STEAM GENERATOR WITH FORCED CIRCULATION

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FIG.1

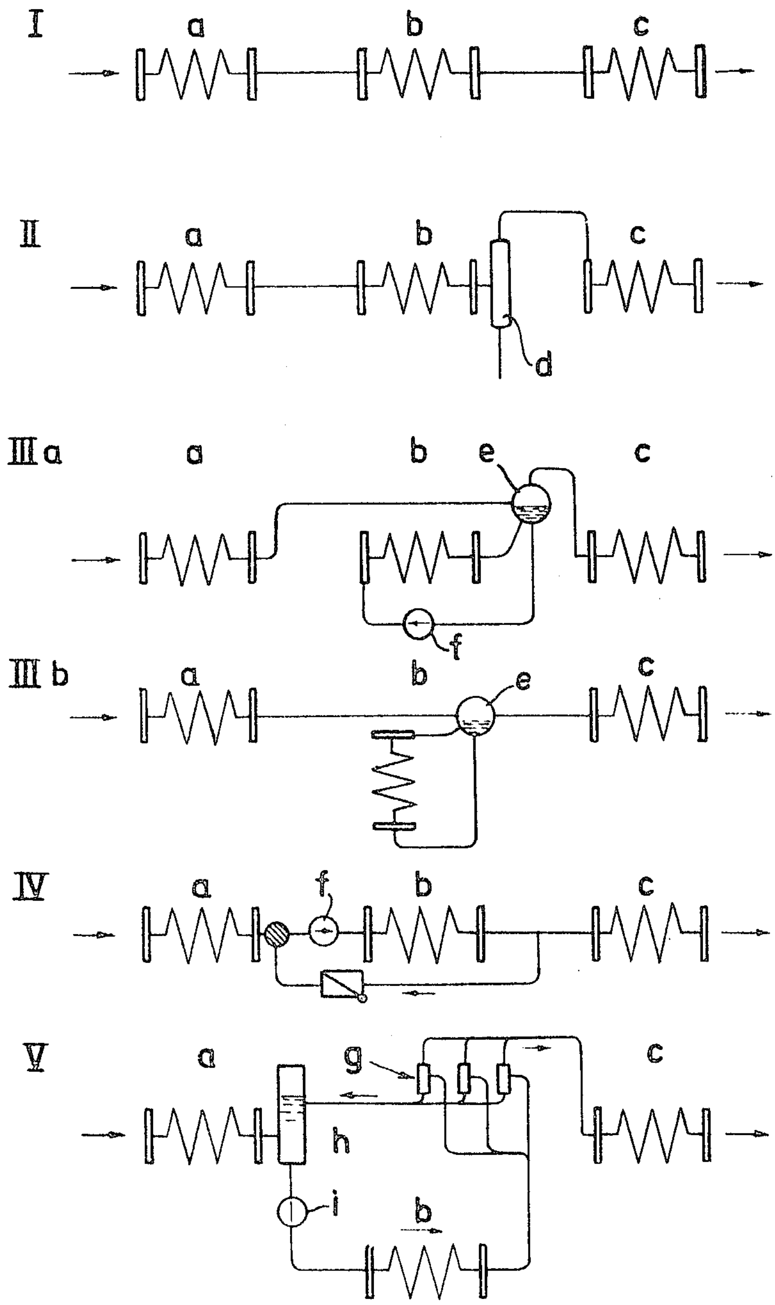

