. A description of some of the types of exchangers commonly used and the factors influencing their selection follow.

A.1.1.1 Floating Head Exchanger

A floating head exchanger consists of a stationery tube sheet. At the opposite end of the stationery tube sheet, the tubes may expand into a freely riding floating-head or floating tube sheet. A floating head cover is bolted to the tube sheet and the entire bundle can be removed for cleaning and inspection. Since the floating tube end is free to move in the shell, this type of construction permits free expansion and contraction with changes in temperature.

A.1.1.2 Fixed Tubesheets Exchanger

Fixed tubesheet exchangers are constructed so both tubesheets are welded to the shell or fixed and the tubes are installed and rolled after the tubesheets are in place. The shell side cannot be exposed for cleaning. Because both tubesheets are fixed, the exchanger is limited to small expansion and contraction unless an expansion joint is provided in the shell.

A.1.1.3 U-tube Exchanger

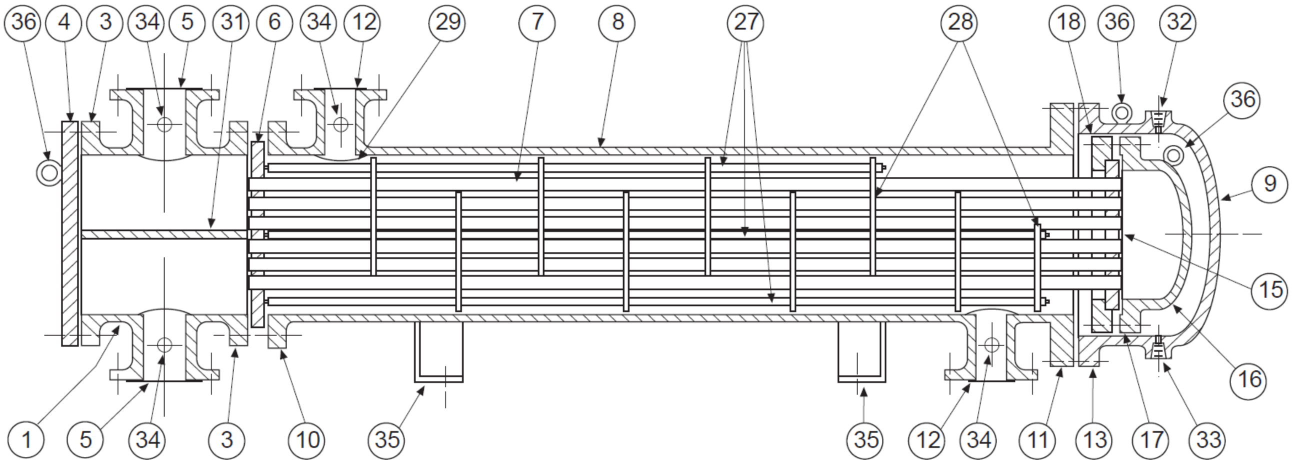
A U-tube exchanger has one fixed tubesheet with the tubes bent in the form of a long U. These exchangers have the same freedom of expansion and contraction as a floating-head exchanger.

A.1.1.4 Double-tubesheet Exchangers

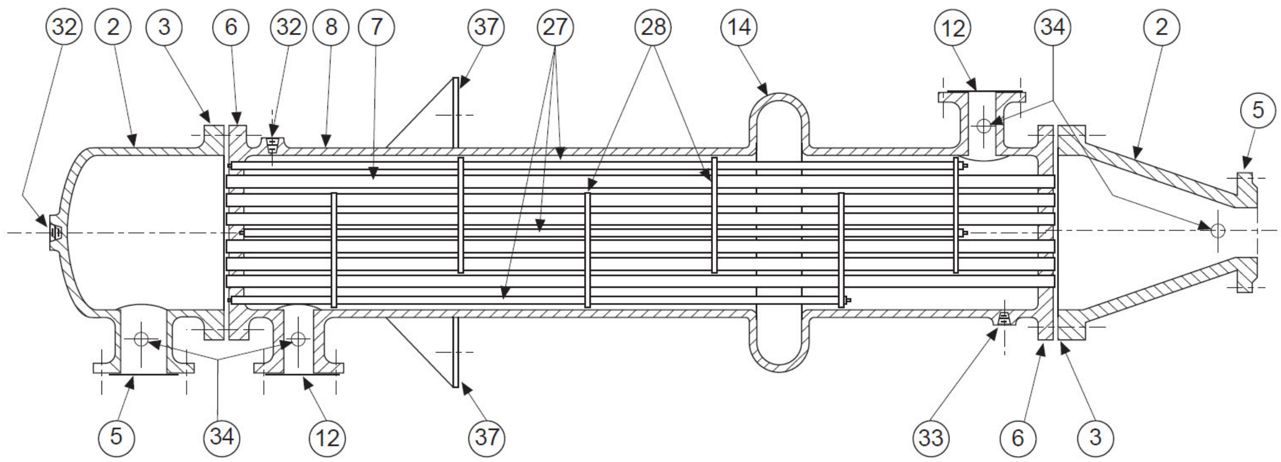
As the name implies, two tubesheets are used together with only a small distance, usually 1 in. (25.4 mm) or less, between them. The tubes are rolled into both tubesheets. The outer tubesheet is attached to the channel and the inner tubesheet is fixed to the shell. The purpose of this arrangement is to cause any leakage from the tube roll to bleed off into the space between the two sheets, thus preventing contamination of one fluid by the other. This construction is applicable only where there is no floating tubesheet.

A.1.1.5 Construction

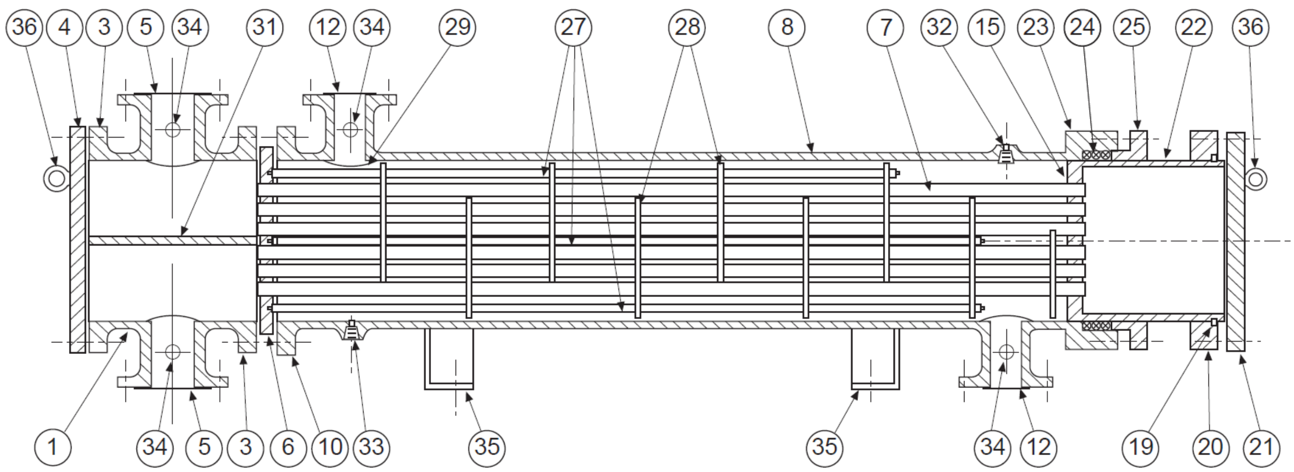
Exchangers are equipped with baffles or support plates, the type and design of which vary with the service and heat load the exchanger is meant to handle. Pass partitions are usually installed in the channels and sometimes in the floating tube-sheet covers to provide multiple flow through the tubes. The flow through the shell may be single pass, or longitudinal baffles may be installed to provide multiple passes. The baffling used in the shell will determine the location and number of shell nozzles required. Figure A.1 and Figure A.2 show various channel and shell baffle arrangements. Frequently, an impingement baffle plate or rod baffle is located below the shell inlet nozzle to prevent impingement of the incoming fluid on the adjacent tubes.



