Fig. 3

Fig. 4

Inventor
Alan Bell

By
Richard H. Thomas, Attorney
STABLE FORCED CIRCULATION BOILERS

Alan Bell, Coalham, England, assignor to Foster Wheeler Corporation, Livingston, N.J., a corporation of New York

Filed Apr. 26, 1963, Ser. No. 276,048
Claims priority, applied for in Great Britain, Apr. 20, 1962, 16,516/62
3 Claims. (Cl. 122—496)

This invention relates to forced circulation boilers.
The terms “water” and “steam” are used herein to include any suitable liquid and its vapour unless the context otherwise requires.

The forced circulation boiler has the advantage over the natural circulation boiler of being of substantially lower weight and, consequently, cost. This arises largely out of the necessity, in a natural circulation boiler, of maintaining the pressure drop due to flow through the tubes of the system as low as possible which involves the use of tubes of relatively large diameter defining fluid paths devoid of substantial or abrupt changes of direction. In the forced circulation boiler, a high pressure drop can be tolerated because although it leads to the provision of relatively high pumping power, there is the compensating advantage that the tubes can be of small diameter and follow almost any path. This can lead to a substantial saving in weight and cost and to valuable flexibility in design and consequent saving of space.

Where, as in a nuclear plant, the boiler parts have to be enclosed in a heavy sealed vessel, the forced circulation system has the further advantage over the natural circulation system that it involves a smaller number of piercings of that vessel.

These advantages of the forced circulation boiler are, however, offset by the disadvantage that the superheated steam produced from it frequently contains a substantial quantity of water entrained in it in the form of droplets. The amount of water so entrained is irregular so that the performance of the boiler is both below and less steady than that of the corresponding natural circulation boiler.
The forced circulation boiler is also subject to considerable vibration which, it is thought, is at least partly the result of the instability of flow in the system which leads to the carrying over of water to the superheated steam outlet. This instability increases with decrease in steam pressure and is particularly troublesome in nuclear installations operating at a pressure of from 400–800 p.s.i.g. and using as the heating medium the primary coolant of a reactor at a temperature of about 600–800° F.

The invention is concerned with eradicating or minimising the above mentioned disadvantages of the forced circulation boiler and, in general terms, consists in introducing at the evaporating stage of a forced circulation boiler a natural circulation akin to that which occurs in the tubes of a natural circulation boiler.
The forced circulation boiler in accordance with the invention has a tubular evaporating section leading to a tubular superheating section and there is provided between the two sections a collecting chamber for the steam and water mixture produced in the evaporating section and in which water is allowed or caused to separate and to be recirculated by natural circulation to and through the evaporating section while the steam passes to the superheating section.

It is found that in this way, while preserving all the usual advantages of the forced circulation boiler, the instability usually associated with such a boiler can be substantially eliminated and the performance at the superheater outlet be made comparable with that of the natural circulation boiler.

In order to induce the natural circulation of the separated water at least one downcomer needs to be provided which connects the collecting chamber to the inlet of the evaporating section, and the heat transfer to which is substantially lower than that to the risers or evaporating tubes. This can be achieved by arranging one or more downcomers outside the casing of the generator but in the preferred form of the invention, a single downcomer is used which is disposed along the axis of a bundle of steam generating tubes and insulated from the heating fluid. The insulation is preferably ensured by providing the downcomer with a jacket filled with a fluid of low heat conductivity such as CO₂ which, in the case in which such a gas is used as the heating fluid, may be a quantity of that gas which is trapped in an open-ended jacket.

The collecting chamber does not have to be of large dimensions. In the preferred form of the invention, the evaporating and superheating sections are formed of tubes terminating in tube plates, the outlet tube-plate of the evaporating section and the inlet tube-plate of the superheating section being joined by a cylindrical casing which defines the said chamber.
The effectiveness of the separation in the collecting chamber can be enhanced by the provision therein of a baffle against which a major part of the steam and water mixture must impinge on entering the chamber. Such a baffle can usually be shaped so that it also serves to collect separated water and deliver it to the downcomer.
The steam which passes to the superheater will inevitably carry some water with it but this can be made small enough to ensure that without necessitating abnormal design of the superheater it will be substantially completely evaporated therein.

An example of a forced circulation boiler in accordance with the invention will now be described with reference to the accompanying diagrammatical drawings in which:

FIGURE 1 is a sectional elevation of the tube system of the boiler.

FIGURE 2 is an enlarged view of the middle portion of the system shown in FIGURE 1 and illustrating in a greater detail the arrangement of the downcomer; and
FIGURES 3 and 4 are sections taken on the lines III—III and IV—IV respectively on FIGURE 1.

The tube system shown in the drawings can be assumed to have a length of about 25 feet and be arranged vertically within a shell or casing (not shown) side-by-side with a large number of identical tube systems.

The system provides a water preheating or economiser section E, an evaporating or steam generating section EV and a superheating section S connected together in series.

Each of the three sections comprises a bundle of straight tubes 10, 12, 14 connected respectively to inlet and outlet tube plates 16, 17, 18, 19; 20, 21. The outlet tube plates of the economiser and evaporating sections are joined by short cylinders 23, 24 respectively to the inlet tube plates of the evaporating and superheating sections, the tube plates and cylinders defining collecting spaces or chambers 26, 28.

