

[54] **MULTIPRESSURE STEAM SYSTEM FOR UNFIRED COMBINED CYCLE POWERPLANT**

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[52] U.S. Cl. .... **60/106, 122/7, 122/401**  
 [51] Int. Cl. .... **F22d 1/00, F22b 37/48**  
 [58] Field of Search ..... **122/448 B, 7, 401; 60/39.18 B, 105-107**

[56] **References Cited**  
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3,703,807	11/1972	Rice.....	60/39.18 B

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[57] **ABSTRACT**

An exhaust heat recovery steam generator is utilized exclusively to develop shaft power to drive a load and includes a high pressure evaporator, low pressure evaporator and deaerator evaporator positioned in that order in the exhaust stack and has provisions for providing deaerated feedwater to each evaporator. The deaerated feedwater is conducted through a split flow system to the low pressure and high pressure evaporator, and preferably also to the deaerator evaporator, to permit individual chemical treatment of the feedwater being provided exclusively to each evaporator so that deaerated and optimally chemically treated feedwater can be passed through each evaporator to abate corrosion and fouling therein. The feedwater is passed through each evaporator at a temperature above the condensation point of the exhaust gas passing thereover. All steam generated by the low pressure and high pressure evaporators is provided exclusively to a steam turbine to drive a shaft driven load and the deaerator evaporator providing steam solely to heat and deaerate the feedwater. The system is optimized in that the pressure levels for high and low pressure evaporators are optimized to produce the maximum practical steam turbine power from the energy in the gas turbine exhaust.