AES
Figure A.1 - Heat Exchanger Parts

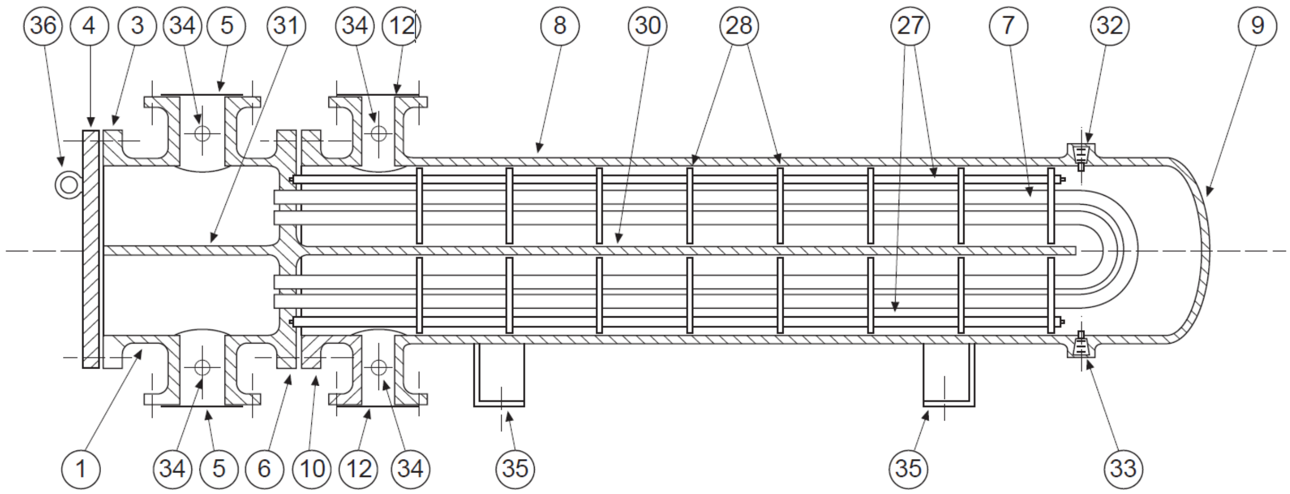


BEM
Figure A.1 - Heat Exchanger Parts (continued)



AEP

Figure A.1 - Heat Exchanger Parts (continued)



CFU

Figure A.1 - Heat Exchanger Parts (continued)

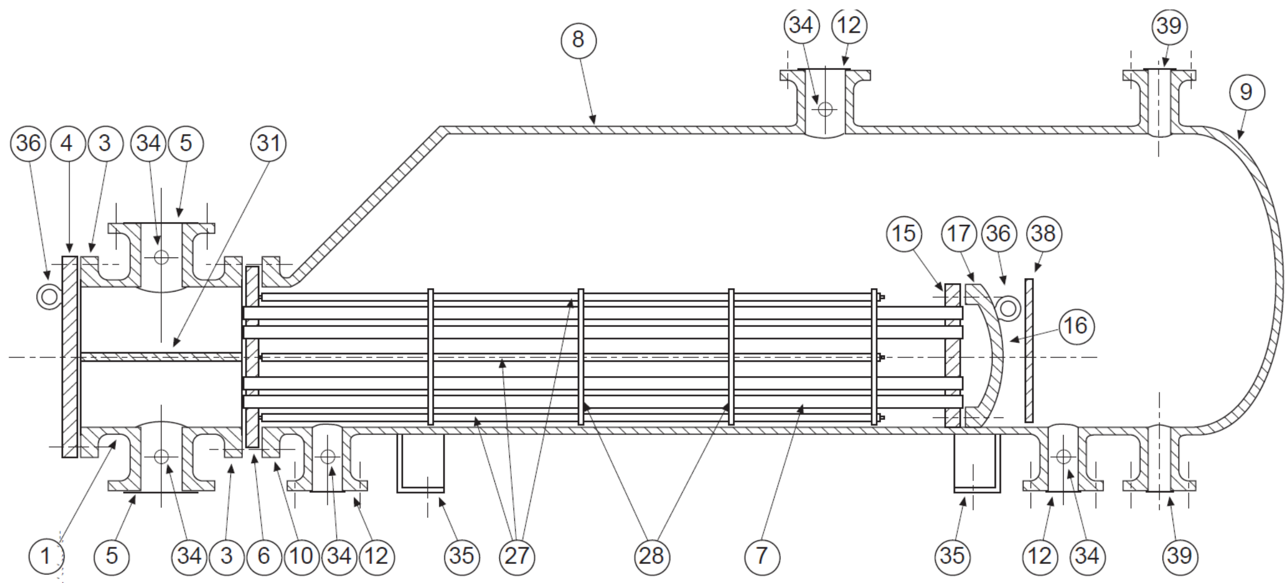


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Figure A.1 - Heat Exchanger Parts (continued)

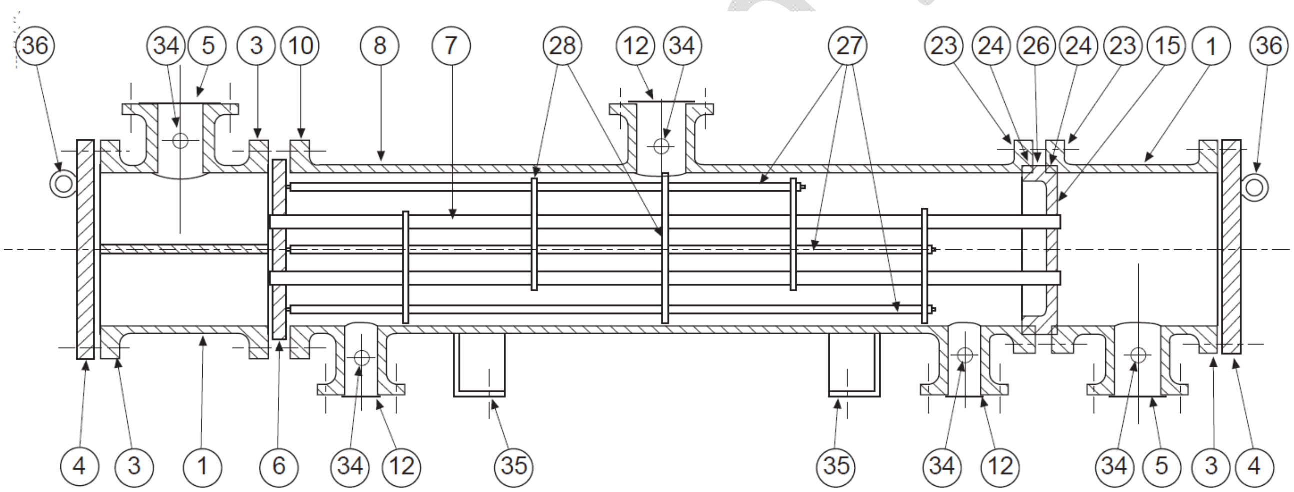

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Figure A.1 - Heat Exchanger Parts (continued)

