# United States Patent [19]

**Sakai et al.**

[11] **3,774,579**

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[54] **METHOD AND APPARATUS FOR RESTARTING BOILER FEED-WATER PUMP SYSTEM**


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[30] **Foreign Application Priority Data**

Feb. 17, 1971 Japan ..... 46/6807

[52] **U.S. Cl.** ..... **122/1 C,** 122/406 ST, 122/451 R

[51] **Int. Cl.** ..... **F22d 7/00**

[58] **Field of Search** ..... 122/1 R, 1 B, 406 R, 122/406 SU, 451 S, 451 R



[56] **References Cited**

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[57] **ABSTRACT**

For a steam turbine plant including an air separator disposed in a feed-water heating cycle, there are provided a method and apparatus for restarting the plant so that the stable and reliable operations of the feed-water pump can be ensured.


**10 Claims, 4 Drawing Figures**

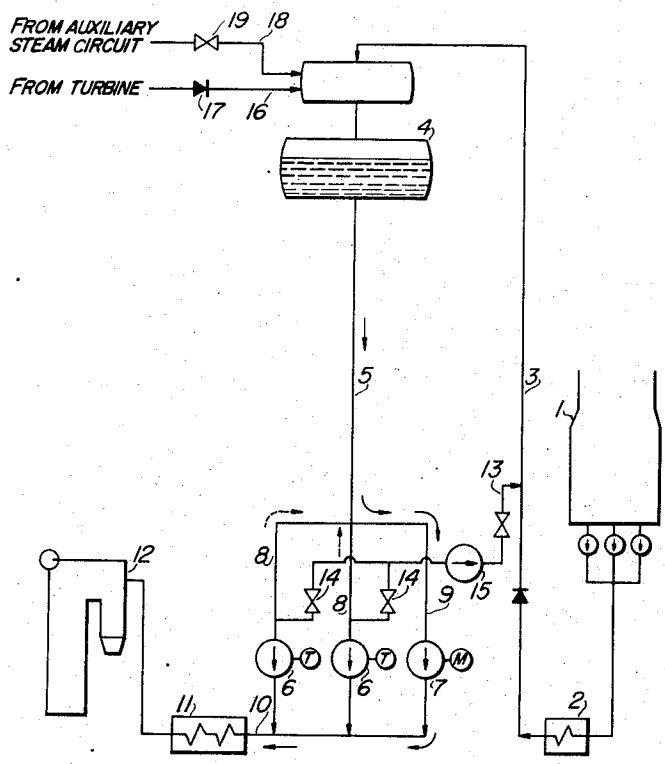

FIG. 1

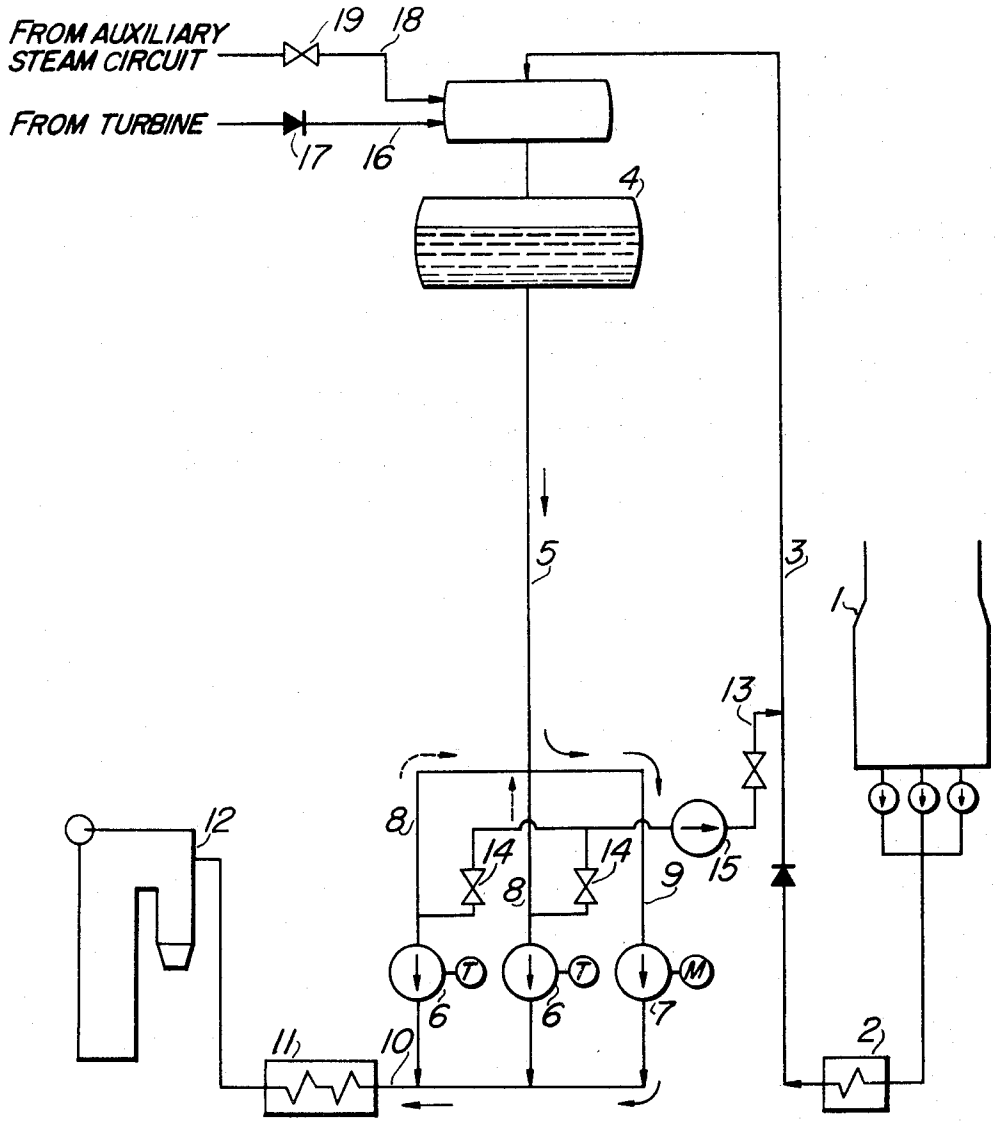
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FIG. 2

