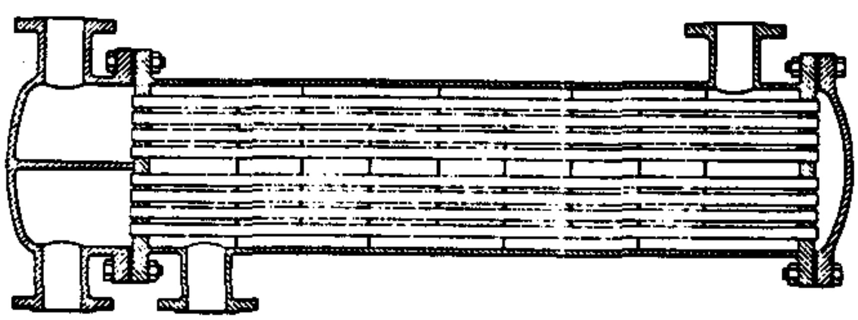
Mechanical Equipment - Course 330.1

HEAT EXCHANGERS

The basic principles of operation of heat exchangers were discussed in Lesson 430.11-1. In this lesson the construction of various types of heat exchangers will be dealt with. Also a more detailed look at the various types of heat exchangers found in nuclear power plants will be undertaken.

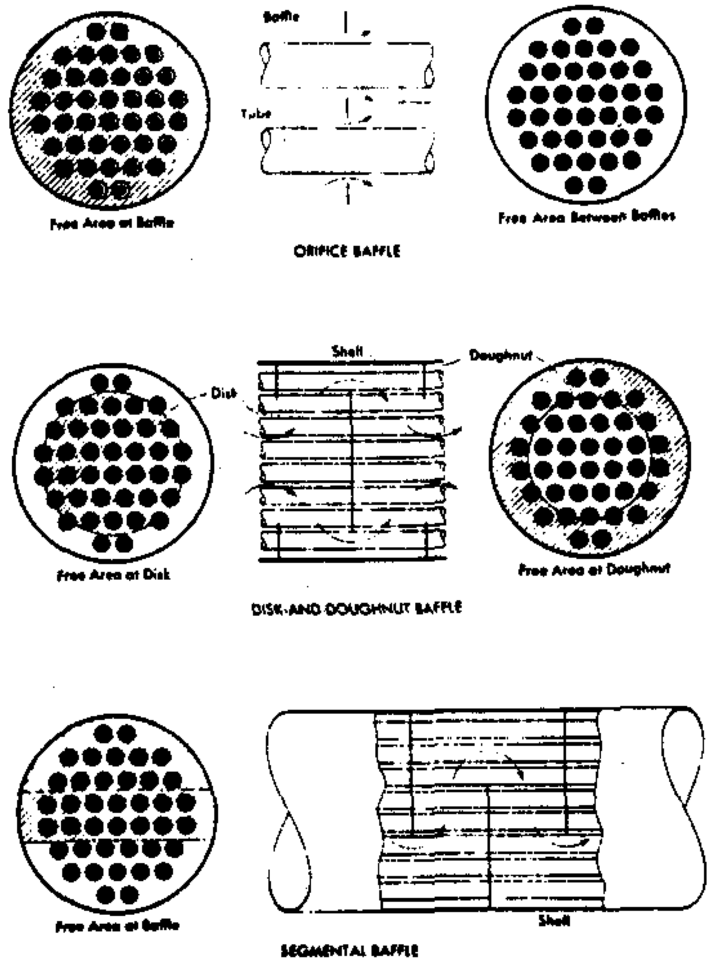
Construction

In Lesson 430.11-1 the basic type of heat exchanger, the tube and shell type, was discussed. The three basic flow patterns utilized with this type are parallel-flow, counter-flow and cross-flow, with the most efficient being the counter-flow method. In order to increase the effective heat transfer surface area per unit volume, most commercial heat exchangers provide more than a single pass through the tubes. The fluid flowing outside the tubes in the shell is routed back and forth by means of baffles. Figure 1 illustrates a cross section of a heat exchanger with two tube passes and one cross-baffled shell pass. The baffles are of the segmental type. This and other typical types of baffles are shown in Figure 2.