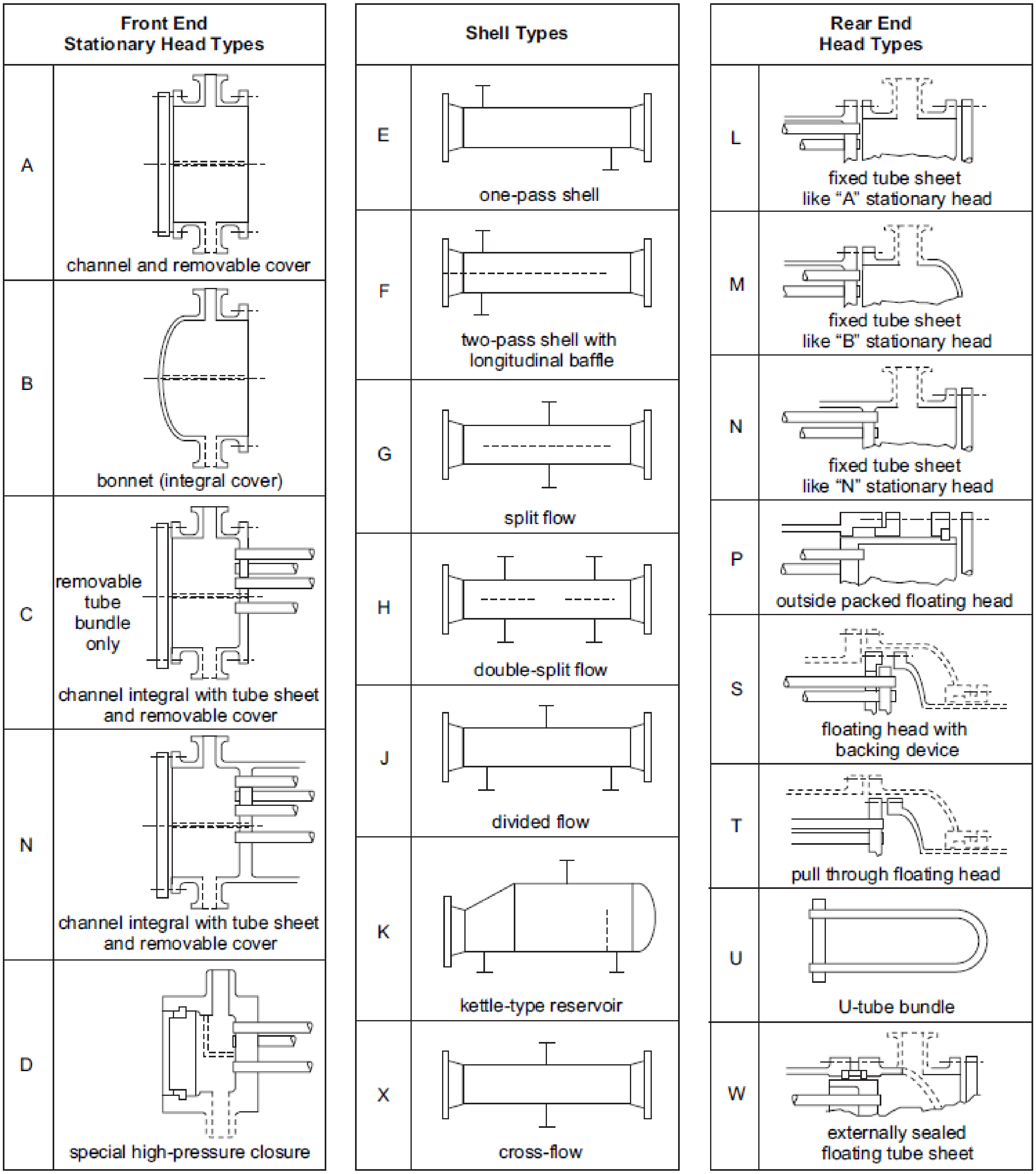


Figure A.2 - Heat Exchanger Types

The tubes may be arranged in the tubesheet on either a square or a triangular pattern. When the fluid circulating around the outside of the tubes may coke or form other dirty deposits on the tubes, the square pattern is generally used. The square pattern arrangement permits better access for mechanical cleaning between the tubes.

Usually, the tubes are attached to the tubesheet by rolling. A properly rolled tube is shown in Figure A.3. The tubes may be rolled and welded or attached by packing glands.

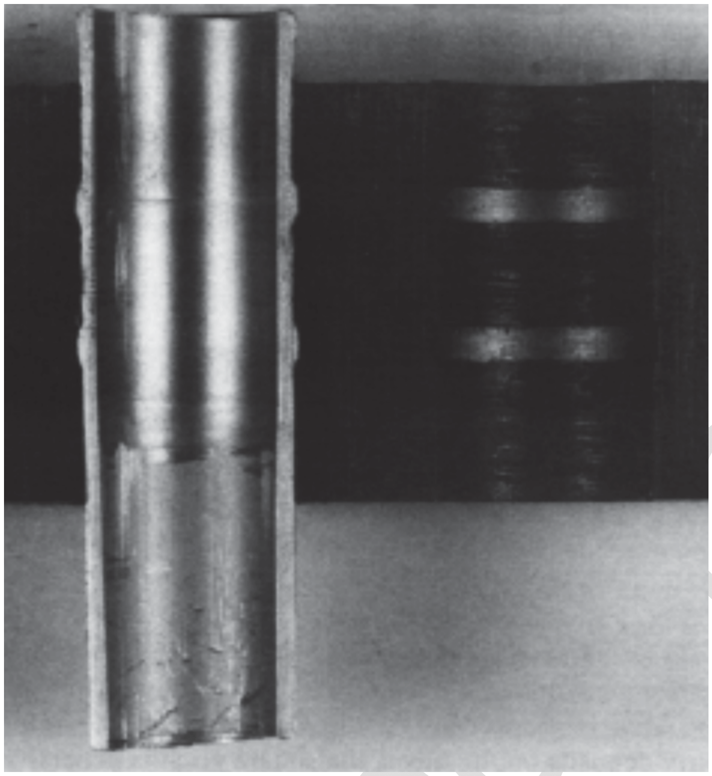


Figure A.3 - Properly Rolled Tube

A.1.2 Inspection of Shell and Tube Exchanger Bundles

A.1.2.1 General

Shell and tube exchanger bundles are difficult to inspect because of limited visibility on both sides. The inspector should know the following when creating an inspection plan:

1) Design and operating conditions on both sides.

2) Process streams and their corrosivity on both sides.

3) Materials of construction.

4) Most likely damage modes and locations.

5) Full details of exchanger inspection, operational, and maintenance history.

A.1.2.2 Tube Bundle Visual Inspection

The first step in bundle inspection is a general visual inspection to establish general corrosion patterns. If possible, bundles should be checked when they are first pulled from the shells because the color, type, amount, and location of scales and deposits often help to pin point corrosion problems.

Exchanger tube bundles may be inspected in-place, if the inspection methods and the selected NDE can effectively identify the credible damage mechanisms for the tubes. When the tube bundle is inspected in-place, the external surface of the tube bundle can be inspected through the shell nozzles and openings. Using a borescope and/or a camera can aid the inspection.

An overall, heavy scale buildup on steel tubes may indicate general tube corrosion. The lack of any scale or deposit on tubes near the shell inlet may indicate an erosion problem. A green scale or deposit on copper base tubes indicates that these tubes are corroding. As an inspector gains experience, these scales and deposits will become a useful inspection guide.

While visually inspecting a bundle, the inspector should ~~make~~ use ~~of~~ a pointed scraper to pick at suspected areas next to tubesheets and baffles. These areas may not have been cleaned completely. Picking in these areas will sometimes disclose grooving of tubes and enlargement of baffle holes. Figure A.4 shows tubes thinned at baffles and Figure A.5 shows fretting damage to the tube from contact with the baffle.

The inside of the tubes can be partially checked at the ends by use of flashlight extensions, fiber optic scopes, borescopes, and special probes. The special probes are slender 0.125 in. (3.2 mm) rods with pointed tips bent at 90° to the axis of the rod. With these tools, it is possible to locate pitting and corrosion near the tube ends.

~~Obviously, o~~Only the outer tubes of a bundle can be thoroughly inspected externally, and without a borescope or fiber optic scope, only the ends of the tubes can be inspected internally. If a complete inspection of the tubes for defects is required, it can be performed using ET methods or UT methods (for internal rotary, use UT thickness measurements).

Tubes may also be removed from the bundle and split for visual inspection. There are devices available for pulling a single tube from a bundle.

Removal of one or more tubes at random will permit sectioning and more thorough inspection for determining the probable service life of the remainder of the bundle. Tube removal is also employed when special examinations, such as metallurgical and chemical, are needed to check for dezincification of brass tubes, the depth of etching or fine cracks, or high-temperature metallurgical changes. When bundles are retubed, similar close inspection of tubes removed will help to identify the causes of failure and improve future service.

The baffles, tie rods, tubesheets, and floating-head cover should be visually inspected for corrosion and distortion. Gasket surfaces should be checked for gouge marks and corrosion. A scraper will be useful when making this inspection. Sufficient gasketed surface should remain to make a tight seal possible when the joints are completed.

Tubesheets and covers can be checked for distortion by placing a straightedge against them. Distortion of tubesheets can result from the overrolling or improper rolling of tubes, thermal expansion, explosions, rough handling, or overpressuring during a hydrotest.

Brass tubes and tubesheets should be examined for dezincification. Without cathodic protection, galvanic corrosion of tubesheets around more noble tube materials can occur in seawater service (e.g., titanium tubes fitted into copper alloy tubesheet).