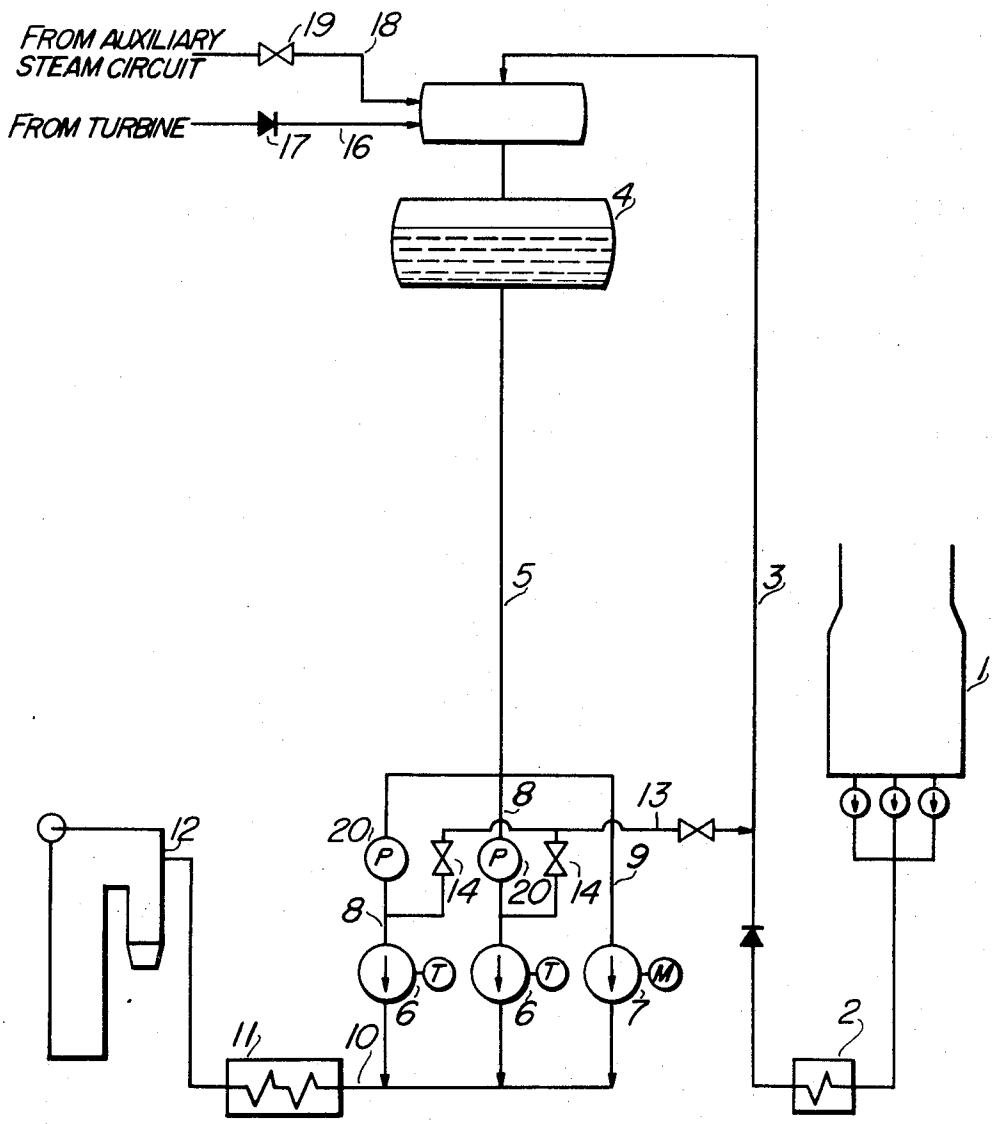
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FIG. 3