Shell and Tube Heat Exchanger

Figure 1



Three types of baffles used in shell and tube heat exchangers

Figure 2

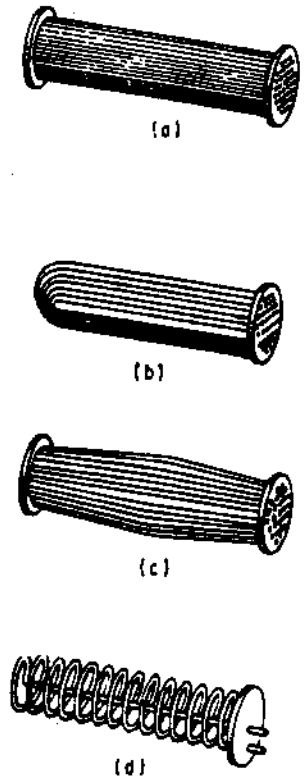
The heat exchanger illustrated in Figure 1 has fixed tube plates at each end and the tubes are welded or rolled into place. Other types of tube bundles used in shell and tube heat exchangers are illustrated in Figure 3.

Figure 3(a) shows the straight tube bundle. The advantage of this type is that it is easy to clean mechanically. To accommodate tube expansion, this type of bundle usually has a free end, commonly referred to as a floating head. Figure 7 illustrates a heat exchanger designed with a floating head.

Figure 3(b) shows a U-tube bundle. This type of bundle solves tube expansion problems. Also there are only one-half as many tube joints. This tube bundle is harder to clean.

Figure 3(c) illustrates a bowed tube bundle. It is bolted solidly to the shell at each end. As the bundle heats, it bows causing scale to crack off.

Figure 3(d) is the coil tube bundle which is used for very high pressures. It does away with gasketed joints in the high pressure circuit.



Four Typical Tube Bundles used in Heat Exchangers

Figure 3

The end plates into which the tubes are sealed are referred to as "Tube Sheets". These are the portions of a heat exchanger where leakage between the two fluids is most likely to occur. Figure 4 illustrates three types of tube joints.

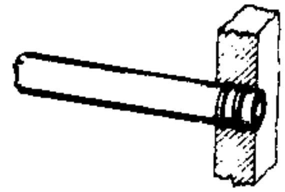
Applications

Shell and tube heat exchangers are among today's most popular design. Typical applications are: -

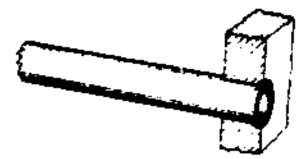
1) Feedwater heating
2) Surface condensers
3) Compressor inter-and-aftercoolers
4) Refrigeration condensers
5) Refrigeration evaporators
6) Lub-oil coolers

Typical types of heat exchangers for these applications will now be briefly described.

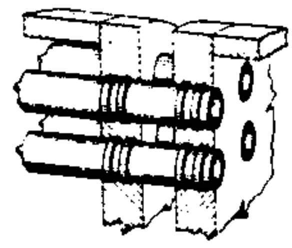
Rolled Tube Joint is the most common form of fastening tubes in tube sheets. Cold rolling flows the tube metal into annular grooves cut in the tube-sheet holes.



Welded Tube Joint usually remains tighter than a rolled joint where considerable expansion must be handled. Sometimes rolled joints are also welded.



Double Tube Sheets give positive protection against accidental leakage of shell fluid into tube fluid or the reverse. If tube joints leak in either tube sheet, the leakage can be collected in the cavity between the two sheets.



