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FALL 2001

NEWSLETTER

VOL I-1

Joe McKee
Sales/Applications Engineer

In our continuing effort to develop partnerships with the process community we have developed this newsletter as a format to share a solution for a challenge experienced in the field of Heat Transfer.

This issue of our newsletter will identify and discuss some common failures that occur in shell & tube heat exchangers, as well as corrective actions for prevention of each type of failure.

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"Mechanical Failure of Shell & Tube Heat Exchangers"

Shell & Tube Heat Exchangers usually provide long service life with little or no maintenance because they have no moving parts. However, there are several types of mechanical failures that can occur, but with a little maintenance and understanding, they can be prevented.

Metal Erosion:

Excessive fluid velocity on either the shell or tube side of the heat exchanger can cause damaging erosion as metal wears from the tubing. Any corrosion already present is accelerated as erosion removes the tube's protective films, exposing fresh metal to further attack.

Most metal erosion problems occur inside the tubes. The U bend of U-type heat exchangers and the tube entrances are the areas most prone to erosion. Fig. 1 shows the metal loss in a U bend caused by high-temperature water flashing to steam.

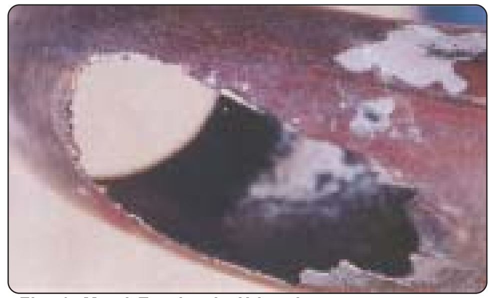
Fig. 1. Metal Erosion in U-bend.

Tube entrance areas experience severe metal loss when high-velocity fluid from a nozzle is divided into much smaller streams upon entering the heat exchanger. Stream dividing results in excessive turbulence with very high localized velocities. High velocity and turbulence produce a horseshoe erosion pattern at the tube entrance.

Maximum recommended velocity in the tubes and entrance nozzle is a function of many variables, including tube material, fluid handled, and temperature. Materials such as steel, stainless steel, and copper-nickel withstand higher tube velocities than copper. Copper is normally limited to 7.5 fps; the other materials can handle 10 or 11 fps. If water is flowing through copper tubing, the velocity should be less than 7.5 fps when it contains suspended solids or is softened.

Erosion problems on the outside of tubes usually result from impingement of wet, high-velocity gases, such as steam. Wet gas impingement is controlled by oversizing inlet nozzles, or by placing impingement baffles in the inlet nozzle.

Steam or Water Hammer:

Pressure surges or shock waves caused by the sudden and rapid acceleration or deceleration of a liquid can cause steam or water hammer. The resulting pressure surges have been measured at levels up to 20,000 psi, which is high enough to rupture or collapse the tubing in a heat exchanger. For example, 3/4 in. x 20 BWG light drawn copper tubing has a burst pressure of 2100 psi and a collapse pressure of 600 psi.

Damaging pressure surges can result from a cooling water flow interruption. The stagnant cooling water is heated enough to generate steam, and the resumption of the flow causes a sudden condensing of the steam and produces a damaging pressure surge, or water hammer. Cooling water flow should always be started before heat is applied to the exchanger.

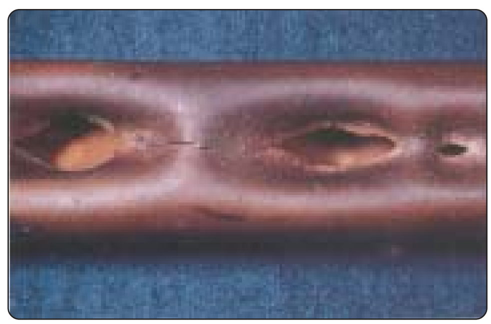
Fig. 2. Tube Damage from Steam Hammer.

Fluid flow control valves that open or close suddenly also produce water hammer. Modulating control valves are preferable to on-off types. Vacuum breaker vents must be provided if condensables are handled in either the shell or tubes; they prevent steam hammer damage resulting from condensate accumulation. Fig. 2 shows typical tube damage caused by steam hammer. In this case, condensate accumulated in the shell and rapidly accelerated, producing a high-pressure shock wave that collapsed the tube and caused the tear holes.

Properly sized steam traps with return lines pitched to a condensate receiver or condensate return pump should be installed to prevent this type of damage.

Vibration:

Excessive vibration from equipment such as air compressors or refrigeration machines can cause tube failures in the form of a fatigue stress crack or erosion of tubing at the point of contact with baffles. Heat exchangers should be isolated from this type of vibration.