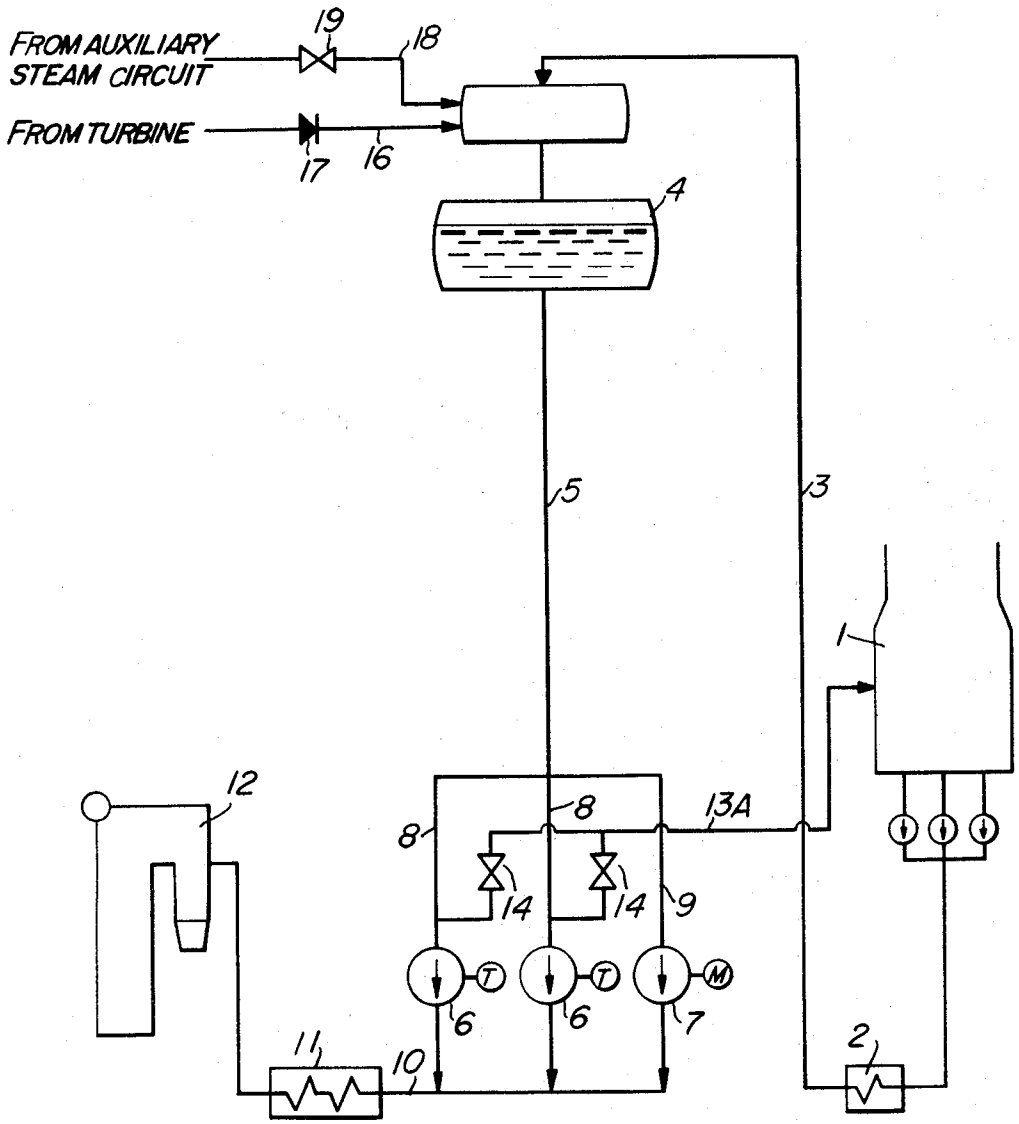
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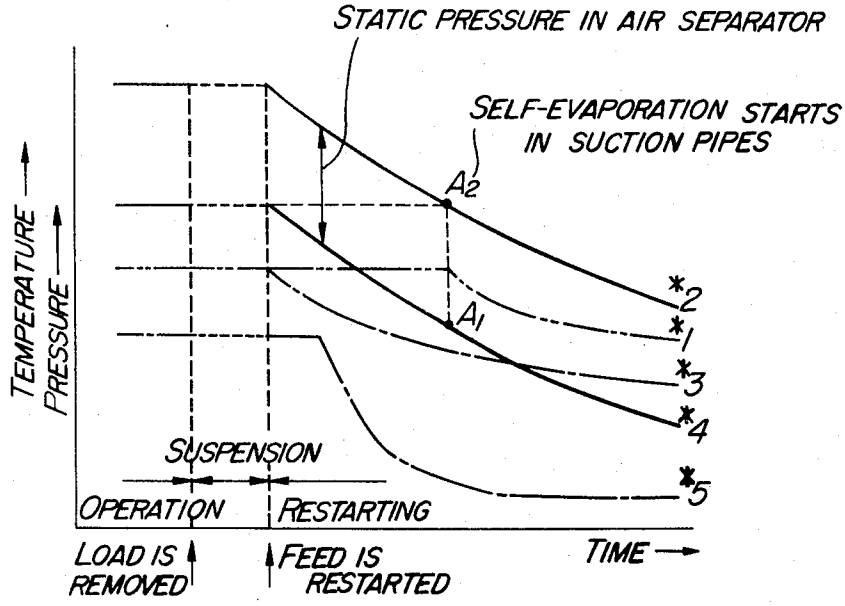
FIG. 4