Tube Joints

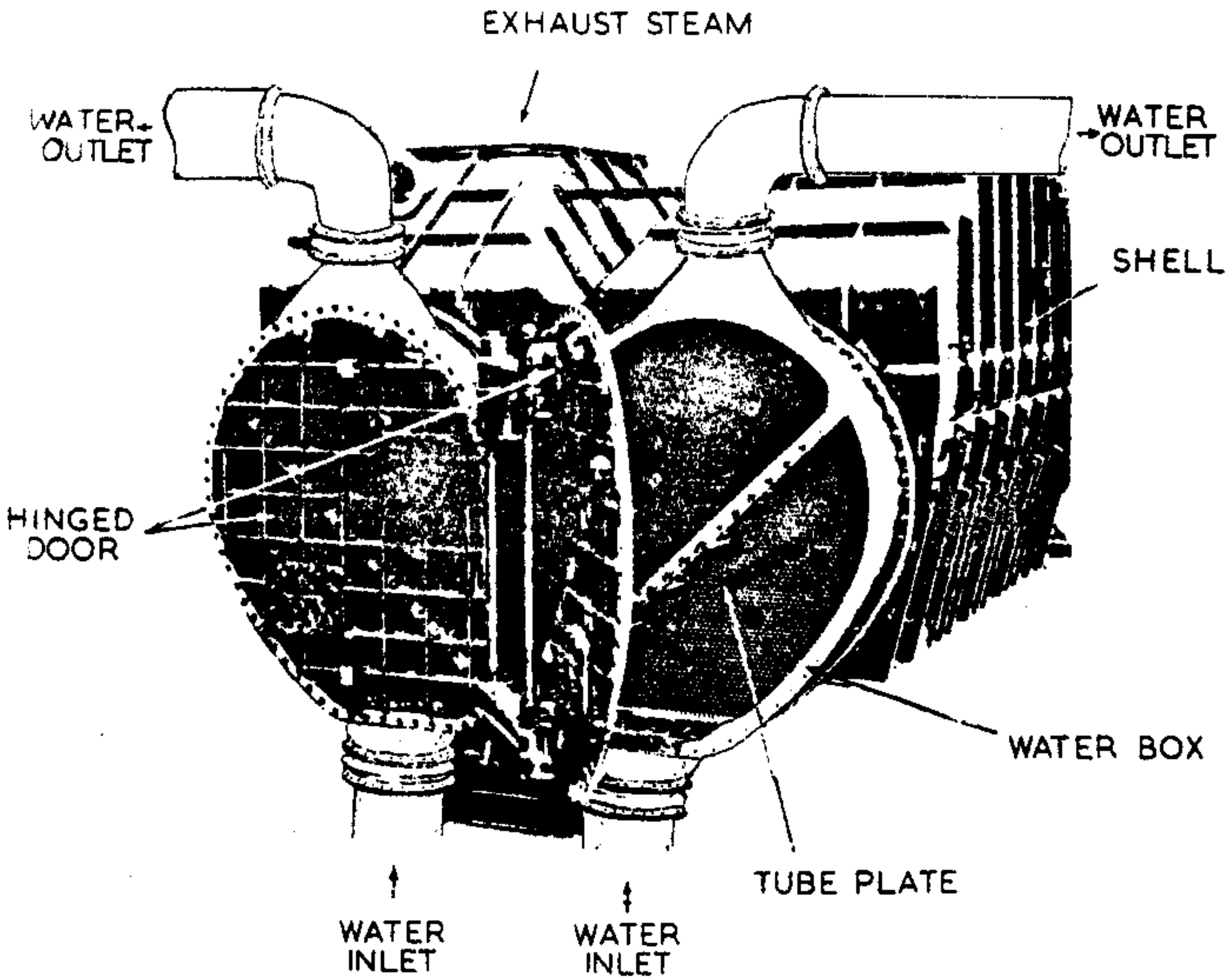
Figure 4

Surface Condenser

Steam surface condensers perform two functions; first, they recover condensate for boiler feed. As this water must be very pure, this results in a big saving in the cost of purifying the feedwater. Second, they reduce the back pressure on the turbines so maximum heat energy can be extracted from the steam.