Tubesheet and floating-head thickness can be measured with mechanical calipers. Except in critical locations, continuous records of such readings are not usually kept. However, the original thickness readings of these parts should be recorded. Thickness readings of tie rods and baffles are not generally taken. The condition of these parts is determined by a visual inspection.

Tube wall thickness should be measured and recorded at each inspection. It is sufficient to measure the inside and outside diameters and to thus determine the wall thickness. Eccentric corrosion or wear noted during the visual inspection should be taken into account in determining the remaining life of the tubes.

Several tools are available for the assessment of tube conditions. Long mechanical calipers can be used to detect general or localized corrosion within 12 in. (30.5 cm) of the tube ends. More detailed measurements along the entire tube length can be achieved with specialized tools such as laser optical devices, internal rotary UT tools, and electromagnetic sensors. Generally, the laser optical and UT devices require a high degree of internal tube

Figure A.4 - Tubes Thinned at Baffles

cleanliness compared to electromagnetic methods. Laser optical devices can only detect and measure internal damage. Electromagnetic methods can detect and provide semiquantitative information on both internal and external flaws. Rotary UTs will generally provide the most quantitative information and can identify if flaws are on the internal or external surface of the tube. Reference API 586 for more details on tubular inspection.

~~A.1.2.2~~A.1.2.3 Likely Locations of Corrosion and Damage

The locations where corrosion should be expected depend on the service of the equipment. However, there are certain locations that should be watched under most conditions of service.

Inspection plans for exchanger shells and channels should include, where applicable, inspection for the following damage and deterioration types;

- Deformation of shell and channel flanges.

- Corrosion or mechanical damage to gasket faces.

- Deformation and fatigue cracking of division plates.

- Circumferential grooving of shell internal at baffle locations.

- Scoring of shell caused by bundle pulling.

- Damage to internal protective coatings or metallic linings.

- Inadequate remaining sacrificial anode material to provide protection over the next service period.

The outside surface of tubes opposite shell inlet nozzles may be subject to erosion or impingement corrosion. When a mildly corrosive substance flows on the shell side of the tube bundles, the maximum corrosion often occurs at these inlet areas. The next most likely point of corrosion under the same conditions would be adjacent to the baffles and tubesheets. Any damage here is probably erosion-corrosion (see Figure A.6). Tube ends should be visually checked for thinning, impingement erosion, and cracking. In seawater service copper alloy bundles are particularly prone to tube end erosion ~~(see Figure A.10)~~ caused by turbulent flow due to insufficient crossover area in floating head covers or by partial blockage by marine life, or debris.

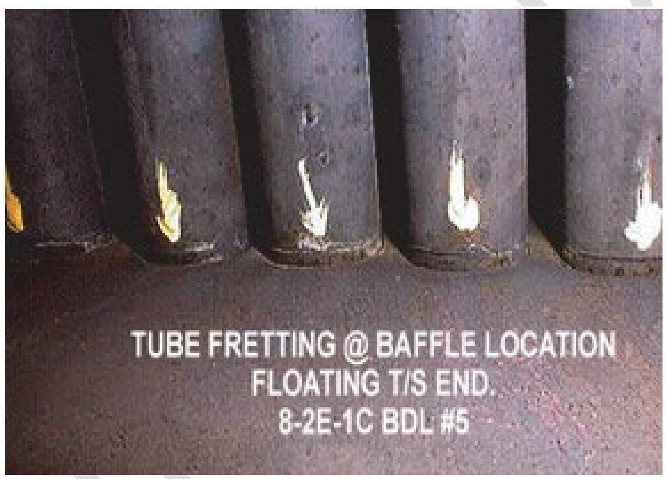


Figure A.5 - Tubes Fretting at Baffles

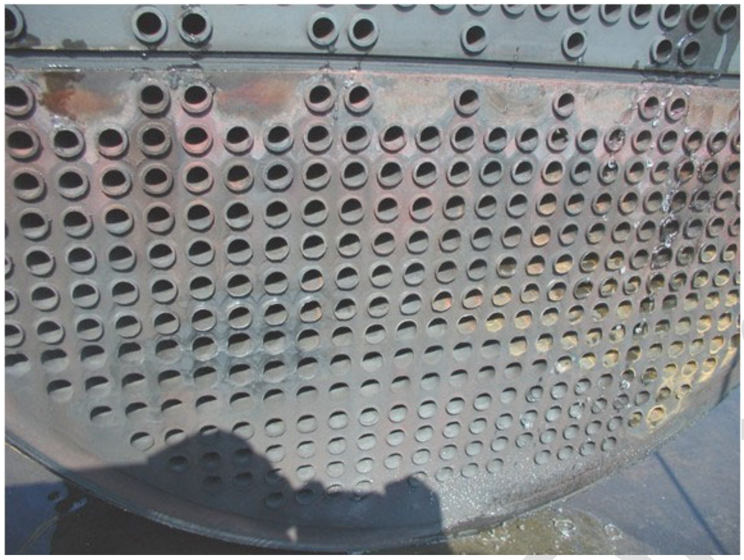


Figure A.6 - Erosion–Corrosion at Tube Ends

When a high-temperature material flows into the tube inlet pass, the backside of the stationary tubesheets or tubes immediately adjacent to it may suffer extensive corrosion.

When process conditions allow a sludge or similar deposit to form, it will generally settle along the bottom of the shell. If the deposit contains a corrosive material, the maximum corrosion will occur along the bottom of the shell and the bottom tubes.

In water service, the maximum corrosion will occur where the water temperature is highest. Thus, when the water is in the tubes, the outlet side of the channel will be the location of maximum corrosion. Figure 23 shows pitting in a channel.

Gray cast iron exchanger parts in water service should be checked for graphitic corrosion. This type of corrosion is most often found in water-service channels or along the bottom of shells where sour water might collect. It can be found by scraping at suspected areas with a stiff scraper. Whether the corrosion is serious depends on its location and depth. Quite often, pass partitions can be almost completely corroded and still function efficiently, unless the carbon shell is broken or chipped.

In any type of exchanger, corrosion may occur where dissimilar metals are in close contact. The less noble of the two metals will corrode. Thus, carbon steel channel gasket surfaces near brass tubesheets will often corrode at a higher rate than they would otherwise.

Cracks are most likely to occur where there are sharp changes in shape or size or near welded seams, especially if a high stress is applied to the piece. Parts such as nozzles and shell flanges should be checked for cracks if excessive stresses have been applied to a unit.

When process stream velocities are high in exchangers, erosion damage can be expected at changes in the direction of flow. Damage would occur on or near such parts as tube inlets in tubular units and at return bends in double-pipe units and condenser box coils. The area of the shell adjacent to inlet impingement plates and bundle baffles is susceptible to erosion, especially when velocities are high.

Reboiler and condensers can be susceptible to severe localized corrosion where corrosive components of the process stream concentrate in the reboiler or condense in the condenser.

A distinctive Prussian blue color on bundle tubes indicates the presence of ferri-ferrocyanide. Hydrogen blistering is likely to be found on the exchanger shell near this color. A long straightedge may prove useful in determining the existence of blistering. Irregularities of the surface show up when the straightedge is placed on it. A straightedge is also useful when investigating pitting.

~~A.1.2.3~~A.1.2.4 Scheduling of inspections

There are at least four common methods of scheduling bundle inspections: time-based, condition-based; risk-based, and consequence based.

A.1.2.3.1 Time-based Scheduling

Time-based scheduling is probably the oldest and simplest method. Scheduling inspections primarily based on the calendar and most often connected with maintenance opportunities like turnarounds.

A.1.2.3.2 Condition-based Scheduling

Condition-based scheduling was the next method developed and entails scheduling inspections primarily based on deterioration rates, i.e., usually corrosion rates calculated from previous inspection data.

A.1.2.3.3 Risk-based Scheduling

Risk-based scheduling is the most recent method, which involves planning inspection based on probability of failure (POF) (i.e., calculated deterioration rates), as well as the consequence of failure (COF) (i.e., potential harm due to tube leaks). Higher risk bundles are inspected at more frequent intervals than lower risk bundles.

API RP 581 describes a methodology to assess the reliability and remaining life of heat exchanger bundles. It also provides a methodology for performing cost benefit analysis to assist in making risk-based inspection and replacement decisions and to determine the optimal replacement frequency of heat exchanger bundles.

