Reactor-Boiler and Auxiliaries - Course 433

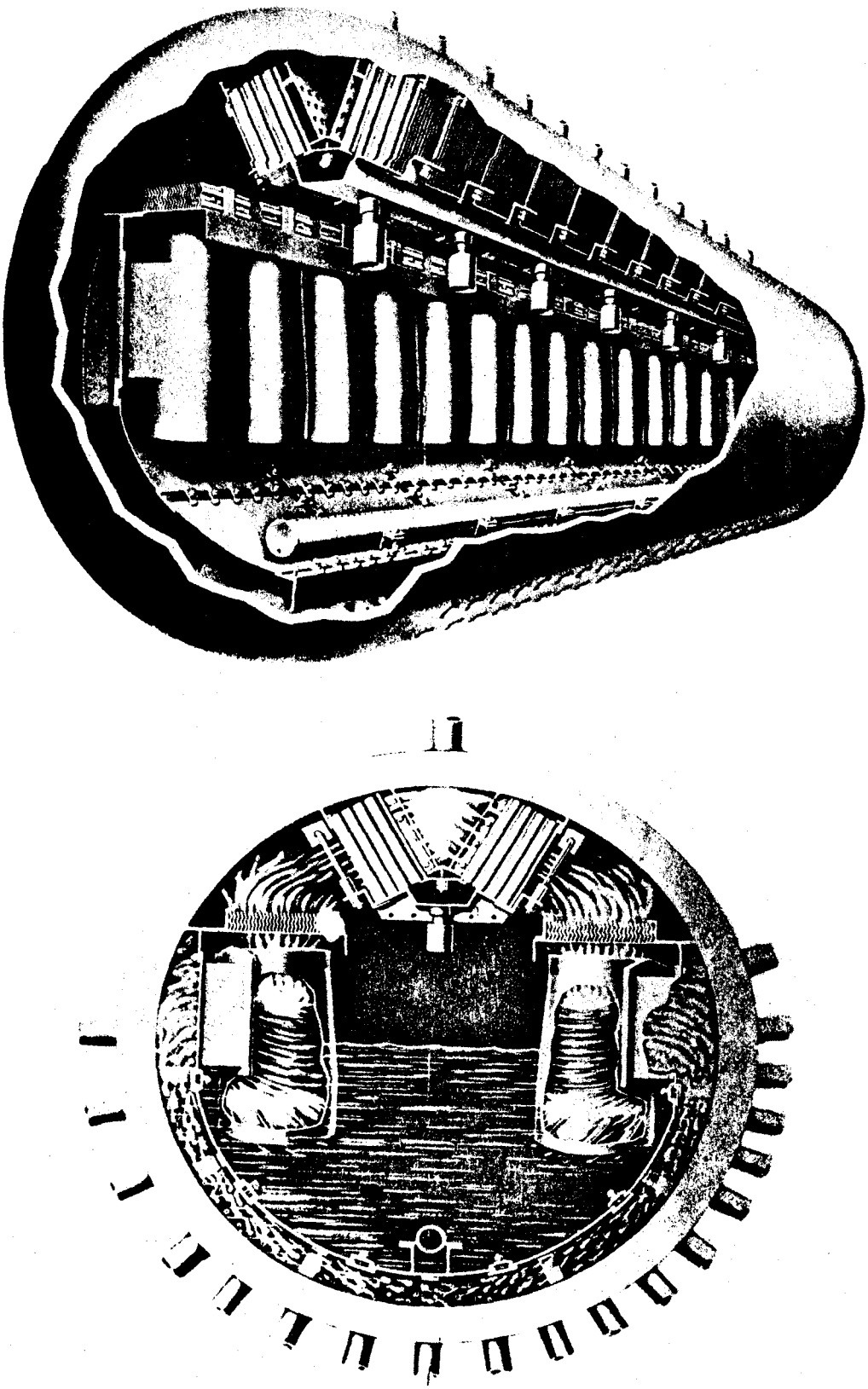
BOILER STEAM AND WATER SYSTEMS

It was noted in an earlier lesson, that the reactor is a source of heat, and serves the purpose of a "furnace" in a nuclear generating station. The use of a reactor results in some major changes in conventional steam production equipment, as well as the special equipment which is associated with the reactor itself. The "boiler" in a fossil fired station normally includes combustion equipment, a superheater, an economizer, an air heater, etc. Depending on the design of a nuclear station, some of this equipment may be used, but probably in a modified form. For example, serious consideration has been given to the use of fossil fired superheaters in a nuclear station to improve steam conditions, and hence increase efficiency. A type of economizer may also be used, and will be discussed later.