The inlet tube plate 16 of the economiser section has welded to it an adapter 30 through which the water to be evaporated is supplied at say the medium pressure of 400–500 p.s.i.g. The outlet tube plate 21 of the superheater section has welded to it a similar adapter 32 forming the superheated steam outlet.
The heating fluid which can be assumed to be the CO₂ coolant of a gas cooled nuclear reactor flows through the casing (not shown) countercurrent to the water flowing through the tubes and heats the water or the steam produced therefrom in the tube bundles 10, 12, 14 by indirect heat exchange.
In the particular example shown here, the economiser bundle 10 is made up of nineteen tubes—a number which is very favourable to optimum utilisation of available space.

The evaporator bundle 12 (shown in greater detail in FIG. 2) is similarly formed except that the central tube 34 is not a riser as are the other eight tubes but a downcomer as will be explained in greater detail further on.

The superheater bundle 14 is substantially the same as the economiser bundle.

In operation, the water is heated in the economiser section 10 to or near its saturation temperature and is passed thence upwards through the risers of the evaporating section 12 to emerge therefrom into the collecting chamber 28 as a mixture of steam and water. In the normal forced circulation boiler, this mixture would be passed directly to the superheater section 14, and it is this, I believe, which leads to the unsatisfactory performance referred to above as being characteristic of such boilers. Here, however, the chamber 28 is made sufficiently large to ensure that there will be a substantial separation of water from steam in it. For this purpose, it does not have to be particularly large. As can be seen from the drawings it is only slightly longer than the corresponding space or chamber 26 between the economiser and the evaporator which itself is no larger than is dictated by considerations of manufacture. The collecting chamber 28 is in no way comparable for size with the steam and water drum of the conventional natural circulation boiler.

To induce or enhance water separation in the chamber 28 a baffle 36 is provided against which a major part of the mixture emerging from the evaporator tubes is caused to impinge. As shown here, this baffle is in the form of a dish in which separated water can collect and be guided through perforations 37 into the central downcomer 34.

In order that the downcomer may act as such, it must be designed disposed or arranged so that the heat transfer to it is substantially lower than is that to the remaining riser tubes of the evaporator. In the case illustrated in the drawings, it is provided over the greater part of its length by a jacket 38 which if filled with a fluid of low conductivity, will form a very effective barrier to the passage of heat to the downcomer even if the annular space defined by the jacket is very restricted indeed—say a small fraction of an inch. Preferably, as shown, the jacket is open at one end with the consequence that it will become filled with the carbon dioxide assumed here to be the heating fluid and which has indeed a low thermal conductivity and, when trapped in the jacket, functions very efficiently as an insulator: To increase the differential heat transfer between the risers and the downcomer, the risers may be given an extended heat transfer surface as by the provision of fins.

The consequence of this differential heat transfer is that the water which collects in the chamber 18 is caused to descend the downcomer into the collecting chamber at the inlet end of the evaporating section and to be recirculated through that section with the water emerging from the economiser. Thus there is combined with the forced circulation through the evaporator a natural circulation added to that of a natural circulation boiler.

As a consequence, the steam which is received by the superheater will have a substantially lowered water content and the quality of the steam which emerges from the superheater outlet 32 will not only be high but will be very uniform as in the case of the conventional natural circulation boiler.

As already stated, the complete steam generator will comprise a number of tube systems such as that illustrated in the drawings arranged side by side in a shell or casing. It is advantageous to utilise the space within the casing to the utmost and to distribute the various tube systems uniformly over the cross section of the casing. The 19-tube bundles of hexagonal cross-section shown in FIGS. 3 and 4 are very suitable for achieving these objects.

It is, however, to be understood that the invention is not restricted to any particular formation of tube bundles. In particular, the superheater tubes may be arranged so as to provide within the superheater section a sub-section which causes evaporation of the bulk of the water carried over from the collecting chamber 28 and thus drying the steam as a preliminary operation before it is subjected to superheating proper.

I claim:

1. A forced circulation boiler comprising:
   a tube system including tubes defining a vapor generating section and superheater section,
   a lower inlet header for said vapor generating section,
   a circular bundle of riser tubes extending upwardly from said inlet header,
   an upper outlet header having a generally hexagonal cross-sectional configuration and arranged to receive the vapor and liquid mixture flowing from said riser tubes, said superheating section including a circular bundle of riser tubes leading from said outlet header,
   a single downcomer tube disposed along the axis of the bundle of riser tubes,
   insulating means encasing said single downcomer tube, means concentrically located within said outlet header for the separation of the vapor and liquid in said mixture and flow of vapor to said superheating section and flow of liquid to said downcomer means, said riser tubes surrounding said downcomer means shielding said downcomer means for the natural thermally induced downward circulation of the separated liquid through said downcomer means to said inlet header and recirculation through said riser tubes.

2. A forced circulation boiler according to claim 1 wherein said separation means includes a dish-shaped container and a vertically disposed pipe extending upwards from said downcomer means through the center of said dish-shaped container and extending beyond the top of said dish-shaped container, said pipe having apertures therethrough located within said container to drain the liquid from said container into said pipe.

3. A forced circulation boiler according to claim 1 further including an economizer section, an inlet header for said economizer section, the economizer section including a plurality of tubes extending to said vapor generating section inlet header whereby the economizer section is in series flow with said vapor generating section.

References Cited by the Examiner

UNITED STATES PATENTS
2,240,100 4/41 Schmidt 122—448
2,265,481 12/41 Hartman 122—448
2,983,260 5/61 Huett 122—32
3,116,721 1/64 Huett 122—34

FOREIGN PATENTS
1,243,429 9/60 France

PERCY L. PATRICK, Primary Examiner.

MEYER PERLIN, ROBERT A. O'LEARY, Examiners.