*1 TEMPERATURE OF WATER ENTRAPPED IN SUCTION PIPES OF STEAM-DRIVEN PUMPS

*2 PRESSURE AT SUCTION PORT OF FEED PUMP

*3 TEMPERATURE OF WATER AT DISCHARGE PORT OF AIR SEPARATOR

*4 PRESSURE IN AIR SEPARATOR

*5 TEMPERATURE AT INLET OF AIR SEPARATOR

# METHOD AND APPARATUS FOR RESTARTING BOILER FEED-WATER PUMP SYSTEM

## BACKGROUND OF THE INVENTION

In general in a steam electric power generation plant of higher than 250 MW, there are provided two steam-driven feed-water pumps of 50 percent capacity and one or more than one motor-driven pumps of 20–25 percent capacity. The steam-driven pumps are generally used in normal operation whereas the motor-driven pumps are used as reserve or for starting the plant. In case of the starting-up the plant, the steam-driven pumps are in generally not used when there is not installed a special auxiliary boiler or the like because the sufficient steam cannot be fed to the steam-driven pumps. Therefore, in case of starting-up, the motor-driven pumps are generally used.

In the plant of the type described, the following problems are encountered when the plant is re-started a short time after the plant has been suspended or shut down as a generator was removed from a load:

In the plant in which the feed-water pumps are immediately stopped when the unit is stopped as the load is removed, the pressure in the air separator or deaerator remains at a level before the load is removed, and the water in the air separator, its downcomer and the suction pipes of the steam-driven pumps remains at a high temperature level before the load is removed. Therefore, when the feeding water into the boiler is started under these suspended conditions by the motor-driven pumps, the low-temperature water flows into the air separator (in this case, no vapor flows into the air separator) so that the pressure in the air separator is suddenly dropped. Consequently, the temperature of water from the air separator is also dropped. On the other hand, the high-temperature water still remains in the suction pipes of the steam-driven pumps, and vaporizes by itself as the pressure in the air separator is decreased, thus forming bubbles. When the pressure in the air separator is further decreased, the bubbles in the suction pipes of the steam-driven pumps are increased in volume and flow into the downcomer of the air separator. The bubbles in the downcomer are cooled by the low-temperature water flowing from the air separator to the motor-driven pumps, and are collapsed, thus causing the water hammer. In some cases, the bubbles are entrained into the motor-driven pumps, and cause the cavitation thus causing the malfunction and destruction of the pumps.

It is therefore the primary object of the present invention to eliminate the problem described above by discharging the high-temperature water entrapped in the suction pipes of the feed-water pumps in an appropriate manner.

## SUMMARY OF THE INVENTION

Briefly stated, according to the present invention, when a steam turbine plant including a condenser disposed in its feed-water heating cycle is restarted a short time after the plant has been suspended or shut down as its turbine is removed from the load, the high-temperature feed-water entrapped in the suction pipes of the feed-water pumps is discharged through the branch pipe or pipes to the condenser or to the circuit in communication with the air separator.

The above and other objects, features and advantages of the present invention will become more apparent from the following description of the preferred embodiments thereof taken in conjunction with the accompanying drawing.



## BRIEF DESCRIPTION OF THE DRAWING

The drawing illustrates some diagrams of the circuits associated with an air separator and feed-pumps in a feed-water heating cycle in a steam electric power generation plant, and

FIGS. **1**, **2** and **3** are diagrams of a first, second and third embodiments of the feed-pump starting apparatus in accordance with the present invention; and