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FIG. 2

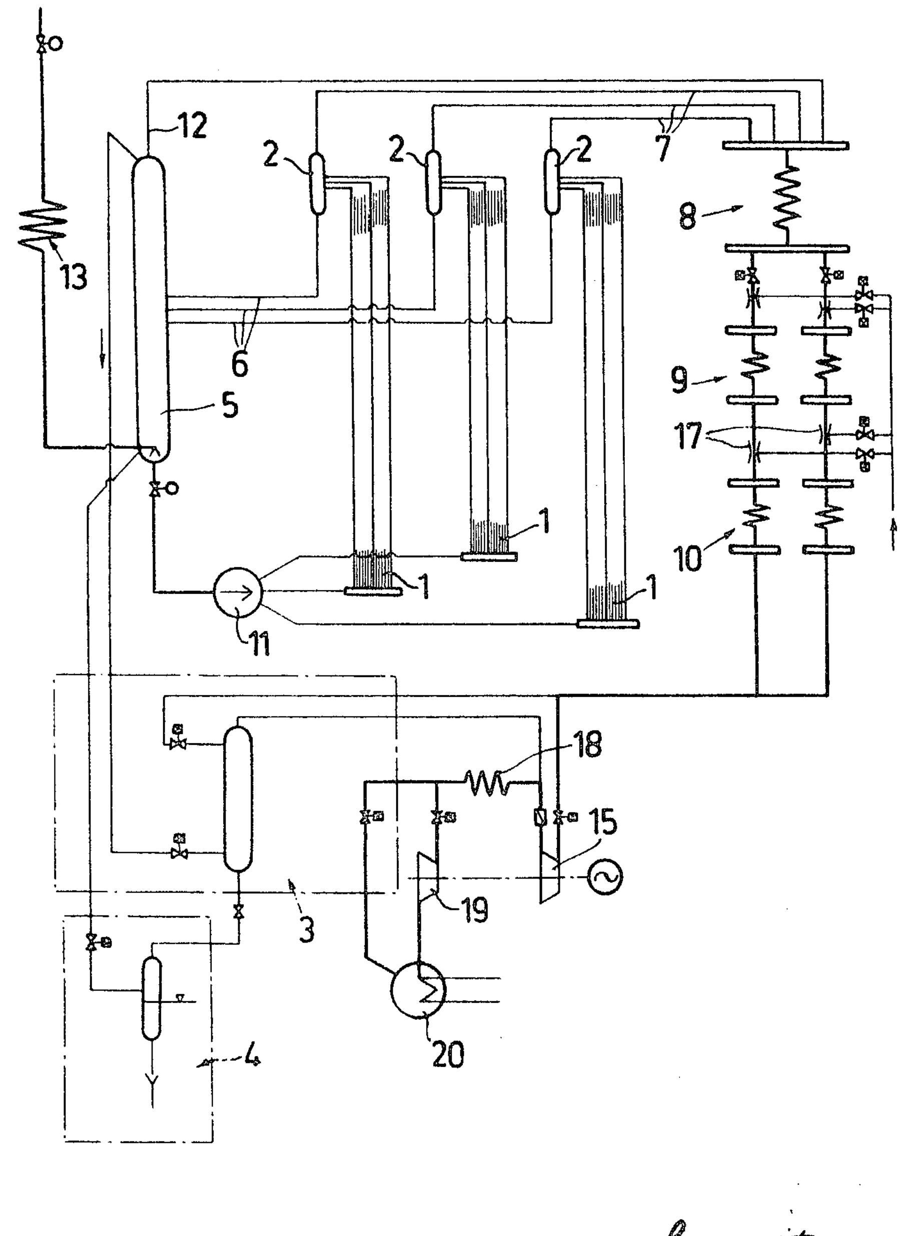

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FIG. 3