Some nuclear station designs involve a direct cycle where steam is produced in the coolant, as it passes through the reactor, and is then taken directly to the turbine. However, the common arrangement (and the one which will be considered in this lesson) is to use a heat transport system which carries heat from the reactor to the boiler. This heat converts light water into steam which is then used in a conventional turbine cycle. This arrangement prevents activity from getting to the turbine; so that no shielding is required in the conventional part of the station.

Heat Exchanger and Steam Drum

The hot heat transport fluid is circulated from the reactor to the heat exchanger, where it gives up its heat and then returns to the reactor. The heat is used to produce steam on the shell side of the heat exchanger. The steam formed is separated from the water in the steam drum, and then proceeds to the turbine as saturated steam. The heat exchanger is connected to the steam drum by risers and downcomers, which permit circulation of the boiler water. In low pressure units (below approximately 2500 psi) natural circulation is generally sufficient. The driving force is due to the difference in density between the steam bubble-water mixture in the riser and the cooler water in the downcomers.



Boiler Steam Drum

Fig. 1

If the pressure is above about 2500 psi, then the density of steam and water are so similar, that natural circulation is inadequate. In these cases, a pump is used to force circulation of the boiler water.

The steam must be adequately separated from the water in the steam drum, so that a minimum amount of water and impurities are carried with the steam to the turbine. This material in the steam would cause serious erosion of the turbine blades. For low steaming rates, there will be sufficient time for the steam bubbles to separate from the mixture by gravity without being drawn into the downcomers, and without carrying entrained water droplets into the steam outlet. However, for this same arrangement at a higher rate of steam generation, the time is insufficient to attain either of these desirable results. Most steam drums, therefore, are fitted with some form of mechanical separator. In a simple form, these separators might be only a set of baffles which force the wet steam to change direction. A more elaborate system may use centrifugal force as a primary separator (steam-water mixture is forced through a "cyclone" separator which swirls the mixture in small cylinders mounted in the steam drum) and scrubbers as a secondary separator. The scrubbers are simply a series of close fitting plates which force the steam to travel a tortuous path between them. The water and impurities in the steam collect on the plates, and drain off the bottom. The general arrangement of the separating equipment in one type of steam drum is shown in Figure 1.

In addition to the risers and downcomers, the following connections are likely to be found on the steam drum:

1. Steam line to turbine
2. Feedwater from the feedheating equipment
3. Pressure relief connection
4. Blowoff connection
5. Chemical feed connection
6. Instrument connections

Two possible arrangements of heat exchanger and steam drum are shown in Figures 2 and 3. The arrangement of Figure 2 is the one used in NPD , and Figure 3 is used at Douglas Point. In Figure 3, one leg of the vertical heat exchanger is used to heat the feedwater, and could perhaps be considered as a type of economizer.