A.1.2.3.4 Consequence-based Scheduling

Consequence-based scheduling is an offshoot of risk-based method of scheduling bundle inspections, and as the name implies is primarily based on the impact of tubular failure. As alluded to in the previous section, consequence-based inspections would not only have higher retirement thickness values established for higher consequence failure, but would likely have shorter inspection intervals established. For instance, bundles classified as a significant consequence to process safety or environmental damage might have inspection intervals scheduled in the range of quarter to half-life, depending upon the magnitude of the consequence. Bundles with little if any consequence to the business from tube leaks could have inspection intervals scheduled at close to full life or even perhaps wait until the detection of a leaking bundle. Each of three types of heat exchanger bundles would be classified as high, medium, or low consequences. For each category a Minimum Practical Renewal Thickness (MPRT) would be established for each bundle.

The above description can be included in a three-tiered categorization of heat exchanger bundles such as the following which can then be modified to suit the site's acceptable consequence thresholds:

High Category heat exchanger Bundles:

- Bundles where significant process safety or environmental consequences are associated with tubular leaks, or tube rupture e.g., light hydrocarbon or hydrogen leaks into cooling water towers, or high design pressure differential leading to rapid overpressure of the low pressure side of the exchanger.
- The established MPRT would be relatively conservative resulting in half or quarter life thicknesses and possibly based on Extreme Value Analysis.
- Inspection intervals established by engineering and inspection with input from HSE and recorded in the inspection data management system (IDMS).

Medium Category heat exchanger Bundles:

- Bundles where the primary consequences are associated with reliability impacts e.g., process unit slow down or partial unit shutdowns and varying degrees of business interruption losses due to tube leaks
- The established MPRT would be relatively conservative for the potential for larger business interruptions costs and less conservative for the potential for smaller business interruptions costs e.g., 25% - 40% - 55% tube metal thickness loss.
- Inspection intervals and due dates would be established in concert with operations and others involved in judging the degree of reliability impacts and recorded in the IDMS.

Low Category heat exchanger Bundles:

- Bundles where the consequences associated with tube leaks are low, not involving any significant process safety or environmental consequences and relatively low reliability impacts.
- The established MPRT would be relatively conservative and may even be run until a leak is detected.
- Inspection intervals and due dates would be established by operations and recorded in the IDMS.

A.2 Exposed Tube Bundles

Exposed tube bundles are used for condensing or cooling and may be located under spraying water or completely submerged. They may be used as heaters, particularly in tanks where they are submerged in the liquid.

A.2.1 Exposed Tube Bundle Under a Cooling Tower

Exposed tubes arranged in compact bundles can be placed under a cooling tower: in this arrangement, the water from the tower flows over the tubes, and heated water is returned to the top of the tower for cooling and reuse. This placement of the tube bundles is most effective in a climate with a low relative humidity resulting in maximum evaporative effect.

A.2.2 Exposed Tube Bundle Under Spray Heads

Spray heads may be installed above an exposed tube bundle to provide an even distribution of water over the tubes (this represents a modification of the method described in Section A.2.1). A receiving tank is located below the tube bundle for use mainly when the water is naturally cool enough to permit recirculation without additional cooling. Where water is plentiful, this type of cooler may be used without a receiving tank, permitting the used water to drain into a treatment system.

A.2.3 Submerged Exposed Tube Sections

Exposed tube sections are submerged, and mounted either vertically or horizontally within a box. The hot fluid enters the top of the headers in vertical installations and the top section in horizontal installations. In either installation, the cooled fluid leaves at the bottom. Cool water enters near the bottom of the box, and the warmed water overflows a weir near the top of the box. This arrangement produces counter current flow resulting in maximum cooling with a minimum use of water.

Submerged sections are used primarily with a hot fluid leaving the cooler. If the water supply should fail, the large volume of water in the cooler box would give partial cooling for an extended period and allow time for an orderly shutdown of the operation if necessary.

A.2.4 Stab-in Reboilers

~~Basically,~~ Stab-in reboilers are a shell and tube exchanger without a shell (also known as a 'Bayonet' exchanger). It most often is a U-tube bundle but any type of internal head can be used. The major benefit is eliminating external piping. Reboilers are sometimes inserted into the bottom of a tower. This type of reboiler may be more difficult to repair a leaking or fouled tube without opening the tower itself.

A.3 Storage Tank Heaters

The tube-bundle version of the tank heater is built in three general types for the following installations:

a) installation outside the tank,

b) installation partially within the tank,

c) installation entirely inside the tank.

The first two are installations of suction line heaters and the third (see Figure A.7) heats the entire contents of the tank.

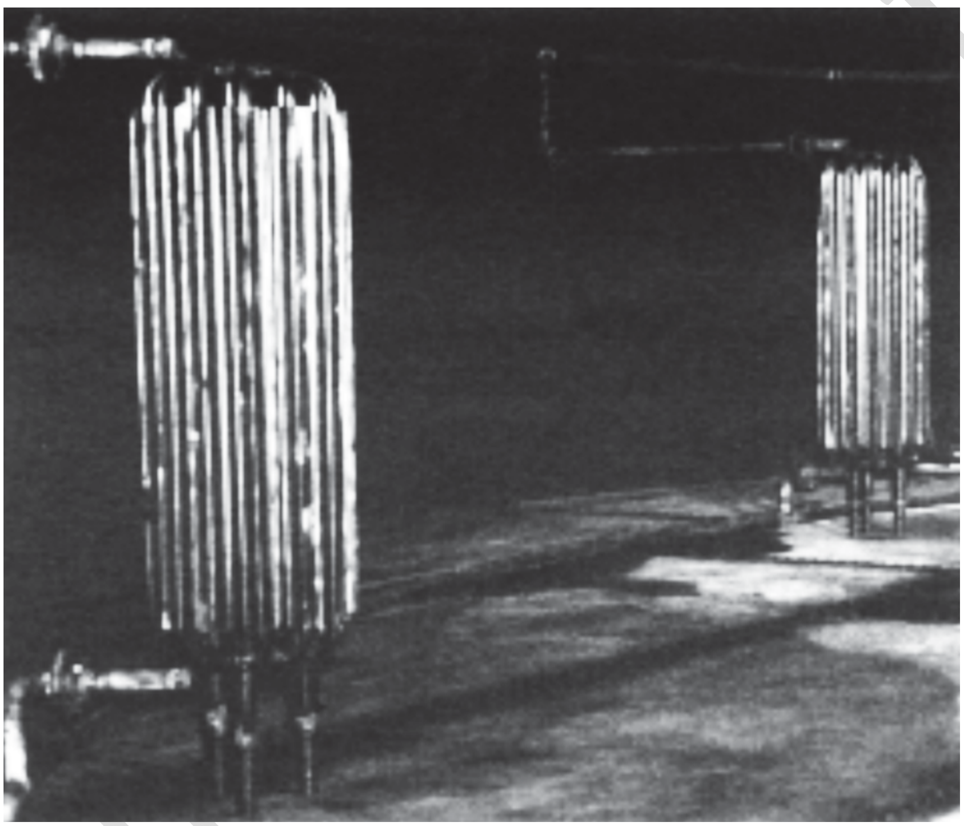


Figure A.7 - Tube-bundle Type of Tank Heater

A.4 Air-cooled Exchangers

A.4.1 Air-Cooled Exchangers

An air-cooled exchanger is used to transfer heat from a fluid directly to ambient air. This is in contrast to transferring heat to water and then air, as with a shell and tube heat exchanger and a wet cooling tower system. Tubes are located in a steel framework through which air is circulated by a fan placed either above or below the tube bank. When the fan is above the tube bank, it is usually referred to as an induced draft air-cooled exchanger ~~cooler~~ and a fan below the tube bank is usually referred to as a forced draft air-cooled exchanger ~~cooler~~. These coolers may be used for the condensing or cooling of vapors and liquids. Figure A.8 illustrates air-cooled exchangers. API 661 covers the minimum requirements for design, materials, fabrication, inspection, testing, and preparation for initial delivery.