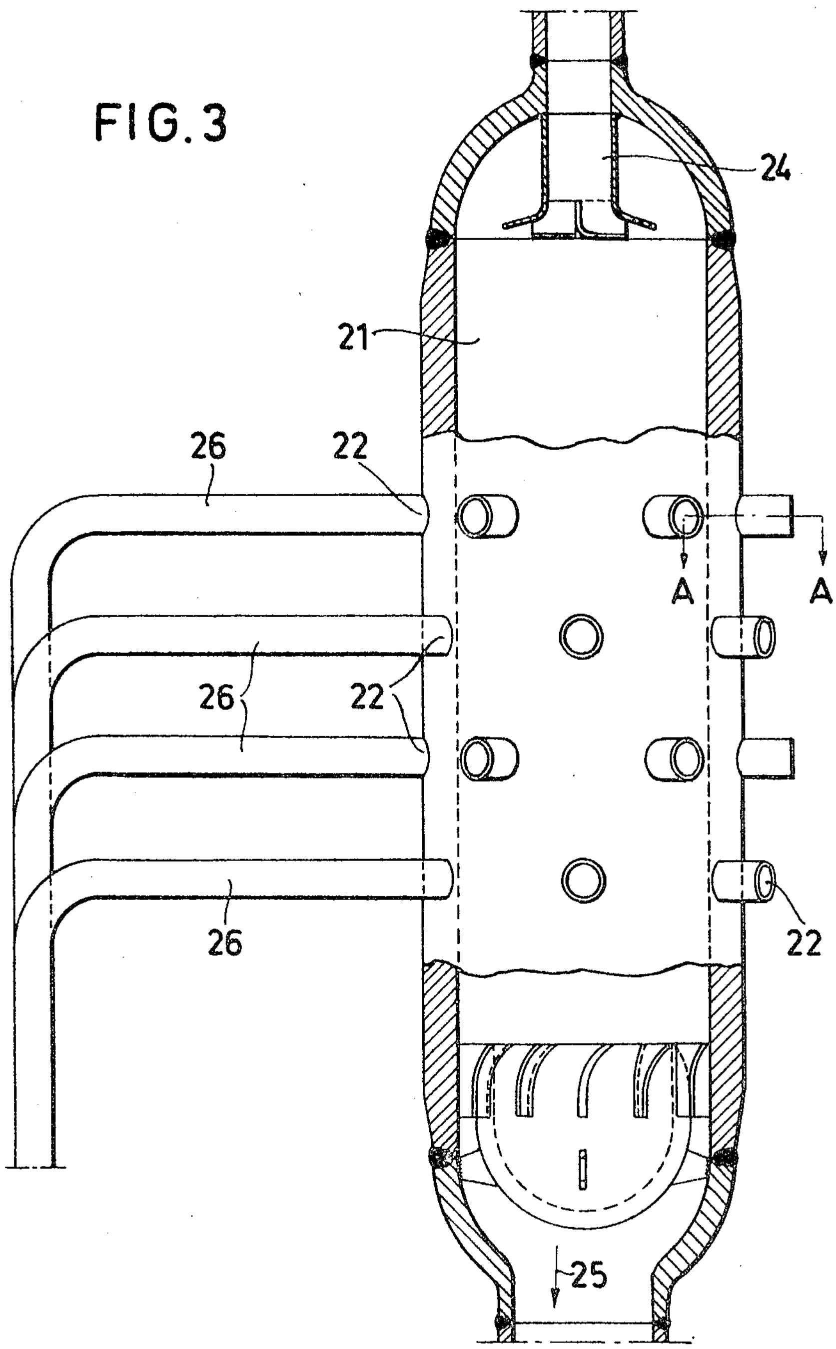

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FIG. 4

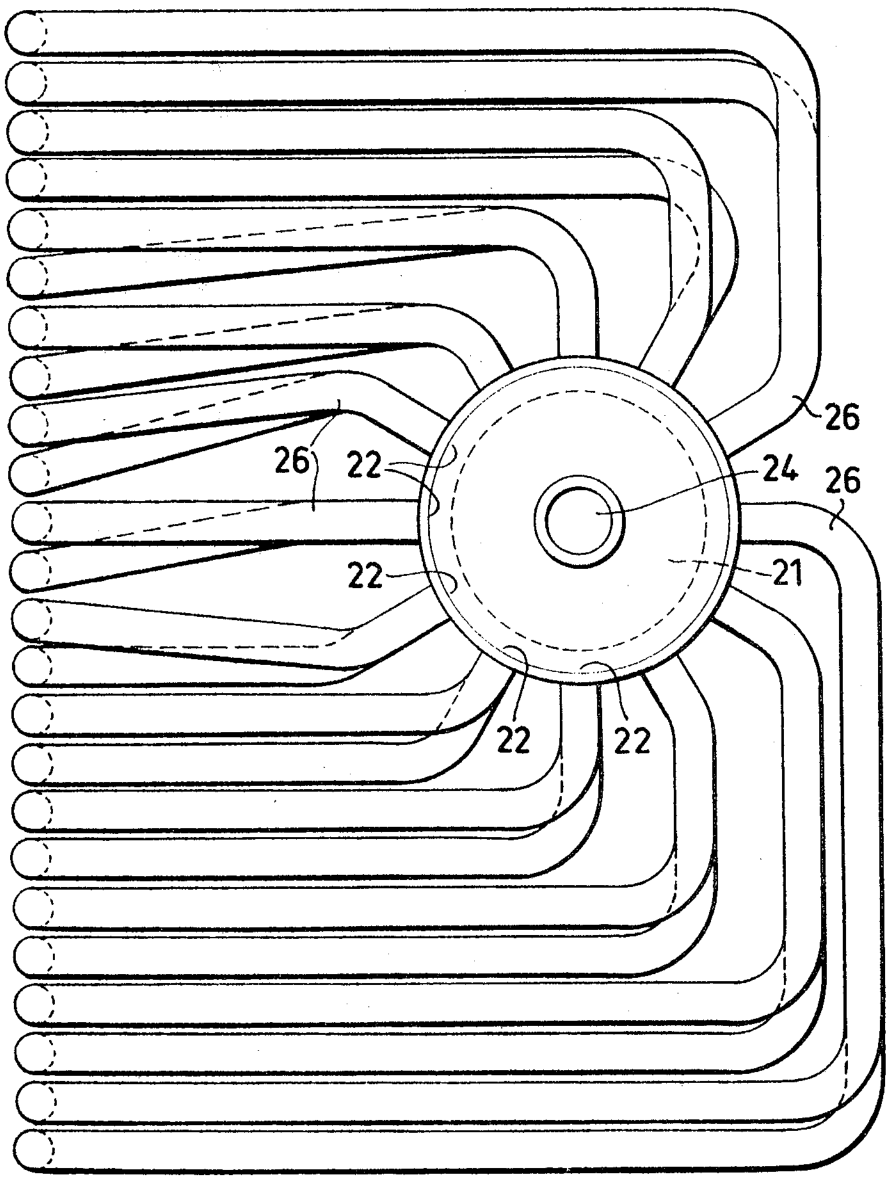