13 Claims, 5 Drawing Figures

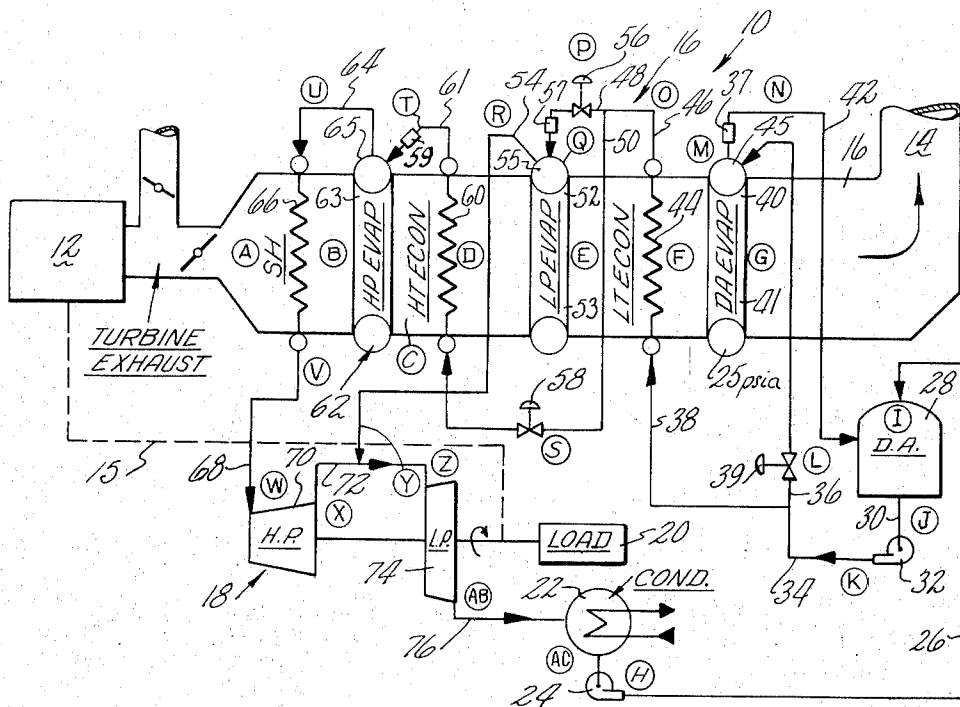


FIG. 1

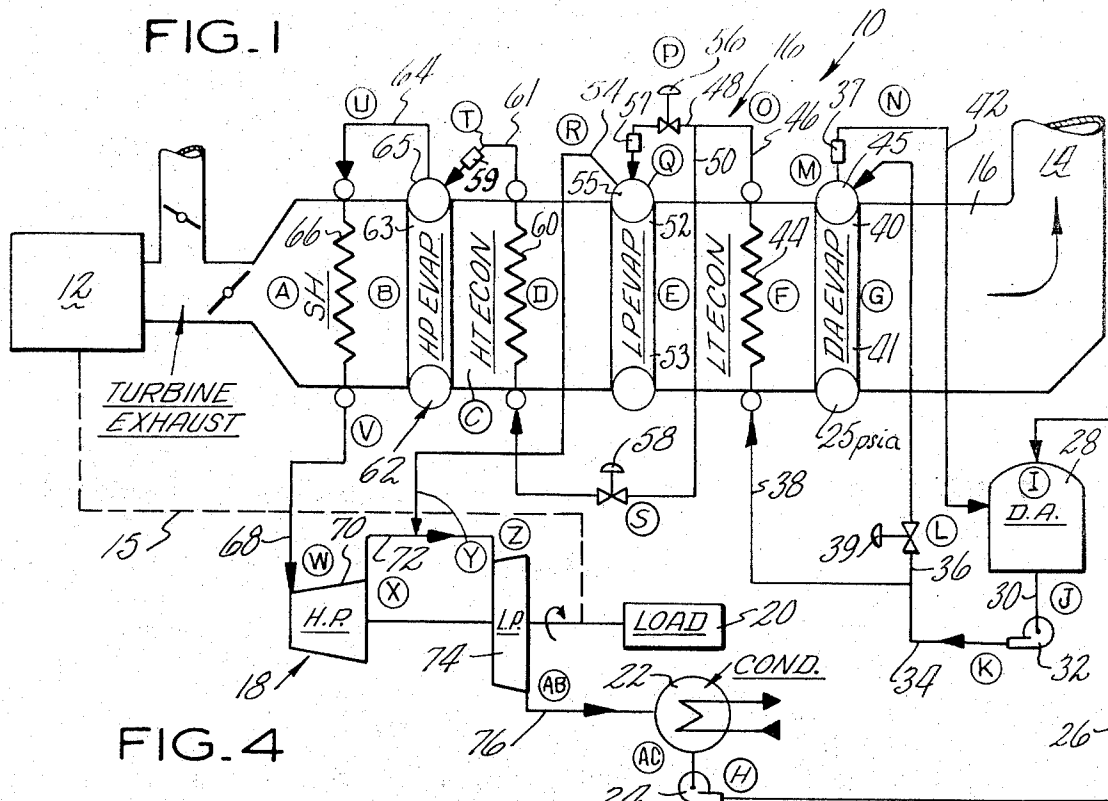


FIG. 4

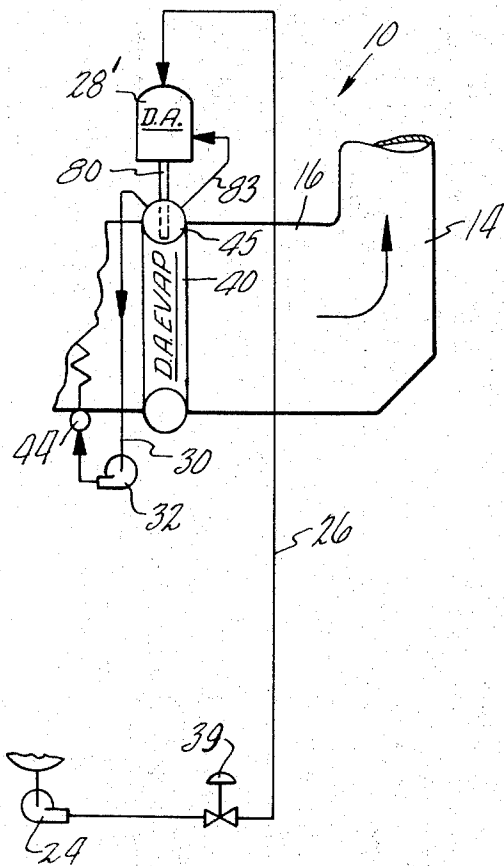


FIG. 5

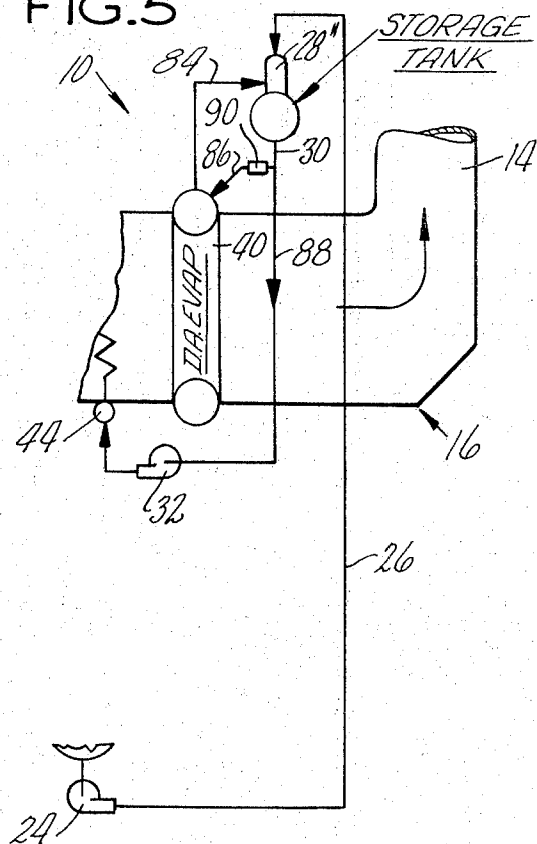


FIG. 2

TEMPERATURE ENERGY DIAGRAM  
FOR HEAT RECOVERY BOILER

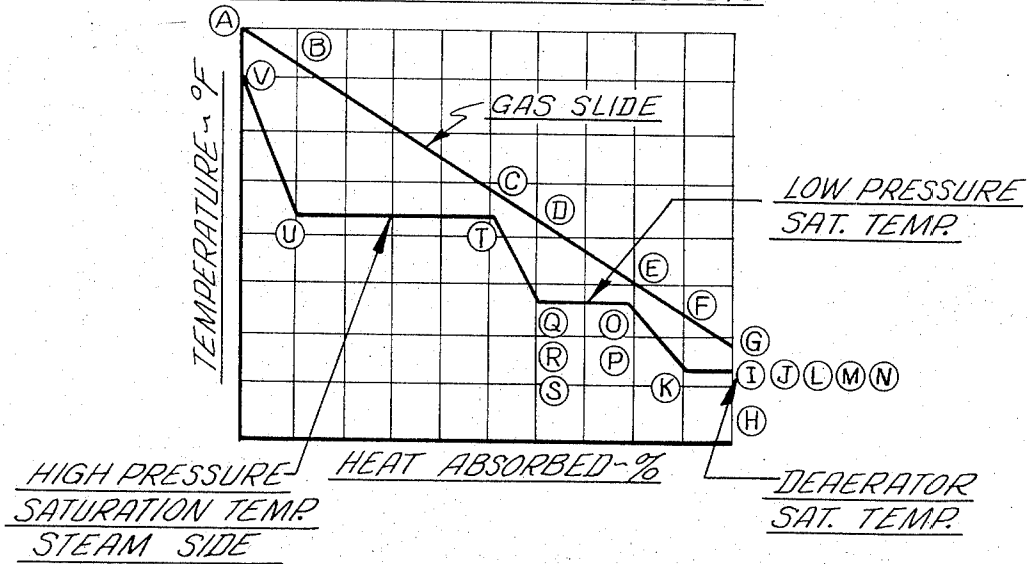
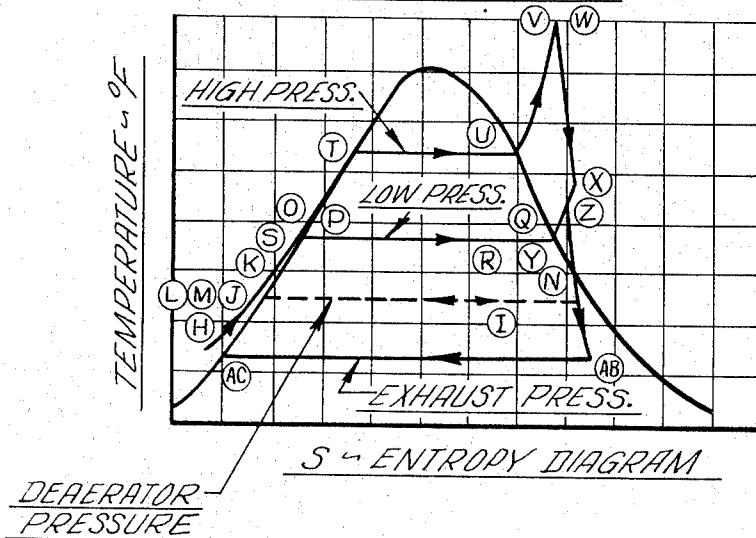