Surface condensers are basically a vacuum tight shell and tube heat exchangers with cooling water flowing through the tubes and prime-mover exhaust steam surrounding the tubes. The steam condensed, collects in a hot well and is introduced in the feedwater system. To maintain vacuum various types of vacuum pumps can be used to remove air which leaks in and gases such as oxygen which is given off by the condensing steam. A more detailed description of the principle of operation of the surface condenser is given in the turbine, generator and auxiliaries course, therefore, little more will be said on this aspect of surface condensers.

Figure 5 illustrates a typical surface condenser. The particular condenser is of the twin shell construction, the shells being connected by means of a balance line. This type of condenser would be used where turbines have two steam exhausts. The shells are more or less independent of each other, having separate water inlets and outlets. This is advantageous in that repairs could be made to tubes in one of the shells without having to shut down completely. The condenser illustrated in Figure 5 is of two pass construction.



A Typical Condenser

Figure 5

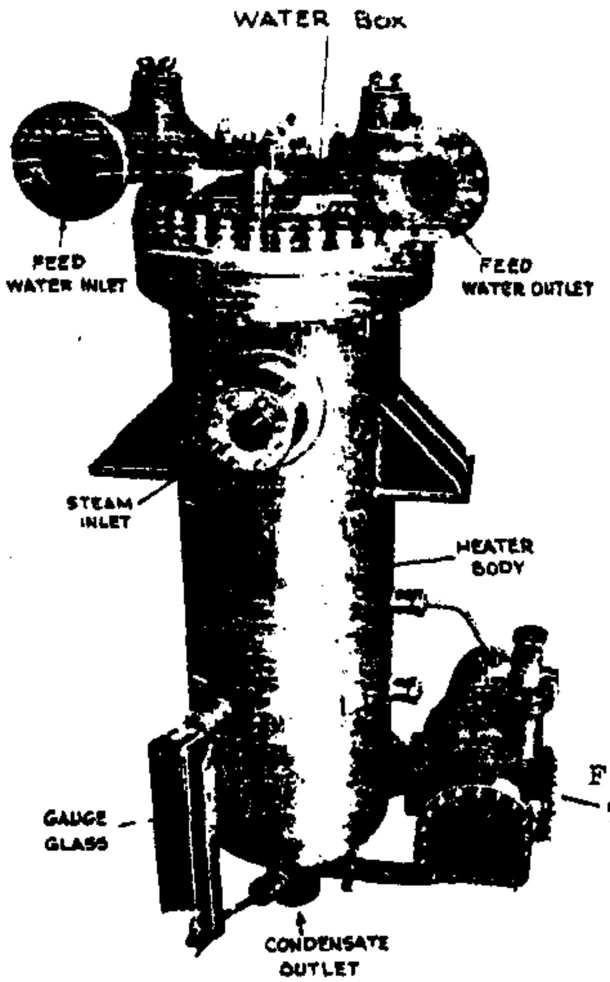
The name "surface condenser" is very appropriate because it contains a great number of cooling tubes. For example, the condenser tubes for the Pickering unit provides a cooling surface of 280,000 sq ft. It contains 27,000 one-inch diameter, 40 foot tubes. It requires 313,000 gallons per minute of lake water. The operating pressure for the water boxes is approximately 30 psig.