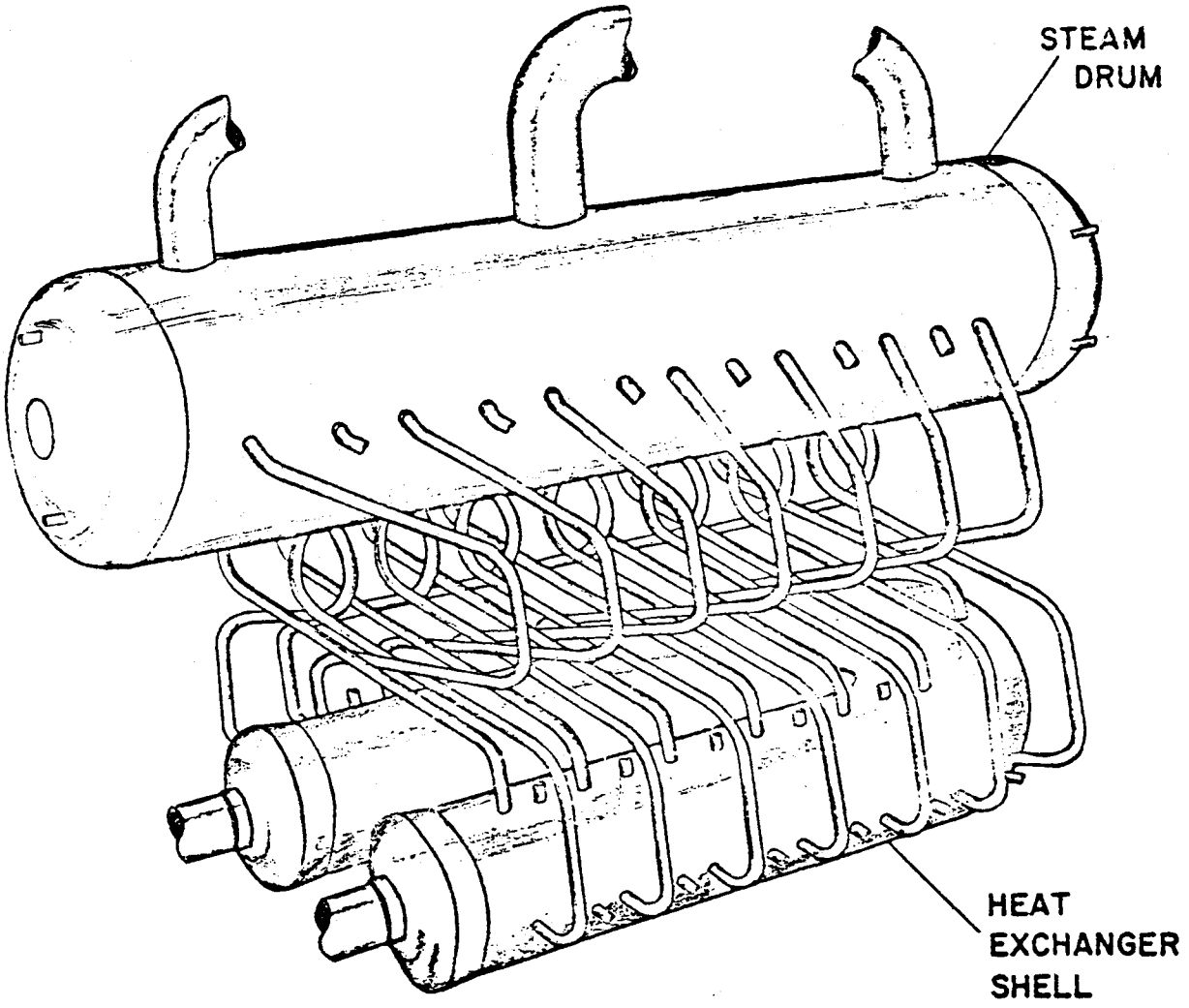

STEAM
DRUM
HEAT
EXCHANGER
SHELL

Fig. 2

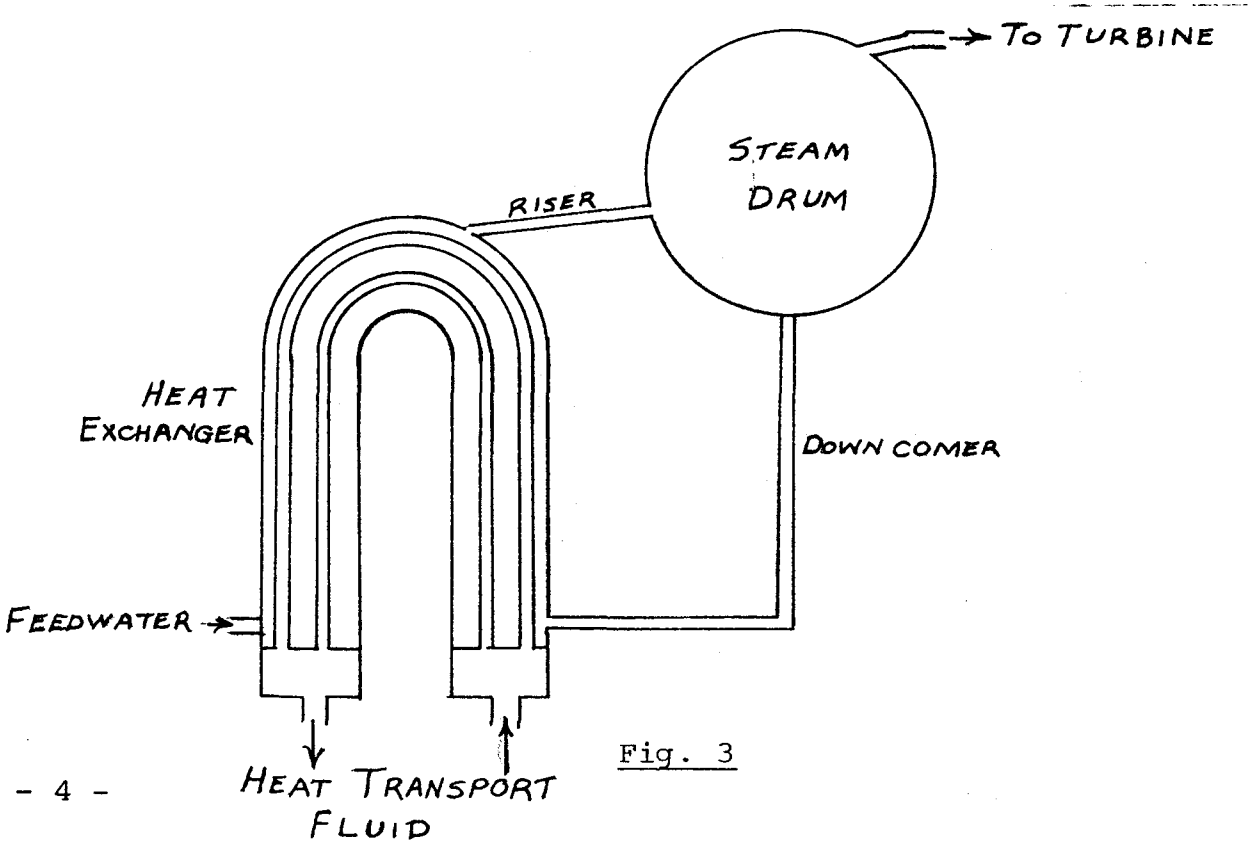

To Turbine
Steam
Drum
Riser
Heat
Exchanger
Down comer
Feedwater
Heat Transport
Fluid

Fig. 3

Steam Relief and Blowdown

Any pressure vessel (a vessel which has a pressure higher than 15 psig) must conform to the ASME Boiler and Pressure Vessel Code. This code includes the requirements for safety valves, specifying the size, shape, number, location, type etc. The basic objective is to guarantee that the safety valves will discharge all the steam that can be generated without the pressure exceeding the valve settings by more than 6 per cent. This ruling is an example of many which must receive special interpretation in a nuclear plant. The limit "all the steam which can be generated" cannot be applied to the reactor since it is capable of generating heat at a rate far in excess of normal operation, but must be applied to the maximum steam raising capacity of the heat transport system or some other assumptions made.

The boiler will also be equipped with some method of blowdown. In normal operation, blowdown lowers the suspended solids and dissolved solids content of the boiler water. These solids are added by the feedwater, and since the steam leaving the boiler is relatively pure, concentration of solids will develop in the boiler water. Excessive amounts of suspended solids will cause deposition of sludge, and may alter the surface tension of the boiler water. This effect, in turn, may be severe enough to cause carryover of water with the steam in the absence of suitable anti-foam agents. Excessive amounts of dissolved solids have the same adverse effects as suspended solids and, in addition, when the solubility of salts present in the boiler is exceeded, scale will be deposited.