FIG. 3

TEMPERATURE ENTROPY DIAGRAM  
FOR STEAM CYCLE



# MULTIPRESSURE STEAM SYSTEM FOR UNFIRED COMBINED CYCLE POWERPLANT

## BACKGROUND OF THE INVENTION

### 1. Field of the Invention

This invention relates to mechanism for generating steam at multiple pressures and more particularly to such a system wherein deaerated and optimally chemically treated feedwater is provided to the low pressure and high pressure evaporators so as to prevent corrosion therein and wherein fluid is passed through the evaporators at a temperature above the condensation point of the exhaust gas being passed thereover and wherein all the steam generated therein is conducted to a steam turbine which is mounted to drive a shaft driven load. A low pressure deaerator evaporator or boiler is used in a downstream station of the exhaust stack to generate low pressure steam to deaerate the feedwater and the feedwater is then pumped by a boiler feedwater pump, positioned downstream of the deaerator, in a split flow path so that the boiler feedwater which is being directed exclusively into the low pressure evaporator can be optimally chemically treated, as can the boiler feedwater which is being directed exclusively into the high pressure evaporator. In such a system all of the steam so generated is utilized in generating the shaft power to drive the load, and performs no auxiliary function except during start-up and very low load operation.

### 2. Description of the Prior Art

Multiple pressure steam generating systems are known, for example, in U.S. Pat. Nos. 1,883,194; 2,443,547; 2,663,144; 3,147,742; 3,150,487; 3,177,659 and 3,304,712, but the prior art does not utilize steam so generated exclusively for developing shaft power to drive a load, does not split the flow of feedwater to the different evaporators or boilers, thereby permitting optimal chemical treatment thereof before entering the boiler to abate corrosion and fouling and does not teach an optimally designed system for maximum efficiency, while abating both internal and external corrosion of the boiler parts.

In the prior art, such as in U.S. Pat. No. 3,150,487, a very large condenser is used to do its own deaerating but not as efficiently as would be hoped. Thereafter, the poorly deaerated water was pumped directly from the condenser to the low temperature economizer and from there into the low pressure evaporator and the high pressure evaporator, with all fluid flowing through the same conduit system. Before the fluid entered the low pressure evaporator, it was necessary to add various purifying chemicals thereto so as to prevent system clogging and other undesirable results. This created a very bad chemical situation in that these chemicals must not only operate properly for the low pressure evaporator condition but also for the high pressure evaporator condition, and no known chemical compositions are capable of operating well under these two different sets of conditions. The result was poor chemical purification of the feedwater. The result is that chemical purification of the feedwater takes place in only one of the evaporators, and because of the compromise which must be made between the operating requirements and the operating conditions of the low pressure and high pressure evaporators, the purification is less than optimum, resulting in a build-up of the system clogging impurities. To remove these impurities

from the prior art construction required excessive system blow-down and this excessive blow-down required the addition of make-up water to the condenser, to thereby cause further deaeration problems to the condenser.

## SUMMARY OF THE INVENTION

A primary object of the present invention is to teach a waste heat steam generating system which can be used with a combined cycle gas turbine and steam turbine powerplant and which utilizes the energy of the steam so generated exclusively to generate shaft power for the powerplant.

It is a further object of this invention to teach such a system wherein the feedwater being provided to each evaporator can be optimally chemically treated and deaerated so as to minimize internal boiler and pump corrosion and fouling, so that feedwater or feedwater generated fluid is passed through each evaporator at a temperature so as to raise the heat exchanger evaporator coils above the condensation or dew point of the stack gases, such as turbine engine exhaust gases, being passed thereover.

It is still a further object of this invention to teach such a system wherein the system is optimized for maximum efficiency.

Other objects and advantages of the present invention may be seen by referring to the following description and claims, read in conjunction with the accompanying drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic showing of the invention used as part of the combined cycle powerplant.

FIG. 2 is a graph which is the temperature energy diagram for my heat recovery boiler.

FIG. 3 is a graph which is the temperature entropy diagram for the steam cycle of my invention.

FIG. 4 is a partial showing of my invention utilizing a first different type of deaeration system.

FIG. 5 is a partial showing of my invention using a second different type of deaeration system.

## DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1 we see my multiple pressure generating steam system 10 used as part of a combined gas turbine-steam turbine cycle wherein the exhaust gases from gas turbine engine 12 are passed through exhaust stack or duct 14 to provide the heat necessary to heat the feedwater being passed through exhaust heat recovery or stack boiler system 16 so as to generate the steam to drive steam turbine 18. Steam turbine 18 is shaft connected to drive load 20, which could be an electric generator or other device. Gas turbine engine 12 may be mechanically connected to steam turbine 18 through conventional connection 15 so that the turbines cooperate to drive load 20, but such is not necessary. While a gas turbine engine 12 is shown to provide the exhaust stack heat to the exhaust heat recovery boiler 16, it will be evident to those skilled in the art that other mechanisms could perform this function.