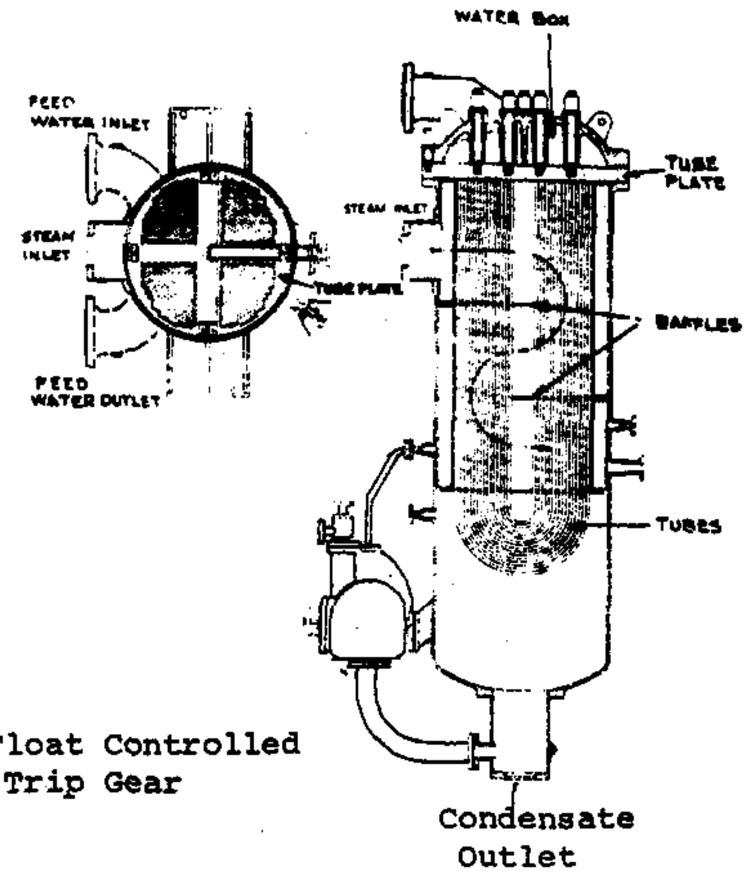
Tube sheets and tubes in condensers are normally made of compositions of non-ferrous metals such as admiralty brass. The criteria used for the metals chosen are usually resistant to corrosion and erosion, high thermal conductivity and cost. The shell is usually of a welded steel construction. (Cast iron is sometimes used for the shell material). The water box is usually made of cast iron. Hinge doors are illustrated in Figure 5. This facilitates cleaning or retubing the condenser.

Feedwater Heaters

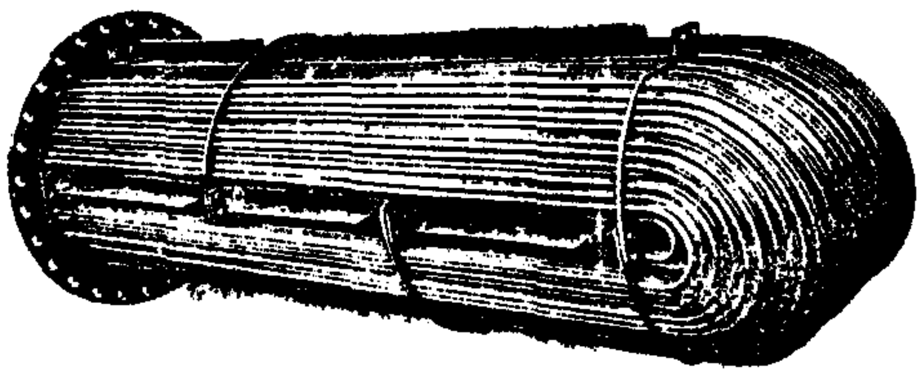
Feedwater heaters normally use steam bled from turbines as the energy supply. Their prime purpose is to raise cycle thermal efficiency by the regenerative heating principle. Modern plants will have low pressure and high pressure heaters.

Figures 6 and 7 illustrate typical vertical and a horizontal feedwater heaters respectively. Both heat exchangers illustrated are high pressure heaters, however low pressure heaters would be very similar in construction. Figures 6 and 7 illustrate two methods used for accommodating differential expansion. One is to use a U-tube and the other is to use a floating head. Generally in high pressure heaters the tubes are U-shaped. Horizontal-closed feedwater heaters as shown in Figure 7 require little headroom but need a clear floor space in front of the heater so that the bundle can be withdrawn from the heater. Vertical heaters may be used when headroom is ample and floor space is at a premium.