FIG. **4** is a graph used for explanation of the transient phenomena when a load is removed in the prior art plant.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. **1** illustrating the first embodiment of the present invention, reference numeral **1** designates a condenser; **2**, a low-pressure feed-water heater; **3**, a condenser tube; **4**, an air separator or deaerator; **5**, a downcomer; **6** and **7**, a steam-driven feed-water pump and a motor-driven feed-water pump respectively; **8**, a steam-driven pump suction tube; **9**, a motor-driven pump suction tube, these two suction tubes being in communication with the downcomer **5**; **10**, a feed pipe whose one end is connected to the steam-driven and motor-driven pumps **6** and **7** and whose the other end is connected to a boiler **12** through a high-pressure feed-water heater **11**; **13**, a branch pipe branched from the suction tubes **8** and connected to the condenser tube **3**; **14**, a stop valve inserted in the branch pipe **13**; **15**, a circulation pump inserted in the branch pipe **13**; **16**, a bleeder tube interconnecting between the turbine (not shown) and the air separator **4**; **17**, a nonreturn valve inserted in the bleeder tube **16**; **18**, an auxiliary steam pipe interconnecting between an auxiliary steam circuit (not shown) and the air separator **4**; and **19**, a reducing valve inserted in the steam pipe **18**.

Referring to FIG. **2**, the second embodiment is different from the first embodiment illustrated in FIG. **1** in that in place of the circulation pump **15** or the first embodiment, a feed-water booster pump **20** is inserted in the suction tube **8**, and the branch pipe **13** is branched from the discharge port of the pump **20** to be connected to the condenser tube **3**.

Referring to FIG. **3**, the third embodiment of the present invention is different from the first and second embodiments thereof in that a branch pipe **13A** is used to interconnect between the suction pipes **8** and the condenser **1** without the use of the circulation pump **15** or the feed-water booster pump **20** because the suction is provided by the condenser **1** in case of the restarting-up of the steam electric power generation plant.

Next the mode of operation will be described first with reference to FIG. **1**. When the plant which has been operating under a high load at or near a rated load is stopped as a generator is cut off from a load, the nonreturn valve in the bleeder pipe to the air separator **4** is closed, and the two steam-driven pumps **6** are stopped so that the water feed to the boiler **12** is stopped.

As a result, as shown in FIG. **4**, the pressures and temperatures in the air separator **4**, the downcomer **5**, and the steam-driven pump suction tubes **8** are main-

tained at the levels before the load was cut off. In order to re-start the plant a short time after the plant has been suspended or shut down in the manner described above, the water is fed into the boiler **12** by the motor-driven pump **7.** However the heated steam will not be supplied to the air separator **4** but the low-temperature water from the condenser tube **3** is fed into the air separator **4.** As a result, the pressure in the air separator is gradually decreased as shown in FIG. **4,** and consequently the pressure at the suction ports of the pumps **6** and **7** as well as the temperature of the water at the discharge port of the air separator **4** are also gradually decreased. The pressure at the inlet ports of the pumps **6** and **7** are given by:

(Pressure in the air separator) + (static pressure), and when the pressure at the inlet ports of pumps **6** and **7** becomes lower than the pressure in the air separator **4** before the plant has been suspended or shut down (as indicated by the points $A_1$ and $A_2$ in FIG. **4**) as the pressure in the air separator **4** is decreased, the self-evaporation of the feed-water entrapped in the suction pipes **8** of the steam-driven pumps **6** occurs in the prior art plant, thus forming air bubbles. When the pressure in the air separator **4** is further decreased, the bubbles in the suction pipes **8** are increased in volume, and flow into the downcomer **5** as indicated by the dotted-line-arrows in FIG. **1.** These air bubbles are cooled by the low-temperature water from the air separator **4,** and collapsed, thus causing the water hammer. When the bubbles flow into the motor-driven pump suction pipe **9,** the cavitation is produced in the pump **7.**

However, according to the present invention, when the motor-driven pump **7** is re-started, the stop valve **14** is simultaneously opened and the circulation pump **15** is also simultaneously started to flow the water entrapped in the suction pipes **8** through the branch pipe **13** into the condenser pipe **3** so that the water in the suction pipes **8** is replaced by the low-temperature water from the air separator **4.** As a result, the water hammer as well as the cavitation encountered in the prior art system will not occur.