In the FIG. 1 system, feedwater from condenser 22 is pumped by condensate pump 24 through conduit 26 into deaerator 28. The initial feedwater which enters deaerator 28 is discharged from the deaerator through conduit 30 and then pumped by boiler feed pump 32

through conduit 34, which splits into conduits 36 and 38 so that the portion of the feedwater from pump 32 which passes through conduit 36 enters deaerator evaporator or boiler 40 exclusively and in passing through the cross tubes 41 thereof, which extend across exhaust duct 14, generate low pressure saturated steam at a pressure whose saturated temperature is above the condensation (or dew point) of the exhaust gases which is extracted through line 42 and directed back into deaerator 28 so as to heat the feedwater entering the deaerator through line 26, thereby liberating all noncondensable gases and air in the feedwater for discharge to atmosphere. Preferably, deaerator 28 is of the fluid-to-fluid type wherein the feedwater is sprayed through the steam entering deaerator 28 to form a saturated mixture at a temperature above the condensation temperature (or dew point) of the exhaust gases passing through the high pressure boiler. Accordingly, after systems start-up, deaerated feedwater is passed from the deaerator 28 to the boiler feed pump 32 for distribution to the evaporators of exhaust heat recovery boiler 16. Deaeration is desirable so that the feedwater is of minimal corrosiveness to the metal of the boiler system through which it passes.

The pressure at the boiler feed pump 32 is the highest pressure in the boiler system and is sufficient to satisfy the pressure requirements of the high pressure evaporator. Pump 32 provides deaerated feedwater to the entire system 16, including the deaerator just described. The portion of the deaerated feedwater which passes through conduit 38 passes through low temperature economizer 44, which is of conventional design, so as to heat the feedwater before it leaves the low temperature economizer 44 through conduit 46. The feedwater from conduit 46 splits into conduits 48 and 50. Approximately one-fourth to one-third of the feedwater passing through conduit 46 passes through conduit 48 and therefrom into low pressure evaporator 52 at a temperature above the condensation point of the exhaust gas passing over the cross tubes 53 of evaporator 52. It should be noted that the feedwater passing through conduit 48 flows exclusively into low pressure evaporator 52 for evaporation therein and so that all steam is extracted therefrom through conduit 54 and directed to a low pressure station in steam turbine 18. The advantage of having all of the feedwater passing through conduit 48 flow exclusively into the low pressure evaporator 52 is that precisely the proper chemical treatment can be made thereto by conventional treatment apparatus 57, to further reduce the harmful effect of the feedwater upon the boiler parts which it flows through. Treatment mechanisms 37, 57 and 59 preferably inject the required chemicals directly into evaporator steam drums 45, 55 and 65, respectively, and are conventional.

Approximately two-thirds to three-fourths, depending on the gas temperature leaving the turbine exhaust, of the feedwater from conduit 46 then passes through conduit 50 at approximately the temperature to which it was raised in low temperature economizer 44 and is chemically treated in conduit 50, and preferably in boiler 65, by a conventional chemical treatment mechanism 59, similar to mechanism 56, and then flows as treated feedwater through the high temperature economizer 60 into the high pressure evaporator 62. It is important to note that all of the feedwater which flows through conduit 50 and the high temperature econo-

mizer 60 flows exclusively through conduit 61 into the high pressure evaporator 52 after being optimally treated chemically by chemical treatment mechanism 59. High temperature economizer 60 raises the temperature of the feedwater and hence the evaporator cross tubes 63 above the condensation temperature of the stack gases passing thereover. All steam is extracted from the high pressure evaporator 62 through conduit 64 and is then passed through conventional superheater 66 and conduit 68 to a high pressure station 70 in steam turbine 18. It will therefore be seen that the superheated steam from high pressure evaporator 62 and the steam from low pressure evaporator 52 is admitted to steam turbine 18 at selected pressure stations in the steam turbine so that both work to power the steam turbine and generate shaft power exclusively therein to drive shaft driven load 20. The superheated steam from conduit 68 expands and reduces in pressure in going through the high pressure portion 70 of turbine 18 and is of substantially the same pressure as is the steam entering turbine 18 from low pressure evaporator 52 via conduit 54 when the two join in mixing chamber or conduit 72 prior to passing through the low pressure portion 74 of the steam turbine 18. After the mixed steam is expanded and reduced in pressure in passing through low pressure turbine portion 74, it passes through conduit 76 to conventional condenser 22 for recycling. Economizers 44 and 60 serve to heat the feedwater passing therethrough so that the feedwater which passes therefrom into evaporators 52 and 62, respectively, is essentially at the saturation temperature of steam in steam drums for 52 and 62 thereby maximizing the amount of steam generated therein. It will accordingly be seen that due to the individual chemical treatment and deaeration of the feedwater passing through the evaporators, the interior of the boiler system is protected optimally, while the elevating of the temperature of the fluid passing through the tubes of the low temperature economizer prevents corrosive condensation thereagainst by particles in the turbine engine exhaust gas passing through stack 14 of heat recovery boiler 16. The system shown in FIG. 1 is a three pressure system in that there are three operating pressures of feedwater and/or steam in my system.

Pressure reducing valves 39 and 56 serve to regulate the pressure of the feedwater being passed through evaporators 40 and 52, respectively, as well as regulate flow to these systems. Regulating valve 58 is a conventional feedwater regulating valve which regulates the flow to evaporator 62.

It will therefore be seen that all of the feedwater passing through conduits 36, 48 and 61, respectively, flow exclusively into deaerator evaporator 40, low pressure evaporator 52 and high pressure evaporator 62, respectively. Therefore optimum chemical treatment can be metered to each pressure system according to its individual and unique needs.

It will also further be noted that all of the steam generated in evaporators 52 and 62 is utilized to generate shaft energy to drive load 20, the steam from the evaporator 40 serving to heat the feedwater and the steam from evaporators 52 and 62 serving to drive steam turbine 18 directly.

The system shown in FIG. 1 is a three pressure system because there are three operating pressures of water and/or steam in the system. To be specific, and as an example, the high pressure evaporator 62 operates at

about 900 psia, the low pressure evaporator 52 operates at about 150 psia and the deaerator evaporator 40 operates at about 25 psia when the exhaust temperature is 850°F. These are the three pressures of my system. In the prior art systems, which do not have a deaerator evaporator, some of the generated steam has to be utilized to perform the function of feedwater deaeration at some station between the condensate pump 24 and the boiler feed pump 32.