Shell-side fluid velocities in excess of 4 fps can induce damaging vibrations in the tubes, causing a cutting action at support points with baffles, Fig. 3. Velocity-induced vibrations can also cause fatigue failures by work hardening the tubing at baffle contact points or in U-bend areas until a fatigue crack appears.

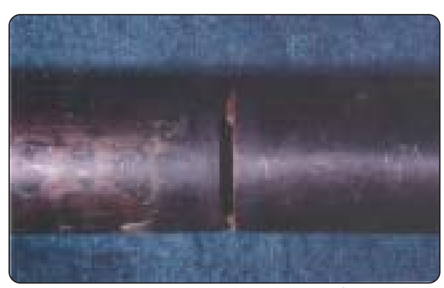
Fig. 3. Velocity-unduced vibration of tube.

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Thermal Fatigue:

Tubing, particularly in the U-bend area, can fail because of fatigue resulting from accumulated stresses associated with repeated thermal cycling. This problem is greatly aggravated as the temperature difference across the length of the U-bend tube increases.

Fig. 4 shows an example of thermal fatigue. The temperature difference causes tube flexing, which produces a stress that acts additively until the tensile strength of the material is exceeded and it cracks. The crack usually runs radially around the tube, and many times results in a total break. In other cases, the crack occurs only halfway through the tube and then runs longitudinally along it.

Fig. 4. Thermal Fatigue Failure in U-bend.

Thermal Expansion:

These failures are most common in steam heated exchangers; however, they can occur in any type in which fluid being heated is valved off without provisions to absorb thermal expansion.

In steam-heated systems, cooling down or condensing residual steam in the shell after the steam control valve closes continues to heat water or other fluids on the tube side. Continued heating causes thermal expansion, which creates pressures far in excess of the strength of tube sheets, cast heads, and other heat exchanger components. Cast iron parts usually fracture because of lack of ductility; steel tube sheets become bowed or permanently distorted because the material's yield point is exceeded. Fig. 8 shows thermal expansion failure of a cast iron heat exchanger head.

Fig. 5. Thermal expansion failure of cast iron exchanger head.

Relief valves are installed in the heated fluid system to prevent this kind of failure. It is also advisable to provide some means to absorb fluid expansion. For example, installing a tank in the heated fluid system prevents periodic discharge of relief valves, which results in loss of system fluid and places an undue burden on the valve. These devices are installed between the heat exchanger and any shutoff or control valves.

Freeze-up:

These failures are most common in evaporators or condensers; however, they can occur in any heat exchanger in which temperatures drop below the freezing point of either fluid in the unit. Freeze-up results from failure to provide thermal protection, a malfunction of the thermal protection control system or protective heater device, improper drainage of the unit for winter shutdown, or inadequate concentration of antifreeze solutions.

For example, assume a chiller has improper settings or malfunctioning controls that cool the water to a point below its freezing point. Ice forms and exerts tremendous pressure in the tubing, which causes it to rupture or collapse. Collapse in an evaporator, Fig. 6, usually occurs near the tube sheet where the tube is not protected by an inner spline.

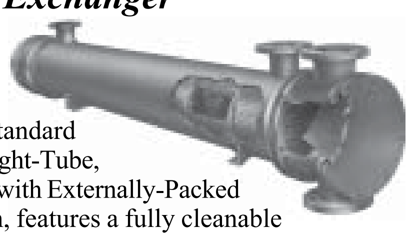
Fig. 6. Callapse of evaporator tube because of freeze-up.

Freeze-up failure in a condenser tube can also occur when cooling water was circulating inside the tube, refrigerant was condensed on the externally finned surface, and the unit was not properly drained for winter shutdown. The tube distortion indicates that it was exposed to excessive pressure caused by the freezing water.

This type of failure is also caused by the sudden release of refrigerant pressure from the condenser. The sudden release caused by a line break or relief valve discharge suddenly drops the pressure below the boiling point of the refrigerant. Boiling extracts heat from water in the tubes and the liquid freezes.

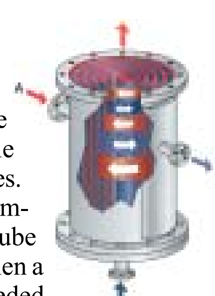
Alternative Designs:

Floating Tube-Sheet Heat Exchanger



Several Floating tubesheet designs are available, the most popular has TEMA designation 'AEW' (ITT Standard 'CPK' & 'FLP'). This Straight-Tube, Removable-Bundle design with Externally-Packed Floating Head construction, features a fully cleanable design with high thermal efficiency. This design allows for differential thermal expansion between the shell and the tubes at an economical price.

