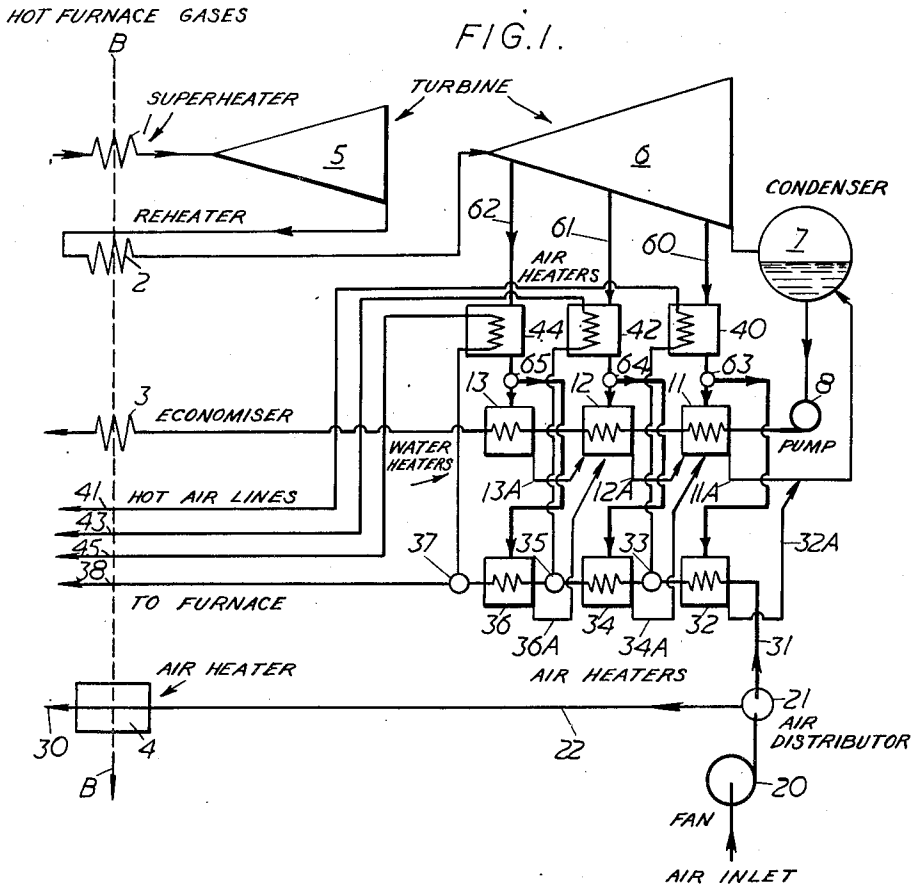
May 8, 1962 P. H. PACAULT 3,032,999

STEAM TURBINE POWER PLANTS

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FIG. 1.



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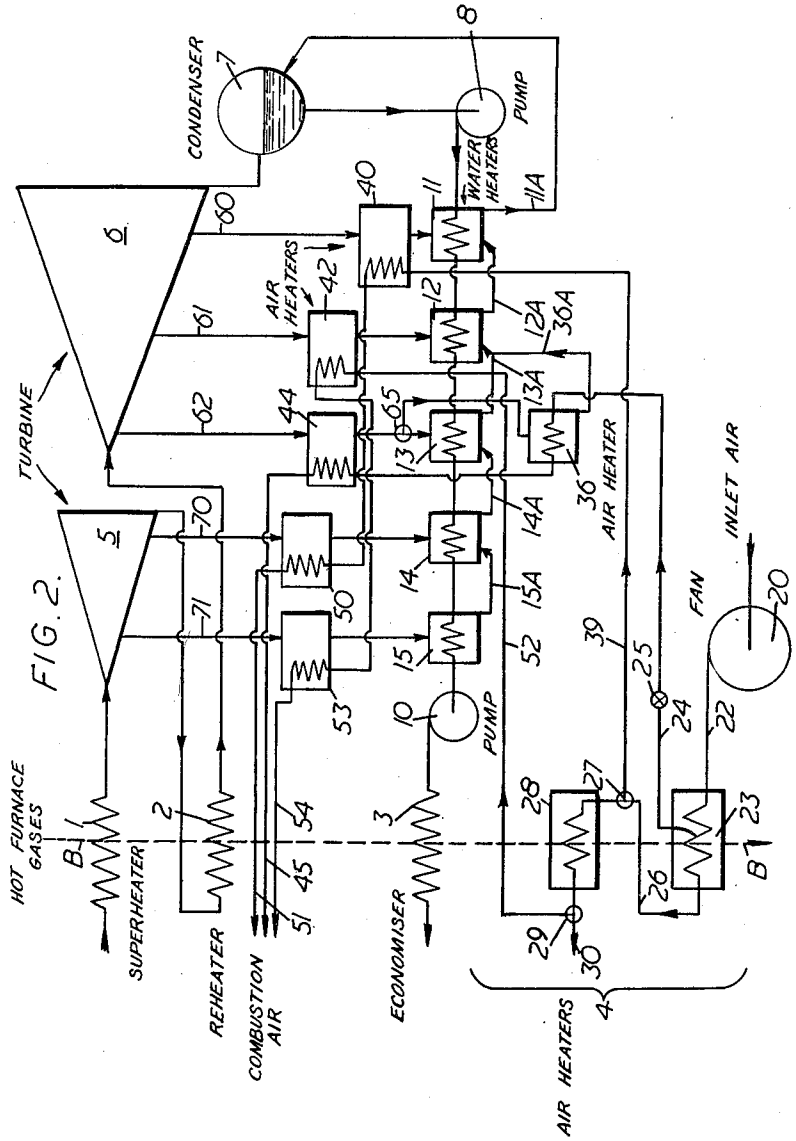


FIG. 2.