A substantial advantage to be gained by this three pressure system is the control which is available over operating temperatures of the steam and water in the heat exchanger system 16. Specifically, the operating temperatures of the feedwater or generated steam are sufficiently high that as the sulphur laden exhaust gases from turbine engine 12 passes through exhaust stack 14 and over the steam or water filled finned cross-over tubes of heat exchanger system 16, such as the tubes 63, 53 and 41 of the evaporator 62, 52 and 40, and the superheater 66, and economizers 60 and 44, the heated water passing therethrough heats the tubes above the condensation or dew point of these sulphur particles and therefore the moisture does not deposit or condense upon the metallic surfaces of heat exchanger 16. The condensed water would provide the mechanism for forming sulphuric acid which is highly corrosive so that the life of the entire system is adversely affected by deposit thereof on the metallic parts of boiler 16.

In my system shown in FIG. 1, by utilizing deaerator evaporator 40, we can use fluid-to-fluid deaerator 26 and then position the boiler feed pump 32 between the deaerator 28 and the low temperature economizer 44 so as to pump the deaerated feedwater to the two evaporators 52 and 62 through a split flow system so that a selected portion of the feedwater enters deaerator 52 exclusively and can be optimally chemically treated for the condition therein, while the remainder of the feedwater enters high pressure evaporator 62 exclusively and can be optimally treated for the condition therein. This permits us to satisfy the sensitive chemical purification requirements of each evaporator.

For the purpose of more specifically describing the operation of my system shown in FIG. 1, attention will now be directed to FIGS. 2 and 3, which are a temperature energy diagram for the heat recovery boiler 16 and a temperature-entropy diagram for the steam cycle, respectively. The condensate is pumped to the deaerator 28 at station (I) by the condensate pump 24 at station (H). At the deaerator 28, the condensate mixes with saturated steam which passes from the deaerator evaporator 40 into deaerator 28 through conduit 42. The steam-water mixture leaving deaerator 28 through conduit 30 is a saturated liquid at station (J). All the feedwater is then pumped by boiler feed pump 32 at station (K) to a pressure required by the high pressure evaporator 62. The effect of the pump work is shown in FIG. 3 at point (H) and (K) and has been exaggerated for illustrative purposes. Some of the feedwater is recirculated back to the deaerator evaporator 40, and in particular the steam drum thereof at station (M), by passing through a pressure reducing feedwater regulating valve 39 at station (L). The remainder of the feedwater passes through the low temperature economizer 40 to station (O). The feedwater has been heated in passing through low temperature economizer 44 to the saturation temperature of the low pressure evaporator 52. Approximately one-quarter to one-third of the flow at

station (O) passes through pressure reducing feedwater regulating valve 56 at station (P) to the low pressure evaporator steam drum at station (Q). The remainder of the feedwater mixture passes through a third feedwater regulating valve 58 at station (S) to the high temperature economizer 60 where it is heated to the saturation temperature of the high pressure evaporator 62. In other installations or under different operating conditions, the flow split between the evaporators 52 and 62 will be different. The steam evaporated in the high pressure evaporator 62 is superheated in superheater 66 in passing from station (U) to (V). The high pressure, superheated steam, which we will call primary flow, enters the steam turbine 18 at the throttle inlet at station (W). This flow expands to station (X) to a pressure approximately the same as the pressure in the low pressure boiler or evaporator 52. The steam generated in the low pressure evaporator 52, which we will call secondary flow, passes out of the steam drum thereof at station (R) and enters the steam turbine at the induction point (Y), where it mixes with the primary flow at station (Z). The mixed flow of primary and secondary flow fluids then expands down to the exhaust pressure at station (AB) and is condensed to saturated liquid in the condenser 22 at station (AB). The encircled or bracketed letters are utilized in FIGS. 1 through 3 since they lend themselves to describing the graphs of FIGS. 2 and 3 and their relationship to the system shown in FIG. 1.

My system 10 lends itself to use with other types of deaerators, for example the types shown in FIGS. 4 and 5. The remainder of the system shown in FIG. 1 is applicable to the FIGS. 4 and 5 constructions and corresponding reference numerals will be used in describing the FIG. 4 and 5 constructions as were used for the FIG. 1 construction.

Referring to FIG. 4 we see that condensate from pump 24 passes through conduit 26, including pressure regulating valve 39, into deaerator 28'. Saturated steam from the deaerator evaporator 40 also passes through conduit 83 into deaerator 28' where the steam and feedwater mix in liquid-to-liquid fashion to deaerate the feedwater. The resulting mixture is saturated liquid at the deaerator pressure. All of the mixture flow passes down through connecting pipe 80, the exit of which is always submerged below the water level in the deaerator evaporator steam drum 43. The feedwater required to supply the high and low pressure system shown in FIG. 1 passes through conduit 30 to the boiler feed pump 32, from which it is pumped in the fashion shown in FIG. 1 to the low temperature economizer, low temperature evaporator, high temperature economizer and high temperature evaporator and superheater to the steam turbine. The remaining flow is mixed with the fluid in the steam drum 41 and joins the circulation system in the deaerator evaporator 28'-40.

Now referring to FIG. 5 we see another deaerator embodiment which can be used with my system 10 otherwise depicted in FIG. 1. In this configuration, the condensate from condensate pump 24 is pumped from conduit 26 into deaerator 28''. There it mixes in fluid-to-fluid fashion with the saturated steam from the deaerator evaporator 40 being passed into the deaerator 28'' through conduit 84. The saturated mixture from deaerator 28' passes through conduit 30 and splits so that a portion thereof recirculates back to the deaerator evaporator 40 through conduit 86, while the re-

mainder thereof passes through conduit 88 to the boiler feed pump 32. It will be noted that in the FIG. 5 embodiment, chemical treatment mechanism 90 is placed in conduit 86 or in the steam drum of deaerator evaporator 40 so as to optimally treat the feedwater entering the deaerator evaporator 40, independently of the remainder of the feedwater system. The feedwater, in both the FIG. 4 and FIG. 5 construction, will be treated independently at the low pressure evaporator steam drum and high pressure evaporator steam drum as shown in the FIG. 1 construction.

I wish it to be understood that I do not desire to be limited to the exact details of construction shown and described, for obvious modifications will occur to a person skilled in the art.