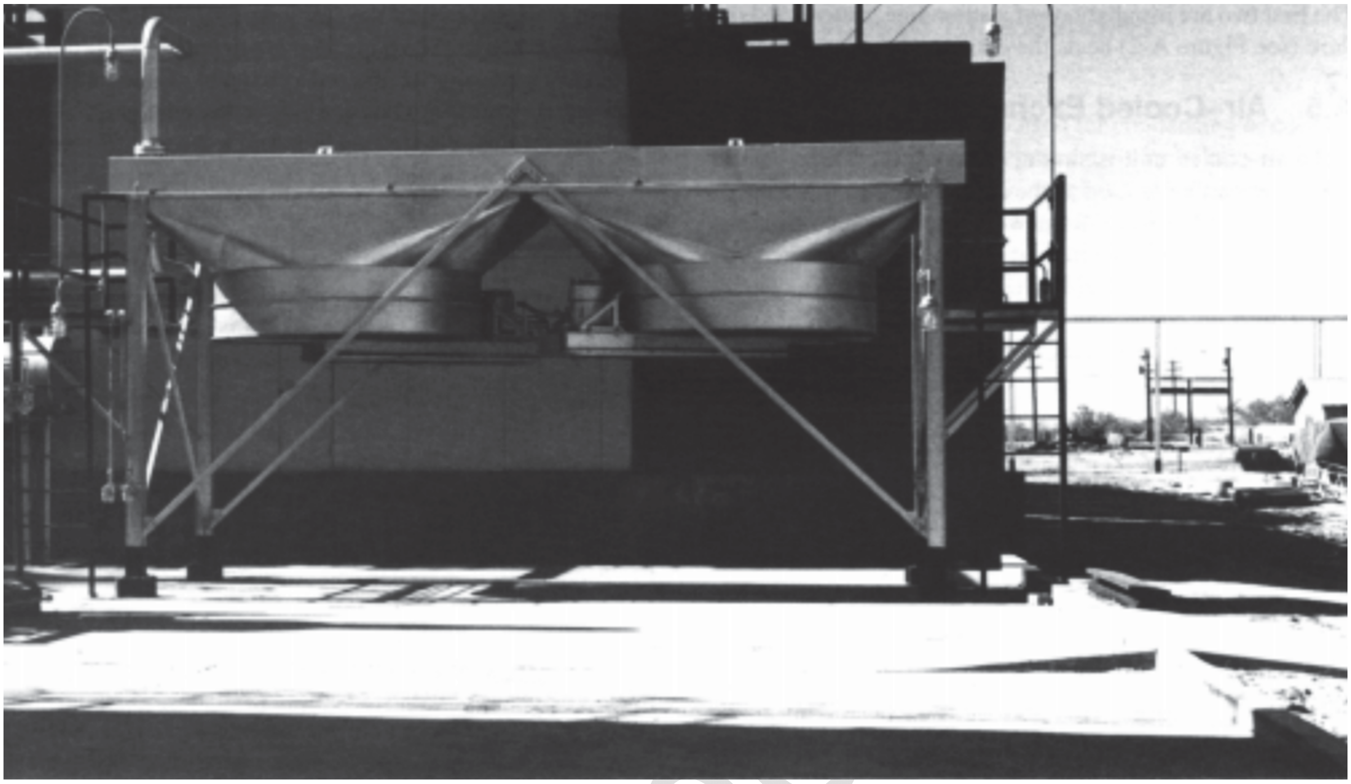


Figure A.8 – Air-cooled Exchangers

A.4.2 Inspection of Air-Cooled Exchanger

Refer to API 661 for descriptions, minimum design criteria, and general information regarding air-cooled exchangers. API 510 and the principles of API 661 are to be followed in any ratings, repairs, and alterations of this type of exchanger. (See Annex C for a sample form for making an inspection report on an air-cooled exchanger.)

Tubes enclosed in fins cannot be inspected from the exterior. The best methods for inspecting the tubes are the internal-rotary, UT thickness devices, ET, or near field ET. These methods work from the interior of the tubes. With competent operators and clean tubes, thicknesses and flaws can be found with these methods. The tubes should be thoroughly cleaned before any method is effective.

The external fins of the tubes should be checked for cleanliness. If the fins need cleaning, washing with clean water alone or clean water with soap may be sufficient. If not, care should be taken in selecting a cleaning solution. Usually, the fins are aluminum and they could be harmed if the wrong cleaning medium is used.

The exterior of the tubes should be inspected between the tubesheet and the start of the fins. Exchangers in intermittent service or in service cool enough to allow moisture to collect in this area are subject to external corrosion severe enough to cause leaks in this area. Coatings applied to this area will alleviate the problem of corrosion.

Plugs and plugsheets should be inspected for thread damage. Fan blades and hubs should be inspected for corrosion or mechanical damage.

The insides of the tubes may be visually inspected near the tube-sheet ends of the air-cooled exchanger~~-cooler~~. Fiber optic devices and borescopes are excellent devices for this type of inspection. A probe rod 0.125 in. (3.2 mm) or less in diameter and approximately 36 in. (91 cm) in length with a pointed tip bent at 90° to the axis of the rod also may help to locate pits or corrosion at the tube ends.

Erosion-corrosion at the tube inlets is a common problem with air-cooled heat exchangers. This damage can be found by visual inspection through the header-box plug holes, or directly if the header box has a removable cover plate. If suitable conditions exist, reflecting sunlight into the tubes with a mirror is useful in inspecting for erosion-corrosion.

The box-type header ends of the air-cooled exchanger ~~cooler~~ should be inspected using the same techniques as recommended for a pressure vessel. In addition, the sharp change of direction caused by its rectangular construction should be carefully checked for cracking. A fiber optics scope may be the only way to check a header that has plug-type closures as opposed to a cover plate.

Ultrasonic Flaw Detection, Straight and Angle Beam techniques can be applied for detection of cracking in the header box corner welds. Phased Array UT has created a significant advantage for optimizing UT beam configuration for examination of the corner welds. Total Focusing Method (TFM) enhances the ability to detect cracks specially for this application.

Review of the header box design, weld preparation, confirmation of dimensions and planning ultrasonic beam interaction with the welds compliments the probability of detecting flaws. A definitive UT scan plan may reveal a viable examination of both plug side and tube side corner welds.

A fiber optics and or video scopes may be the only way can be used to check header internal surfaces that has plug-type closures as opposed to a cover plate. Some video scopes have Ultraviolet Lights which compliments the use of florescent penetrant for internal surface examinations. Cleaning the internal surfaces is essential for an effective penetrant examination. Consult a Penetrant Testing expert in effort to select a surface cleaning technique that does not impede the effectiveness of the examination.

External inspection can usually be performed while air-cooled exchanger ~~cooler~~ is in operation. Inspections should include, in addition to the items covered in Section 10.1, the following:

- Louvres and associated drive or positioning mechanisms for damage or malfunction.

- Tubes for corrosion, sagging, and distortion. If thermal distortion associated with fouling is suspected, top row tube metal temperatures can be measured across full width of cooler by thermographic imaging.

- Fins on top rows of tubes as far as possible for corrosion and mechanical damage.

- Fan guards for corrosion and break-up.

- Plenum plates for corrosion or other deterioration.

Refer API RP 932-B for inspection and testing of Reactor Effluent Air Coolers. API RP 932-B provides guidance to engineering and plant personnel on equipment and piping design, material selection, fabrication, operation, and inspection practices to manage corrosion and fouling in the wet sections of hydroprocessing reactor effluent systems.

A.5 Pipe Coils

Pipe coils are of two types:

a) double-pipe coils,

b) single-pipe coils.

A.5.1 Double-pipe Coils

A.5.1.1 General

Double-pipe coils are used when the surface required is small because they are more economical than the shell or tube type of exchanger in such service. They are also used where extremely high pressures are encountered because their small diameter and cylindrical shape require a minimum wall thickness.

A.5.1.2 Clean-service Double-pipe Coils

Clean-service double-pipe coils consist of tubes within tubes (see Figure A.9). The internal tubes are connected at one end by return bends that are enclosed by return bends connecting the external tubes of the same coil unit. At the opposite end, the internal tubes project beyond the outer tube and through a tight closure that prevents leakage. Internal tubes terminate in piping or are connected to adjacent units with exposed return bends. The external tubes are connected to piping or adjoining external tubes by branch-flanged nozzles.