In the similar manner as described above, in case of the second embodiment shown in FIG. **2,** as soon as the motor-driven pump **7** is restarted, the stop valve **14** is opened and the feed-water booster pump **20** is started to flow the water entrapped in the suction pipes **8** into the condenser tube **3** through the branch pipe **13.**

In case of the third embodiment of the present invention illustrated in FIG. **3,** as soon as the motor-driven pump is restarted, the stop valve **14** is opened so that the water entrapped in the suction pipes **8** may flow into the condenser **1** through the branch pipe **13A.**

In the above embodiments of the present invention, both the steam-driven and motor-driven pumps are disposed, but in case of a small capacity steam electric power generation plant less than 250 MW, no steam-driven pump is in general provided and all pumps are of the motor-driven type. However it is very clear that the present invention may be advantageously applied also to such small-capacity plant and that any of the motor-driven pumps may be used for restarting-up. But it should be noted that all of the motor-driven pump suction pipes must be provided with branching pipes and stop valves.

According to the present invention, when it is desired to re-start-up the plant a short time after the plant has been removed from the load, the water hammer as well as the cavitation can be positively prevented, and the stable and reliable operation of the feed-water pumps can be ensured.

What is claimed is:

**1.** In a plant of the type comprising a condenser, an air separator, a boiler interconnected with one another by a piping system, and feed-water pumps inserted into the circuit interconnecting said air separator and said boiler, a method for restarting said feed-water pumps wherein, when said plant is restarted, the water entrapped in a circuit connecting said air separator to said feed-water pumps is discharged into said condenser.

**2.** In a plant of the type comprising a condenser, an air separator, a boiler interconnected with one another by a piping system, and feed-water pumps inserted into the circuit interconnecting said air separator and said boiler, an apparatus comprising a branch pipe one end of which is connected to the circuit interconnecting said air separator and said feed-water pumps and the other end of which is connected to said condenser.

**3.** The method of claim **1,** wherein the plant includes stop valve means disposed in said circuit interconnecting said air separator and said boiler, the method including selectively opening and closing said stop valve means to control the discharge of the entrapped water into said condenser.

**4.** In a plant of the type comprising a condenser, an air separator, a boiler interconnected with one another by a piping system, and feed-water pumps inserted into the circuit interconnecting said air separator and said boiler, a method for restarting said feed-water pumps wherein, when said plant is restarted, the water entrapped in a circuit connecting said air separator to said feed-water pumps is discharged into a circuit connected to said air separator.

**5.** The method of claim **4,** wherein the plant includes at least one stop valve means disposed in said circuit interconnecting said air separator and said boiler, and a circulation pump disposed in said circuit connected to said air separator, the method including selectively opening and closing said stop valve means to control the discharge of the entrapped water into said circuit connected to said air separator, and operating said circulation pump when said stop valve is opened to aid in discharging the entrapped water from said circuit interconnecting said air separator and said boiler.

**6.** The method of claim **4,** wherein the plant includes at least one stop valve means and at least one feed-water booster pump means disposed in said circuit interconnecting said air separator and said boiler, the method including selectively opening and closing said stop valve means to control the discharge of the entrapped water into said circuit connected to said air separator, and operating said booster pump means when said stop valve is opened to aid in discharging the entrapped water from said circuit interconnecting said air separator and said boiler.

**7.** In a plant of the type comprising a condenser, an air separator, a boiler interconnected with one another by a piping system, and feed-water pumps inserted into the circuit interconnecting said air separator and said boiler, an apparatus comprising a branch pipe one end of which is connected to the circuit interconnecting said air separator and said feed-water pumps and the other end of which is connected to the circuit interconnecting said condenser and said air separator.

8. An apparatus as set forth in claim 7 wherein a pump is inserted in said branch pipe in order to facilitate the discharge of the entrapped water.

9. An apparatus as set forth in claim 7 wherein a stop valve which is opened when said plant is restarted is inserted in said branch pipe.



10. An apparatus as set forth in claim 7 wherein a pump is inserted in the circuit interconnecting between said air separator and said feed-water pumps in order to discharge the entrapped water into said branch pipe.

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