I claim:

1. A combined gas turbine-steam turbine cycle powerplant wherein the exhaust gases of the gas turbine provide all of the heat to the steam boiler to generate steam for the steam turbine which is connected to drive a shaft driven load including:
  - A. a gas turbine engine,
  - B. a steam turbine engine,
  - C. an exhaust stack boiler through which the gas turbine engine exhaust gases are passed and including:
    1. an exhaust stack positioned so that the exhaust gases from said gas turbine engine pass therethrough and having an exhaust gas inlet end and an exhaust gas outlet end,
    2. steam generating means operatively associated with said exhaust stack including:
      - a. a superheater having tubes extending across said exhaust stack closest said exhaust gas inlet end,
      - b. a high pressure evaporator having tubes extending across said exhaust stack next downstream of the superheater,
      - c. a high temperature economizer having tubes extending across said exhaust stack next downstream of said high pressure evaporator,
      - d. a low pressure evaporator having tubes extending across said exhaust stack next downstream of said high temperature economizer,
      - e. a low temperature economizer having tubes extending across said exhaust stack next downstream of said low pressure evaporator, and
      - f. a deaerator evaporator having tubes extending across said exhaust gas stack next downstream of said low temperature economizer,
  - D. means to pass feedwater through said steam generating means including three feedwater flow path conduit systems including:
    1. a first flow path conduit system directing a first selected quantity of feedwater exclusively to the deaerator evaporator at a selected temperature so that the feedwater being passed through said deaerator evaporator is above the temperature of the condensation point of the exhaust gases passing over the deaerator evaporator,
    2. a second flow path conduit system passing a second selected quantity of feedwater exclusively through said low temperature economizer and then into said low pressure evaporator so that the temperature of the feedwater being passed through both is above the condensation point of the exhaust gases being passed thereover, and

3. a third flow path conduit system directing a third selected quantity of feedwater from said low temperature economizer exclusively through said high temperature economizer and said high pressure evaporator such that the temperature of the feedwater passing through both is above the condensation point of the exhaust gases passing thereover,
- E. means to extract steam from said high pressure evaporator and pass it through said superheater and conduct said superheated steam to a high pressure station in the steam turbine,
- F. means to extract steam from said low pressure evaporator and direct it to a low pressure station in said steam turbine so as to cooperate with said superheated steam to power said steam turbine to drive said shaft driven load, and
- G. means to add selected quantities of water purifying chemicals to the selected quantity of feedwater introduced exclusively to the deaerator evaporator, to the selected quantity of feedwater being directed exclusively to the low pressure evaporator, and to the selected quantity of feedwater being directed exclusively to the high pressure evaporator, respectively.
2. A powerplant according to claim 1 and including:
  - A. a condenser connected to said turbine to receive steam therefrom for condensation therein,
  - B. a feedwater deaerator positioned between said condenser and said deaerator evaporator, and
  - C. a boiler feed pump positioned between said deaerator and said three feedwater flow path conduit systems so as to pump deaerated boiler feedwater therethrough.
3. An unfired, waste-heat-steam turbine cycle powerplant wherein waste-heat provides all of the heat to the steam boiler to generate steam for the steam turbine which is connected to drive a shaft driven load including:
  - A. a steam turbine,
  - B. a waste-heat stack boiler through which the waste-heat is passed and including:
    1. a waste-heat stack positioned so that the waste-heat passes therethrough and having an inlet end and an outlet end,
    2. steam generating means operatively associated with said waste-heat stack including:
      - a. a superheater having tubes extending across said waste-heat stack closest said inlet end,
      - b. a high pressure evaporator having tubes extending across said waste-heat stack next downstream of the superheater,
      - c. a high temperature economizer having tubes extending across said waste-heat stack next downstream of said high pressure evaporator,
      - d. a low pressure evaporator having tubes extending across said waste-heat stack next downstream of said high temperature economizer,
      - e. a low temperature economizer having tubes extending across said waste-heat stack next downstream of said low pressure evaporator, and
      - f. a deaerator evaporator having tubes extending across said waste-heat stack next downstream of said low temperature economizer,

- C. means to pass feedwater through said steam generating means including three feedwater flow path conduit systems including:
1. a first flow path conduit system directing a first selected quantity of feedwater exclusively to the deaerator evaporator at a selected temperature so that the feedwater being passed through said deaerator evaporator is above the temperature of the condensation point of the waste-heat gases passing over the deaerator evaporator,
  2. a second flow path conduit system passing a second selected quantity of feedwater exclusively through said low temperature economizer and then into said low pressure evaporator so that the temperature of the feedwater being passed through both is above the condensation point of the waste-heat gases being passed thereover, and
  3. a third flow path conduit system directing a third selected quantity of feedwater from said low temperature economizer exclusively through said high temperature economizer and said high pressure evaporator such that the temperature of the feedwater passing through both is above the condensation point of the waste-heat gases passing thereover,
- D. means to extract steam from said high pressure evaporator and pass it through said superheater and conduct said superheated steam to a high pressure station in the steam turbine,
- E. means to extract steam from said low pressure evaporator and direct it to a low pressure station in said steam turbine so as to cooperate with said superheated steam to power said steam turbine to drive said shaft driven load, and
- F. means to add selected quantities of water purifying chemicals to the selected quantity of feedwater introduced exclusively to the deaerator evaporator, to the selected quantity of feedwater being directed exclusively to the low pressure evaporator, and to the selected quantity of feedwater being directed exclusively to the high pressure evaporator, respectively.
4. A multipressure steam generating powerplant including a heat recovery boiler having:
- A. a heat duct having an upstream end and a downstream end,
  - B. a high pressure evaporator having tubes in said heat duct at an upstream station,
  - C. a low pressure evaporator having tubes in said heat duct at a downstream station,
  - D. first feedwater conduit means connected to provide a selected quantity of feedwater exclusively to said low pressure evaporator and including:
    1. means to selectively chemically treat the feedwater so introduced into the low pressure evaporator,
  - E. a second feedwater conduit means connected to provide a selected quantity of feedwater exclusively to the high pressure evaporator and including:
    1. means to selectively chemically treat the feedwater so introduced into the high pressure evaporator, and
  - F. means to extract steam from both said low pressure evaporator and said high pressure evaporator.