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FIG. 5

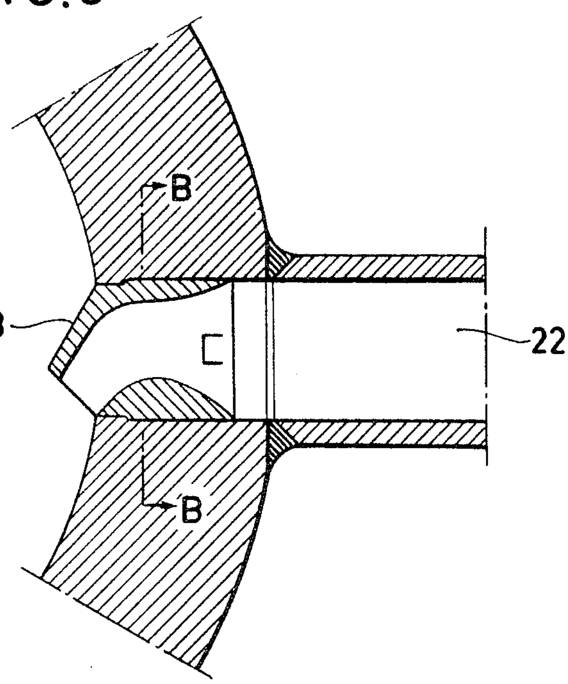
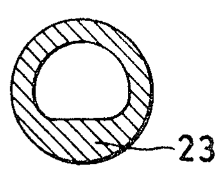