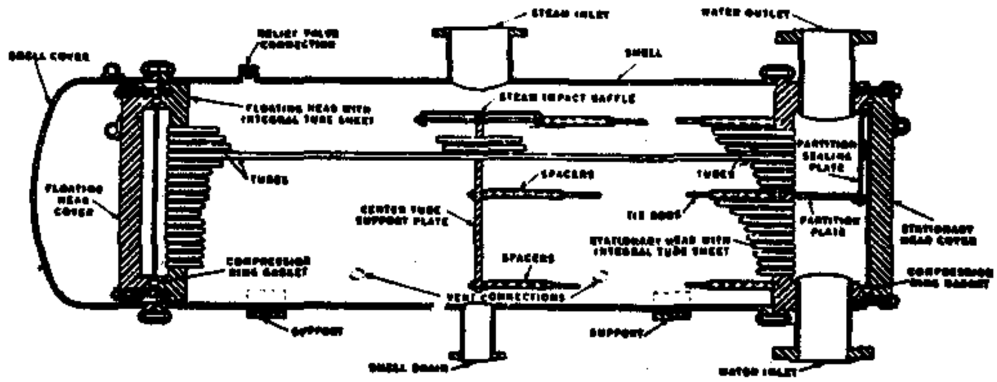
Sections through Heater to show Water Box and Steam Flow



Tube Nest

H.P. Feedwater Heater

Figure 6



Horizonal H.P. Feedwater Heater

Figure 7

It is interesting to note that both Douglas Point and Pickering generating stations utilize horizontal low pressure and high pressure U-tube heaters.

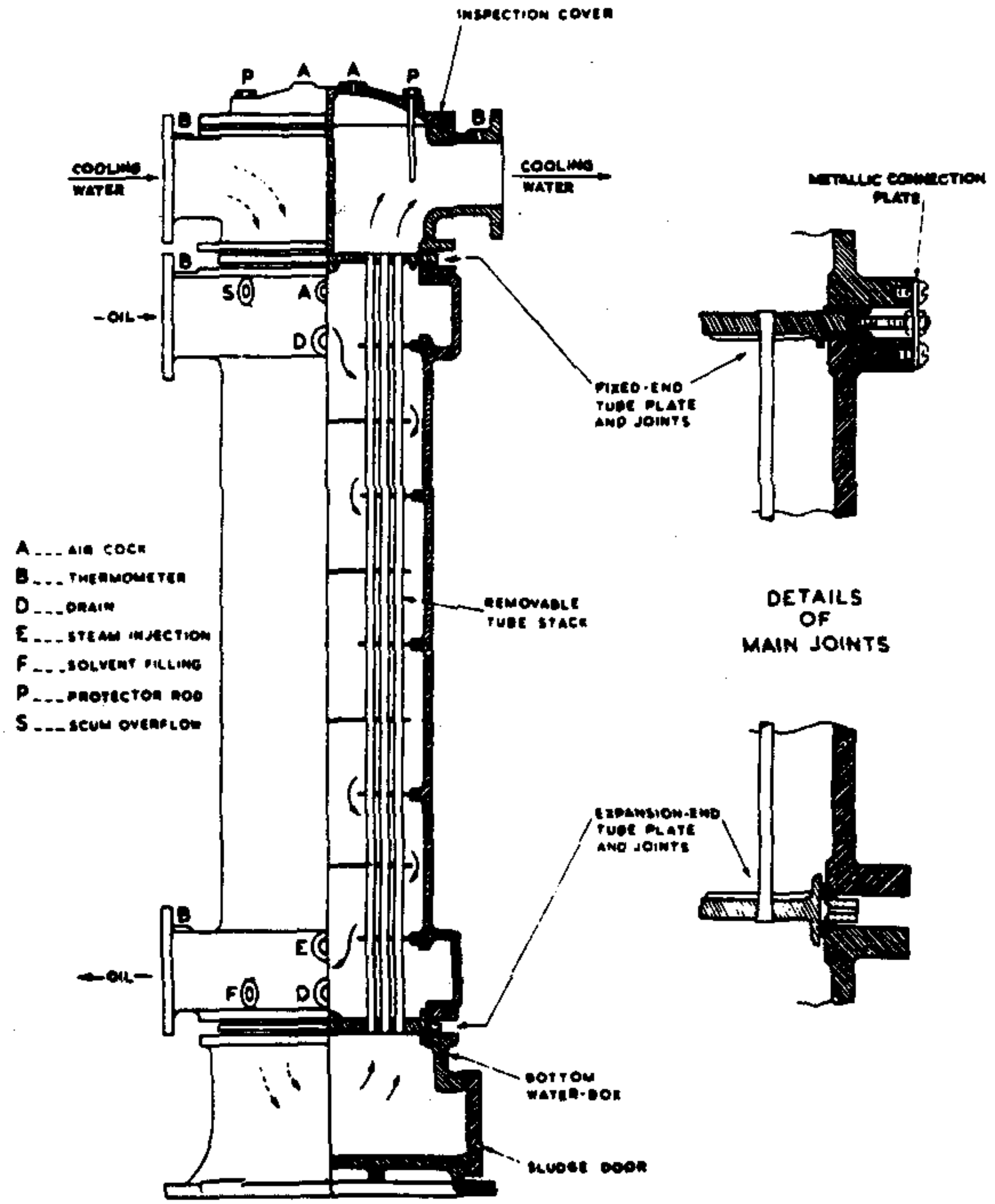
The material for these heaters is usually carbon steel because of the high operating pressures.