5. A powerplant according to claim 4 and including means to deaerate the feedwater to be passed through said first and second conduit means.
6. A powerplant according to claim 5 wherein said feedwater deaeration means includes:
- A. a deaerator evaporator positioned in said heat duct downstream of said low pressure evaporator,
  - B. a fluid-to-fluid deaerator, and
  - C. conduits connecting said deaerator to said deaerator evaporator to conduct feedwater from said deaerator to said deaerator evaporator to generate low pressure steam therein and to conduct said steam back to said deaerator to heat and deaerate the entering feedwater.
7. A powerplant according to claim 6 and including:
- A. means located in said first feedwater conduit means to heat the deaerated feedwater passing therethrough to a point at which the deaerated feedwater will heat the low pressure evaporator above the condensation temperature of the waste-heat gas passing thereover, and
  - B. means located in said second feedwater conduit means to heat the deaerated feedwater passing therethrough to a point at which the deaerated feedwater will heat the high pressure evaporator to a temperature above the condensation temperature of the waste-heat gas passing thereover.
8. A powerplant according to claim 5 wherein said feedwater deaerator includes a fluid-to-fluid deaerator positioned externally of the heat stack and a deaerator evaporator having tubes in said heat stack at a station downstream of said low pressure evaporator and conduit means connecting said deaerator and said deaerator evaporator so that the low pressure steam generated in said deaerator evaporator is directed to said deaerator so as to heat the feedwater entering the deaerator to deaerate the feedwater and so that the saturated mixture of feedwater and steam accumulated in said deaerator after said mixing will be passed in part to said deaerator evaporator, in part to said low pressure evaporator and in part to said high pressure evaporator.
9. A gas turbine-steam turbine unfired, combined cycle powerplant wherein the exhaust gases of the gas turbine provide all of the heat to the steam boiler to generate steam for the steam turbine which is connected to drive a shaft driven load including:
- A. a gas turbine engine,
  - B. a steam turbine engine,
  - C. a waste-heat boiler through which the gas turbine engine exhaust gases are passed and including:
    1. an exhaust stack positioned so that the exhaust gases from said gas turbine engine pass therethrough and having an exhaust gas inlet end and an exhaust gas outlet end,
    2. steam generating means operatively associated with said exhaust stack including:
      - a. a superheater having tubes extending across said exhaust stack closest said exhaust gas inlet end,
      - b. a high pressure evaporator having tubes extending across said exhaust stack next downstream of the superheater,
      - c. a high temperature economizer having tubes extending across said exhaust stack next downstream of said high pressure evaporator,

- d. a low pressure evaporator having tubes extending across said exhaust stack next downstream of said high temperature economizer,
- e. a low temperature economizer having tubes extending across said exhaust stack next downstream of said low pressure evaporator, and
- f. a deaerator evaporator having tubes extending across said exhaust gas stack next downstream of said low temperature economizer,
- D. a condenser connected to said steam turbine to receive steam therefrom for condensation therein,
- E. a feedwater deaerator connected to said condenser to receive condensate feedwater therefrom,
- F. a boiler feed pump connected to said deaerator to receive deaerated feedwater therefrom,
- G. means to pass deaerated feedwater from said boiler feed pump through said steam generating means and to said steam turbine including three feedwater flow path conduit systems including:
  - 1. a first flow path conduit system directing a first selected quantity of deaerated feedwater exclusively to the deaerator evaporator from said boiler feed pump including:
    - a. a first conduit connecting said boiler feed pump to said deaerator evaporator,
    - b. a second conduit conducting low pressure steam generated in said deaerator evaporator to said deaerator to serve as the deaerating steam and to be condensed therein for recycling as a saturated mixture through said first and second conduits,
  - 2. a second flow path conduit system directing a second selected quantity of deaerated feedwater exclusively to the low pressure evaporator including:
    - a. a first conduit extending between said boiler feed pump and said low temperature economizer through which a selected quantity of deaerated feedwater is passed to be elevated to a selected temperature above the condensation temperature of the low temperature economizer and the low pressure evaporator,
    - b. a second conduit connecting said low temperature economizer to said low pressure evaporator to direct said second selected quantity of deaerated and selectively heated feedwater at a temperature above the low pressure evaporator condensation point to the low pressure evaporator, and
    - c. a conduit connecting said low pressure evaporator to said steam turbine to direct all the steam generated in the low pressure evaporator to said steam turbine,
  - 3. a third flow path conduit system directing a third selected quantity of deaerated feedwater from said boiler feed pump exclusively to said high pressure evaporator and including:
    - a. a first conduit connecting said boiler feedwater pump to said low temperature economizer,
    - b. a second conduit connecting said low temperature economizer to said high temperature economizer in which the deaerated feedwater is heated to a temperature above the condensation temperature of said high pressure evaporator,
    - c. a third conduit connecting said high temperature economizer to said high pressure evapora-

- tor so that the deaerated feedwater passing through said first and second conduits and said low temperature and high temperature economizers is directed into said high pressure evaporator above the condensation temperature thereof,
- d. a fourth conduit connecting said high pressure evaporator to said superheater, and
- e. a fifth conduit connecting said superheater to said steam turbine so that the steam generated in said high pressure evaporator is passed through said fourth conduit to be superheated in passing through said superheater and then directed through said fifth conduit to said steam turbine so that all of the steam generated in this multipressure system is utilized to generate shaft energy in said steam turbine to drive a shaft driven load,
- H. means to add selected quantities of water purifying chemicals to the selected quantity of feedwater being so introduced exclusively to the deaerator evaporator, to the selected quantity of feedwater being directed exclusively to the low pressure evaporator, and to the selected quantity of feedwater being directed exclusively to the high pressure evaporator, respectively.
- 10. A powerplant according to claim 9 wherein said third system splits from said second system so that about one-fourth to one-third of the deaerated feedwater enters said low pressure evaporator and about three-fourths to two-thirds of the deaerated feedwater enters said high pressure evaporator.
- 11. An unfired, waste-heat-steam turbine combined cycle powerplant wherein waste-heat provides all of the heat to the steam boiler to generate steam for the steam turbine which is connected to drive a shaft driven load including:
  - A. a steam turbine,
  - B. a waste-heat stack boiler through which the waste-heat is passed and including:
    - 1. a waste-heat stack positioned so that the waste-heat passes therethrough and having an inlet end and an outlet end,
    - 2. steam generating means operatively associated with said waste-heat stack including:
      - a. a superheater having tubes extending across said waste-heat stack closest said inlet end,
      - b. a high pressure evaporator having tubes extending across said waste-heat stack next downstream of the superheater,
      - c. a high temperature economizer having tubes extending across said waste-heat stack next downstream of said high pressure evaporator,
      - d. a low pressure evaporator having tubes extending across said waste heat stack next downstream of said high temperature economizer,
      - e. a low temperature economizer having tubes extending across said waste heat stack next downstream of said low pressure evaporator, and
      - f. a deaerator evaporator having tubes extending across said waste-heat stack next downstream of said low temperature economizer,
  - C. a condenser connected to said steam turbine to receive steam therefrom for condensation therein,
  - D. a feedwater deaerator connected to said con-