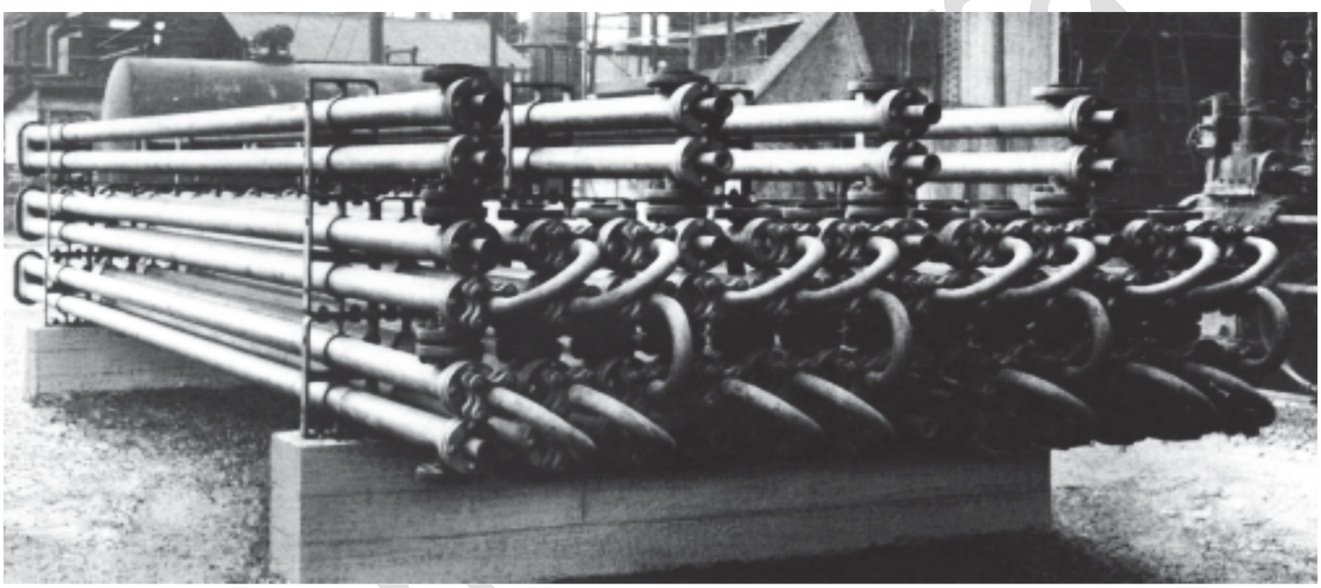


Figure A.9 - Clean-service Double-pipe Coils

A.5.1.3 Dirty-service Double-pipe Coils

Dirty-service double-pipe coils (scraper-type coils) are identical to clean-service double-pipe coils with the exception that a scraper is added to the inside of the inner tube. Each internal tube is equipped with scrapers mounted on a rod or shaft extending the full length of the tube. The rod projects through the return bends at each end. To prevent leakage, a bearing for the rod is capped at one end, and a bearing and a stuffing box are used at the other end. The rod extends through the stuffing box and a sprocket is mounted on the end of the rod. The rods and scrapers are rotated by a sprocket chain driven by some form of prime mover, usually an electric motor.

A.5.2 Single-pipe Coils

A.5.2.1 General

Single-pipe coils are used in several different ways, but essentially all are continuous runs of pipe through which flows a medium to be cooled or heated.

A.5.2.2 Condenser or Cooler Coils

Condenser or cooler coils consist of a continuous pipe coil or a series of pipe coils installed in a box through which cold water flows. The pipe coil or coils rest on supports in the box and are free to move with any expansion or contraction. Water enters near the bottom of the box and overflows a weir near the top.

A.5.2.3 Chilling Coils

Chilling coils are pipe coils installed in cylindrical vessels to cool a product below atmospheric temperature. Usually, a refrigerant is circulated through the coils to accomplish the cooling. The pipe may be coiled near the internal periphery of the vessel and extend from the bottom to the top or may be arranged as a flat, spiral coil near the bottom of the vessel.

A.5.2.4 Flat-type Tank Heater Coils

The flat-type coil extends over most of the bottom of a storage tank and is a continuous coil with return bends connecting the straight runs of pipe. Steam enters one end of the coil and condensate is drained at the other end through a steam trap. The coil rests on low supports at the bottom of the tank and slopes gently from the inlet to the outlet to facilitate drainage of the condensate. The pipe is usually fabricated of steel, and generally all joints are welded to minimize the probability of leakage.

A.5.2.5 Box-type Tank Heater Coils

The box-type coil is constructed in a rectangular shape, as shown in Figure A.10, and extends diametrically from the tank outlet to within a few feet of the opposite side of the tank. The coil is enclosed in a box fabricated of steel or wood. The end of the box opposite the tank outlet remains open to permit the entrance of oil. The oil flows through the box, around the coil, and to the tank outlet. Steam enters the top of the coil and flows downward to the outlet where condensate is drained through a steam trap. The entire coil is sloped gently from the inlet to the outlet to facilitate drainage of the condensate.

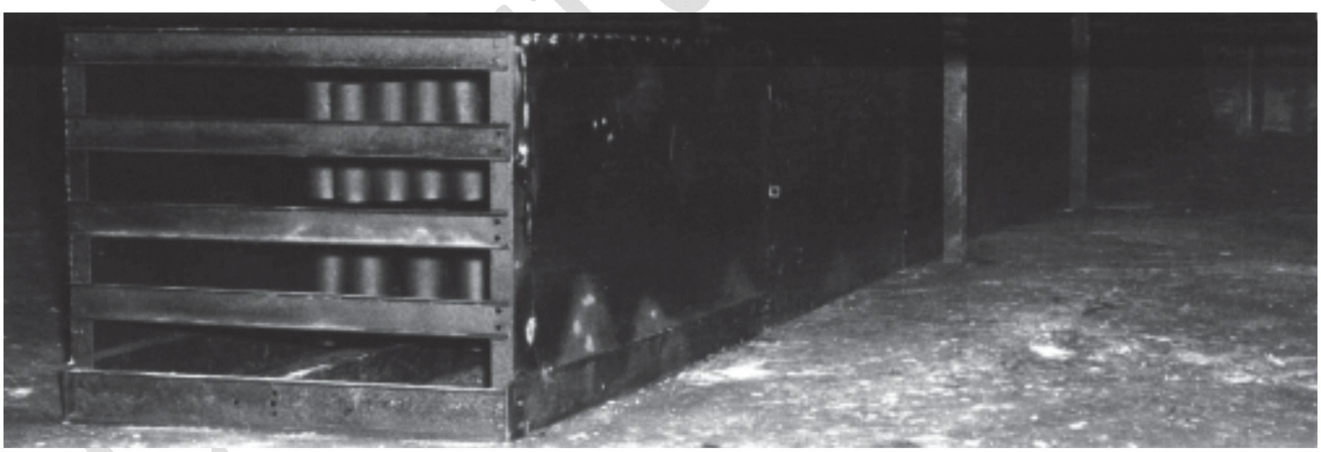


Figure A.10 - Tank Suction Heater with Everything but Forward End Enclosed; Shell Suction Nozzle Enclosed in Far End

A.5.3 Inspection of Coils and Double-pipe Exchanger Shells

~~Basically, c~~Coils in open condenser boxes and double-pipe exchanger shells are generally constructed of piping material~~composed of pipe~~. They should be inspected according to the procedures detailed in API RP 574. (See Annex C for a sample form for making an inspection report on a double-pipe exchanger.)

First, a thorough visual inspection should be performed. A scraper may be used to detect external pitting, a common flaw found on the outside of coils in condenser boxes.

Following the visual inspection, thickness measurements should be taken. It is generally sufficient to use calipers to measure the open ends of double-pipe exchanger shells. To measure the wall thickness of coils and the middle section of double-pipe shells, UT and ET devices can be used. Depending on the thickness of the pipes in a double pipe exchanger, profile RT may be used in some cases, to obtain estimated wall thicknesses of the inner and outer pipe in service.

The enclosures of condensers or cooler boxes are made of concrete or light-gauge carbon steel. These enclosures should be visually inspected when the enclosed coil is inspected. When the container is fabricated of carbon steel, thin spots in the container wall can be found with UT. Calipers can be used to measure the wall thickness at the open top. If measurements below the top are required, the NDE instruments can be used or test-hole drilling can be applied. Concrete walls are inspected best by picking at selected points with a scraper to check for spalling, cracks, or soft spots.