Spiral Heat Exchanger



A Spiral Heat Exchanger consists of two sheets of metal rolled into a spiral, with space between them separating fluids by a single surface with excellent heat transfer properties. Spirals are true counter flow devices that combine many of the benefits of both Shell & Tube and Plate Heat Exchangers. They excel when a close approach or temperature cross is needed, are cleanable, reduce pressure drop and allow for thermal expansion.

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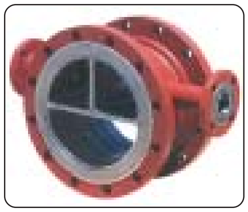
Please welcome to the Process Solutions Line...

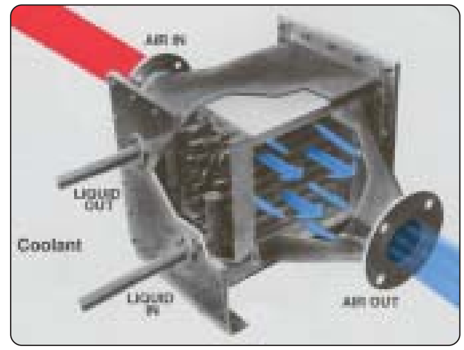
Special Metals, Inc.

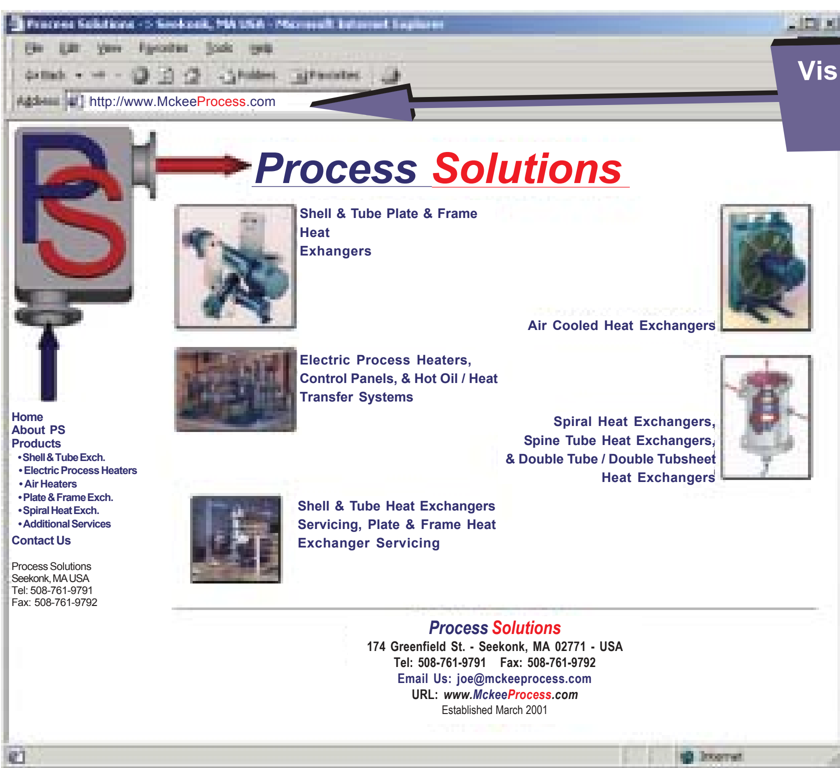


As one of the largest Tantalum metal fabricators in the United States, Special Metals' experience with refractory metals and inert shielding enables them to fabricate equipment of other materials such as Titanium, Zirconium and Nobium. In addition to Shell & Tube Heat Exchangers, they routinely line vessels, piping, and other process equipment for the Chemical and Pharmaceutical industries. We are proud to add them to our offerings.

Xchanger, Inc.

With an unmatched commitment to quality and customer satisfaction, Xchanger, Inc. has demonstrated the versatility of 'Bar-and-Plate' and 'Tube-and-Fin' construction for Heat Exchangers. Complex Gas-to-Air, Gas-to-Liquid and Solvent-Recovery and Condensing applications are solved with several rugged economical designs, many boasting low gas-side pressure drops, below 10" w.c. We welcome their addition to our team.





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Coming up in future issues:

- Continued discussion of Heat Exchanger failures Incuding:
  - *Chemical Induced Corrosion*
  - *Chemical/Mechanical Induced Corrosion*
  - *Scale, mud, and Algae Fouling*
- Process Heater Maintenance Issues
- Extending Electric Heater life with proper controls

[Source: Article by Marvin P. Schwartz, Chief Product Engineer, ITT Fluid Handling Division, ITT Standard, "Four types of Heat Exchanger Failures"]

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