FIG. 6



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STEAM GENERATOR WITH FORCED CIRCULATION

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U.S. Cl. 122—406 2 Claims

ABSTRACT OF THE DISCLOSURE

A steam generator with forced circulation having a preheater, an evaporator, a superheater, a plurality of steam separators, and a mixing vessel. The steam separators are connected directly between the steam generating tubes of the evaporator and the preheater and the steam separators have return tubes which, together with the output of the preheater, are connected to the mixing vessel. A means is also provided for maintaining a predetermined amount of the working medium in the mixing vessel.

This invention relates to a steam generator with forced circulation which is adapted to work up to an optional pressure both below and above the critical point of the working medium.

In known steam boilers or generators the medium is heated in channels or tubes which are heated from the outside. Thereby a division can be made between the portion which heats the medium, so that evaporation is effected (boiling area), or in overcritical operation to a point close to the critical point, and that portion of the apparatus which generally is defined as superheater and which heats the medium to the desired final condition. The present construction refers to the portion which heats the medium to evaporation or to a point close to the critical point of the medium. Hereinafter this portion is referred to as the "evaporation portion" of the apparatus.

In conventional steam generators a division is made between the systems illustrated in FIG. 1.

Alternative I illustrates a straight flow with pre-heater *a*, evaporation portion *b* and superheater *c*, which substantially are comprised also in Alternative II, in the system of which, however, a small number of steam separators *d* are incorporated to which the collected medium flow from portion *b* is introduced. At generally lower loads of the unit, in Alternatives I and II, the desired minimum flow can be obtained in that the medium, via valves and pumps, is returned from a point between *b* and *c* to the inlet side. At high loads the medium has in Alternative I a direct flow and in Alternative II a substantially direct flow, a smaller amount being returned via the steam separator. The steam separator can be designed as a cyclone separator with level control for conducting away separated medium.

In the embodiment according to III*a* and III*b* the steam separation normally takes place in a horizontally mounted pressure vessel *e*, a drum, and separated medium which is not evaporated is returned by natural circulation (III*b*) or by one or several pumps *f* to the inlet or before the evaporation portion (III*a*). This principle is applied in the known drum boiler. The steam separation in the shown pressure vessel *e* or dome can take place in a number of small cyclones or within the drum. The control of the medium flow supplied is made via level determination in the said pressure vessel.

In the embodiment according to Alternative IV which is intended only for overcritical operation, a re-circulation takes place over a certain part of the load range from a point between *b* and C via the shown return flow line to the inlet side of the pump *f*. At the operation pressures applied, steam separation is not of interest.

In the present new construction according to Alternative V, evaporation takes place in a usual way in the portion marked *b*. The steam separation takes place in a plurality of small cyclones *g* each of which is connected to groups of evaporation tubes. The separated medium is recirculated to a mixing vessel *h*. The drive force for the medium is obtained by a pump means *i* or possibly by natural circulation. The incoming medium is controlled on the basis of a level determination or of another method in the mixing vessel, so that there is a sufficient amount of medium for ensuring the function of the apparatus. The steam separator function, thus, is separated in the way described from that portion of the system which primarily serves for mixing the incoming and the recirculated medium and via measuring devices to control the flow of incoming medium.

The advantages obtained by the new device over the conventional system are as follows:

(1) The steam separation can take place in a point very close to the evaporation portion. The introduction of the principle described, with a plurality of steam separators, implies that the great pressure vessel, the drum, and certain collecting headers can be replaced by smaller mixing vessels plus the steam separators. The necessary flow area are relatively small compared with the conventional drum boiler, a.o., for the reason that there the entire medium flow from the evaporation portion must be introduced into the drum.

(2) By utilizing an amount of returned medium which is suitable in relation to the evaporated medium flow, the tube arrangement with substantially vertical tubes which is characteristic of a conventional drum boiler can be maintained.