A.6 Extended Surface or Fin-type Tubes

Extended surface or fin-type tubes are used ~~quite extensively~~ for more efficient heat exchange, especially when the exchange is between two fluids having widely different thermal conductivities. The addition of the extended surface requires less internal tube surface. Consequently, an exchanger smaller than would be required if plain tubes were used is necessary. The use of fin-type tubes in a double-pipe coil is shown in Figure A.11.

A.7 Plate-type Exchangers

A.7.1 Plate-type Exchangers

The plate-type exchanger is constructed with an extended surface, making use of alternating layers of thin plates and corrugated sections. Integral channel and manifold sections enclose the open ends. The process material flows into the corrugated openings. Because the flow openings are small, they are easily clogged by dirt and products of corrosion. This is one of the reasons these units are constructed of materials that are highly resistant to corrosion. A plate-type exchanger installation for storage tank heating service is illustrated in Figure A.12.

A.7.2 Inspection of Extended Plate Exchangers

Extended plate exchangers are designed so the flow openings between the plates are quite small. For this reason and because of the inaccessibility of the unit interior, these exchangers are usually built of alloys highly resistant to corrosion in their expected service. In most cases, the alloys used also will be highly resistant to corrosion in refinery atmospheres. The outer surfaces can be checked for nicks, cuts, gouges, or other forms of mechanical damage and for bulging from internal failures.

These units are usually built with integral channels and distribution manifolds, the thickness of which can be accurately measured with the UT instruments and then recorded. It is not advisable to use drilling equipment on the exchangers because the equipment could be easily damaged at these points. Welding of the alloys used in the units, such as aluminum and austenitic stainless steel alloys, requires welder skills not always readily available.

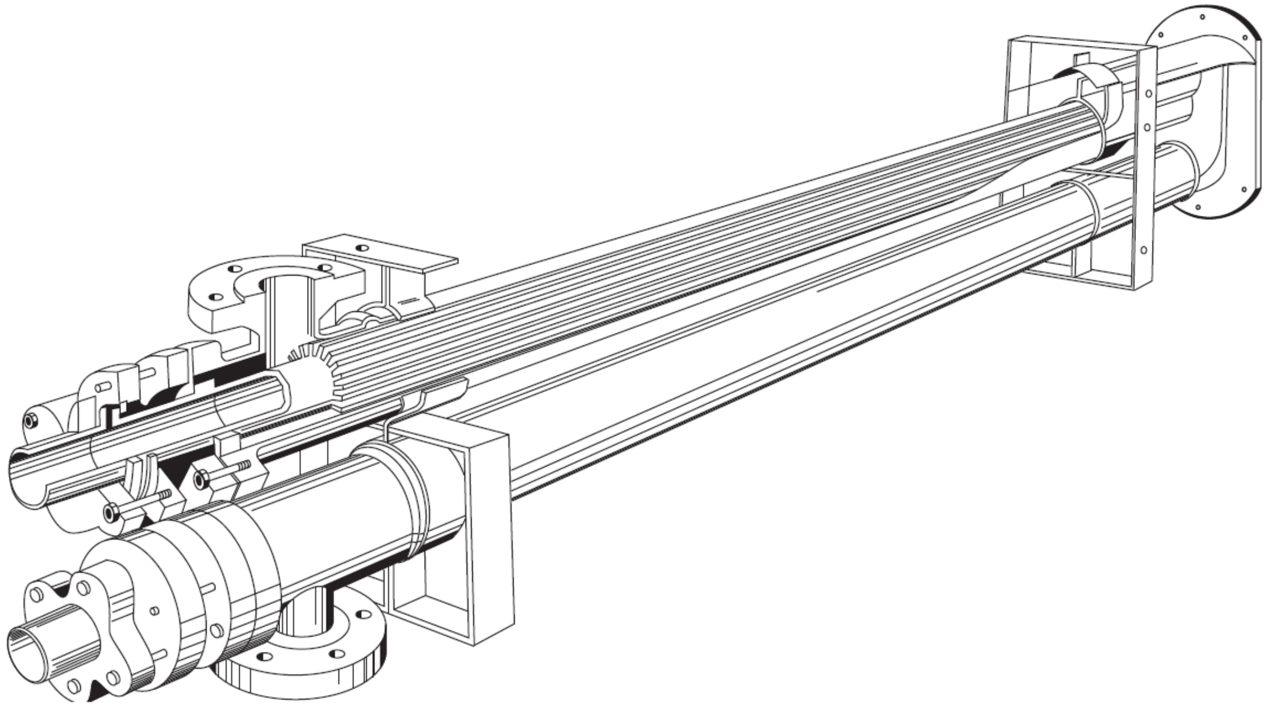
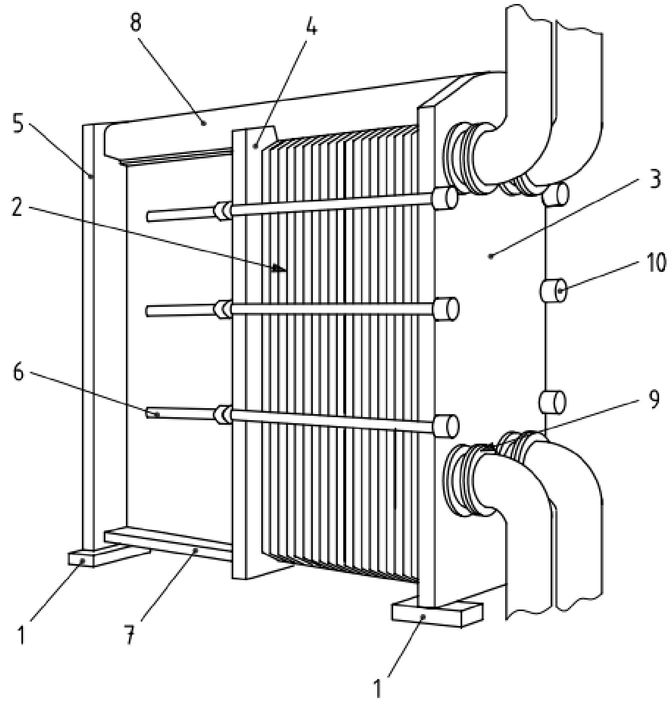


Figure A.11 - Fin-type Tubes in Double-pipe Coil



Key

1	mounting feet	6	tie bolts
2	plate pack	7	guide bar (bottom)
3	fixed cover	8	carrying bar (top)
4	movable cover	9	connections, studded or flanged
5	support column	10	tie nuts

Figure 1 — Typical single-pass plate-and-frame heat exchanger

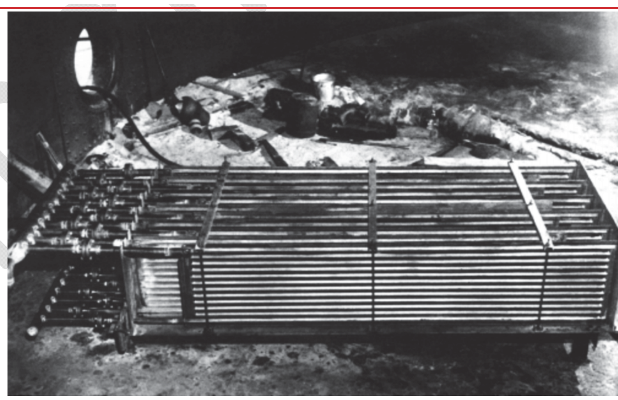


Figure A.12 - Plate-type Exchanger

A.8 Plate-Fin Exchangers (aka – Brazed Aluminum Heat Exchangers or Cold Boxes)

~~A~~ Brazed Aluminum heat exchangers used in cryogenic gas processing is an all brazed and welded compact heat exchange device designed in accordance with pressure vessel codes. These types of vessels are commonly found in cryogenic gas processing applications including air separation, nitrogen rejection, LNG liquefaction, hydrogen recovery, ethylene plants and other low temperature natural gas and petrochemical processes. They are typically either stand-alone units, battery assemblies or Cold Box assemblies including multiple process equipment such as vessels and drums in a carbon steel enclosure.

Physical inspection of these vessels is limited due to the physical configuration and construction materials utilized.