There are two principle types of blowdown - intermittent manual blowdown and continuous blowdown. Manual blowdown or sludge blowdown, is necessary for the operation of a boiler regardless as to whether or not continuous blowdown is also installed. The blowdown or blowoff connection is usually at the lowest part of a boiler (ie, the bottom of the heat exchanger) so that in addition to lowering the dissolved solids concentration of the boiler water, it will also remove a portion of the sludge which is generally more concentrated in the lower part of the boiler.

Another type of blowdown which may be encountered, uses a take-off line located slightly below the working water level for the purpose of skimming sediment, and oil from the surface of the water. This type of installation is generally referred to as surface blowdown equipment.

Chemical Feed Equipment

Chemicals are fed into the feedwater and boiler systems to control corrosion, and the concentration of undesirable salts. The boiler system is generally made of carbon steel which corrodes when the water contains significant quantities of dissolved gases such as carbon dioxide or oxygen. The carbon dioxide can be kept to a low concentration by maintaining a high pH and the oxygen can be removed with an oxygen scavenging material such as sodium sulphite or hydrazine.

The salts are removed by precipitating them in the boiler to form a sludge which is then removed by blowdown. This minimizes the formation of scale in the boiler. The precipitation is often accomplished by the addition of sodium phosphate.

The chemicals are generally added to the feedwater, and to the water in the steam drum as a solution. The equipment will normally include chemical mixing tanks and injection pumps. The injection pumps will be designed so that the amount of chemical solution added can be carefully controlled.

ASSIGNMENT

1. What is meant by and what causes natural circulation in a boiler?

2. Why are separators installed in a steam drum?

3. What is the purpose of boiler blowdown?

4. What are the two places in a boiler where you might find blowdown take-offs?

5. What is the purpose of putting chemicals in the boiler water?

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