(3) Owing to the design of the system, low pressure losses can be obtained. A contributing factor hereto is that velocity, i.e. the kinetic energy in the evaporation channel also can be utilized for the steam separation.

(4) The system permits the mass velocities required for stable heat transfer conditions to be chosen independently of the load and pressure, and the minimum load can be adjusted to the flow zero.

(5) That portion of the pressure vessel which at varying load at subcritical operation has a varying steam-water volume, is substantially only the tubes in the evaporation area. This implies good control and good possibility of adjusting in a simple manner the level in the mixing vessel before the pumps.

(6) The pressure drop in the system can be maintained the lowest possible. The pressure drop in the evaporation portion is overcome by said pump means, with a resulting lowest possible pressure at the inlet to the apparatus.

(7) The maximum operation pressure can be chosen to amount up to and beyond the critical point.

The system and a type of steam separator are described in the following with reference to the drawing, FIGURES 2–6.

FIG. 2 shows a wiring diagram for a steam generating system according to the invention idea.

FIG. 3 shows a longitudinal section through a cyclone separator.

FIG. 4 shows in a horizontal view the cyclone separator according to FIG. 3.

FIG. 5 shows a section along A—A in FIG. 3.

FIG. 6 shows a section along B—B in FIG. 5.

In FIG. 2 an embodiment of the invention in question is shown in a wiring diagram. The system of evaporation areas which encloses the furnace resembles in principle known constructions and comprises upright furnace tubes **1**. At the outlets of these tubes are mounted a relatively great number of steam separators **2**. A conventional starting and a bottom blowing system **3** and **4** respectively can, as shown, be built into the system.

The said separators can be designed, for example, according to FIGS. 3–6 which show a selected embodiment in which the tubes or channels for the partially evaporated medium coming from the furnace area can be connected directly to the steam separator. Hereby the smallest possible flow losses are obtained, and the medium velocity which has been reached already in the evaporation area, possibly however with a slight increase, can be utilized for obtaining a good separation effect.

The medium separated in the steam separators **2** flows back to a mixing vessel **5** from the steam separators either in separate channels **6** or in one channel common to several separators. The separated steam flows via usually a plurality of tubes **7** from the separators to the inlet in the superheater portions which in the embodiment shown comprises the superheaters **8**, **9** and **10**.

The recirculated medium separated in the separators **2** flows back to the mixing vessel **5** of which one or several are comprised in the apparatus, where it is mixed with the incoming medium and from where it is returned to the evaporation elements **1** by the shown pump means which, for example, is constructed as circulation pump **11** driven by an electromotor. In a steam boiler of the described type, the mixing vessel can be designed, for example, as a vertical container where at subcritical operation the level is maintained substantially at or below the level of the separators. The admixing of new introduced medium can entirely or partially take place in the container, but always before the evaporation area. The mixing vessel is provided for pressure equalization in a suitable way with a connection **12** to a point before the superheater **8**. New introduced medium is preheated in a preheater **13** prior to the mixing with circulating medium.

The steam separation in the described cyclones **2** is a self-adjusting process. A considerable problem, however, is the level adjusting or control of the mass contents in the mixing vessel **5**. As already mentioned, the medium supplied can be admixed in this vessel, which means that the vessel possibly contains medium in homogenous phase but of different temperatures, according to load etc., medium in two phases with liquid phase of saturation temperature, but also liquid phase of a lower temperature.

It is of interest that a fairly constant level or constant mass contents is established for avoiding that the medium in liquid phase reaches the superheater.

It may prove sufficient to operate with a constant mass contents which would eliminate the problems at critical points, at which, of course, a conventional level determination does not work.

The mass contents can be measured in different ways. One example is the direct measuring of the weight of the mixing vessel.