As steam condenses in either a vertical or horizontal heater, the condensate falls to the shell bottom and forms an effective seal against steam blowing through. This seal also prevents noncondensible gases from leaving the heater. The accumulation of these gases, however, can reduce the heaters effectiveness, therefore at each end of the steam space in the shell, vents are located. In addition to removing gases, the vents help to distribute the steam more uniformly throughout the shell.

Turbine Oil Coolers

The purpose of oil coolers is to cool the oil which is being supplied to the steam turbine bearings to a temperature of approximately 110-120°F. A typical oil cooler is illustrated in Figure 8. Cooling water flows through a two pass tube bundle while the oil passes over the outside of the tubes being directed by a series of internal baffle plates. Most coolers are placed in an upright position as illustrated in Figure 8. It is general practice to maintain the oil pressure in the cooler at a higher pressure than the circulating water to ensure that, in the event of tube failure, there will be no ingress of water into the oil system.

The coolers usually consist of a cast iron shell inside of which is a nest of brass tubes.



Typical Oil Cooler

Figure 8

General

As indicated in the earlier part of this discussion, there are many applications of tube and shell heat exchangers in Power Plants. Most of the examples taken were from the conventional side of power plants. There are many examples that could have been taken from the primary heat transport system and moderator system of Nuclear Power Plants. Some that come to mind are the main steam generators, which are U-tube and shell design, the shut down cooling heat exchangers, bleed condensers and moderator cooling heat exchangers.

All of these would be basically similar in construction to the ones already discussed. The main differences would be in the added precaution taken to ensure minimum heavy water leakage. This would involve welded tube joints, double gasketed joints, seal welds, etc.

ASSIGNMENT

1. Explain the purpose of increasing the number of tube passes in a heat exchanger.

2. What useful purpose does a double tube sheet perform?

3. Describe the methods by which axial expansion can be accommodated in heat exchanger tube nests.

4. For what purposes are vents installed in feedwater heaters?

5. Give two applications of tube and shell heat exchangers in a thermal power plant.

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