- denser to receive condensate feedwater therefrom,
- E. a boiler feed pump connected to said deaerator to receive deaerated feedwater therefrom,
- F. means to pass deaerated feedwater from said boiler feed pump through said steam generating means and to said steam turbine including three feedwater flow path conduit systems including:
  1. a first flow path conduit system directing a first selected quantity of deaerated feedwater exclusively to the deaerator evaporator from said boiler feed pump including:
    - a. a first conduit connecting said boiler feed pump to said deaerator evaporator,
    - b. a second conduit conducting low pressure steam generated in said deaerator evaporator to said deaerator to serve as the deaerating steam and to be condensed therein for recycling as a saturated mixture through said first and second conduits,
  2. a second flow path conduit system directing a second selected quantity of deaerated feedwater exclusively to the low pressure evaporator including:
    - a. a first conduit extending between said boiler feed pump and said low temperature economizer through which a selected quantity of deaerated feedwater is passed to be elevated to a selected temperature above the condensation temperature of the low temperature economizer and the low pressure evaporator,
    - b. a second conduit connecting said low temperature economizer to said low pressure evaporator to direct said second selected quantity of deaerated and selectively heated feedwater at a temperature above the low pressure evaporator condensation point to the low pressure evaporator, and
    - c. a conduit connecting said low pressure evaporator to said steam turbine to direct all the steam generated in the low pressure evaporator to said steam turbine,
  3. a third flow path conduit system directing a third selected quantity of deaerated feedwater from said boiler feed pump exclusively to said high pressure evaporator and including:
    - a. a first conduit connecting said boiler feedwater pump to said low temperature economizer,
    - b. a second conduit connecting said low temperature economizer to said high temperature economizer in which the deaerated feedwater is heated to a temperature above the condensation temperature of said high pressure evaporator,
    - c. a third conduit connecting said high temperature economizer to said high pressure evaporator so that the deaerated feedwater passing through said first and second conduits and said low temperature and high temperature economizers is directed into said high pressure evaporator above the condensation temperature thereof,
    - d. a fourth conduit connecting said high pressure evaporator to said superheater, and
    - e. a fifth conduit connecting said superheater to said steam turbine so that the steam generated

- in said high pressure evaporator is passed through said fourth conduit to be superheated in passing through said superheater and then directed through said fifth conduit to said steam turbine so that all of the steam generated in this multipressure system is utilized to generate shaft energy in said steam turbine to drive a shaft driven load,
- G. means to add selected quantities of water purifying chemicals to the selected quantity of feedwater being directed exclusively to the deaerator evaporator, to the selected quantity of feedwater being directed exclusively to the low pressure evaporator, and to the selected quantity of feedwater being directed exclusively to the high pressure evaporator, respectively.
- 12. multipressure steam generating powerplant including a heat recovery boiler having:
  - A. a heat duct having an upstream end and a downstream end,
  - B. a high pressure evaporator having tubes in said heat duct at an upstream station,
  - C. a low pressure evaporator having tubes in said heat duct at a downstream station,
  - D. an intermediate pressure evaporator having tubes in said heat duct at a station between said high pressure evaporator and said low pressure evaporator,
  - E. means to direct a first quantity of deaerated feedwater exclusively to said low pressure evaporator,
  - F. means to direct a second quantity of deaerated feedwater exclusively to said intermediate pressure evaporator,
  - G. means to direct a third quantity of deaerated feedwater exclusively to said high pressure evaporator, and
  - H. means to optimally chemically treat said deaerated feedwater exclusively entering each of said low, intermediate, and high pressure evaporators.
- 13. A multipressure steam generating powerplant including a heat recovery boiler having:
  - A. a heat duct having an upstream end and a downstream end,
  - B. a high pressure evaporator having tubes in said heat duct at an upstream station,
  - C. a low pressure evaporator having tubes in said heat duct at a downstream station,
  - D. an intermediate pressure evaporator having tubes in said heat duct at a station between said high pressure evaporator and said low pressure evaporator,
  - E. means to direct a total quantity of deaerated feedwater so that a first portion thereof flows exclusively to said low pressure evaporator, so that a second portion thereof flows exclusively to said intermediate pressure evaporator, and so that the remainder thereof flows exclusively to said high pressure evaporator, and
  - F. means to optimally chemically treat the deaerated feedwater being conducted exclusively into each of said low, intermediate, and high pressure evaporators.

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UNITED STATES PATENT OFFICE  
CERTIFICATE OF CORRECTION

Patent No. 3,769,795 Dated November 6, 1973

Inventor(s) ERIC G. RORSTROM

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In the heading of the patent please delete "Eric G. Rostrom" and insert --Eric G. Rorstrom--

In the Claims:

Claim 1, column 7, line 20 Delete "burbine" and insert  
--turbine--

Claim 13, column 14, line 50 Delete "tubs" and insert  
--tubes--

Signed and sealed this 23rd day of April 1974.

(SEAL)  
Attest:

EDWARD M. FLETCHER, JR.  
Attesting Officer

C. MARSHALL DANN  
Commissioner of Patents