Steam generators with supercritical operation must meet the requirement that safety against thermal shock effect, for example in the superheater portions **8–10** and in the steam lines to the turbine **15** is obtained. The supercritically operating evaporation portion, i.e. the tubes **1**, must also be protected from faults in the adjusting or control system. Shocks can be caused, for example, by rapid pressure decrease during the critical pressure and simultaneous filling of the entire system with medium in liquid phase. For safety reasons, therefore, a stop device and control means must be mounted before the portions exposed. This is usually made between the portion *b* and the portion *c* which are the designations used in FIG. 1 where Alternative IV shows a supercritical system.

For systems, however, which operate either only subcritically or alternatively sub- and supercritically, another location must be chosen, because upon the throttling of the saturated medium leaving the cycles at a higher pressure, a certain amount of water is obtained as component in the medium after the place of throttling. This water can be separated in ducts and distribution vessels before the superheater and cause primarily a nonuniform flow distribution.

For this reason, in the diagram according to FIG. 2 the stop and control device according to the present invention has been placed after the first superheater portion **8**. The device comprises control valves **16**, one valve for every duct, for controlling the pressure. After the control valve, a temperature control by injection coolers **17** is arranged. Such coolers are mounted also between the second and the third superheater **9** and **10** respectively. The advantages obtained by this arrangement are as follows:

(1) Dry steam is ensured even after the control device (valve).

(2) The evaporation portion can be started with these valves closed, for avoiding condensate formation in cold superheater elements.

(3) Constructively, the point chosen is in most cases the first point where the medium flow is united to one or two collected medium flows before the injection place shown.

(4) At operation with highly varying load, the device, in combination with suitable temperature control, permits the construction data of the superheater to be chosen in an optimal way. This implies a.o. that the pressure in the superheater portions **9** and **10** can be limited to the values permitted by the prevailing feed temperature, which is of interest a.o. at rapid load decreases at the turbine unit.

(5) The transition from subcritical to supercritical operation can be carried out in steps, in that first the pressure in the evaporation portion and superheater portion before the control valve of the latter is increased to the supercritical range, and thereafter the pressure in the superheater portions **9** and **10**.

(6) At conditions differing from the construction data the control valve, in combination with the subsequent temperature controls, can be adjusted such that the stresses in the superheaters are kept under control. The described effect is utilized advantageously so that at working pressures exceeding the chosen construction pressure of the superheater, the temperature is lowered below the construction temperature, whereby a detrimental effect on the life of such a mode of operation is avoided.

FIG. 2 shows in addition to the aforementioned means also, as in conventional installations, an intercooler **18**, low-pressure turbine **19**, condenser **20** and an economizer **13**.

In FIGS. 3–6 a cyclone separator is shown which comprises a container **21**, in the casing of which a plurality of inlets **22** for partially evaporated medium are provided. It appears from FIG. 5 which shows a section A—A in FIG. 3, that the inlets **22** are arranged tangentially by a special nozzle insert **23**. The cross-sectional shape of the insert **23** is shown in FIG. 6 which is a cross-section along the line B—B in FIG. 5. The steam is conducted away in usual manner in the cyclone upwardly through the nozzle **24**, while the water follows the inner walls and is led off at the bottom, see the arrow **25**. As appears from FIGS. 3 and 4 which show a horizontal view of the cyclone, a great number of inlet pipes **26** are connected to different points in the cyclone casing. This contributes substantially to a high cyclone effect.

What I claim is:

1. A steam generator with forced circulation and adapted for operation up to a pressure which may be either above or below the critical point of the working medium and comprising,

a preheater,

an evaporator having steam generating tubes,

a superheater,

and a plurality of steam separators having return tubes for separating the steam in said evaporator, said steam separators being directly connected between said steam generating tube of said evaporator and said preheater,

a mixing vessel,

said return tubes of said steam separators being connected to said mixing vessel,

the output of said preheater also being connected to said mixing vessel,

and means for maintaining the amount of said medium in said vessel substantially at a predetermined constant value.

2. The combination of claim 1 in which each said steam separator is a cyclone-type separator.

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