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STEAM TURBINE POWER PLANTS

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The present invention relates to improvements in steam turbine power plants arranged to receive steam from steam generating and superheating units.

In a steam turbine power plant an improved overall efficiency may be obtained if feed-water is preheated by steam bled from stages of the turbine, and the tendency has been progressively to increase the amount of feed-water heating in this manner, since the maximum improvement in efficiency would be given by heating the feed-water by an infinite number of steam bleeds to the temperature of saturated steam at the working pressure of the steam generating unit. Withdrawal of steam from the higher pressure stages of the turbine after that steam has been expanded to only a small degree necessitates an increase in the mass flow rate of steam into the turbine for a given power output. This increase in mass flow rate necessitates the use of a larger superheater, which is undesirable since superheater and reheater heat exchange surfaces are the surfaces exposed to the most onerous conditions in the steam generating and superheating unit.

A further difficulty that arises from the use of a large degree of feed-water heating is that the feed-water flowing to the economiser of the steam generating unit is at a high temperature, so that the temperature of the heating flue gases leaving the economiser is also relatively high. In order to improve the efficiency of the installation by reducing the temperature of the gases discharged to the chimney flue to a reasonable value, an air heater located in the flow of flue gases subsequent to the economiser is then required to extract sufficient heat from the flue gases to effect this reduction in temperature, and this presents a difficulty in some cases because the permissible upper temperature limit of the combustion air is fixed by the fuel used.

An object of the present invention is the provision of an improved steam turbine power plant arranged to receive steam from a steam generating and superheating unit. Further objects and advantages of the invention will be apparent from the subsequent description of embodiments of the invention.

The invention will now be described, by way of example, with reference to the accompanying drawings, in which FIGURES 1 and 2 are schematic drawings of two alternative arrangements of steam turbine power plant and of parts of a steam generating and superheating unit.

Referring first to FIGURE 1, dotted line B—B indicates the flow of hot furnace gases through the steam generating and superheating unit and the arrowhead on that line indicates the direction of gas flow. Disposed in that gas flow are a steam superheater 1, a steam reheater 2, an economiser 3 and an air heater 4, suitably of the rotary regenerative type. The steam turbine includes a high pressure stage 5 arranged to receive steam flowing from the superheater 1, and to discharge partly expanded steam to the reheater 2 and a low pressure turbine stage 6 arranged to receive steam from the reheater 2, and to discharge steam to a condenser 7. An extraction pump 8 is arranged to extract condensate from the condenser 7 and to force it through series connected feed-water heaters 11, 12 and 13 of the closed type to the inlet to the economiser 3.

A forced draught fan 20 is arranged to supply air to a distributor 21 from which part of the air flows through conduit 22 to the air heater 4 and thence through

conduit 30 to combustion apparatus of the furnace associated with the steam generating unit, and from which the remainder of the air flows through conduit 31 to a steam-heated air heater 32. The outlet of heater 32 is connected through a distributor 33 to a second steam-heated air heater 34, the outlet of which is connected through a distributor 35 to a third steam-heated air heater 36, the outlet of which is connected through a distributor 37 to a conduit 38 connected to the combustion apparatus mentioned above.

The distributor 33 is connected through a steam-heated air heater 40 to a conduit 41, the distributor 35 is connected through a steam-heated air heater 42 to a conduit 43, and the distributor 37 is connected through a steam-heated air heater 44 to a conduit 45, the conduits 41, 43 and 45 all being connected to the combustion apparatus mentioned above.

The turbine low pressure stage 6 is provided with three steam bleeds 60, 61 and 62 from different pressure points in the stage, bleed 60 being at the lowest bleed pressure and bleed 62 being at the highest bleed pressure. Bleed 60 heats the steam-heated air heater 40, divides in a distributor 63 into two streams of desuperheated or substantially desuperheated steam one of which heats the feed-water heater 11 and the other of which heats the steam-heated air heater 32. Condensate from heaters 11 and 32 is extracted by drains 11A and 32A respectively and fed to the condenser 7. Bleed 61 heats the steam-heated air heater 42, divides in a distributor 64 into two streams of desuperheated steam one of which heats the feed-water heater 12 and the other of which heats the steam-heated air heater 34. Condensate from heaters 12 and 34 is extracted by drains 12A and 34A respectively and fed to the heating steam/water space of feed-water heater 11. Bleed 62 heats the steam-heated air heater 44, divides in a distributor 65 into two streams one of which heats the feed-water heater 13 and the other of which heats the steam-heated air heater 36. Condensate from heaters 13 and 36 is extracted by drains 13A and 36A respectively and fed to the heating steam/water space of the feed-water heater 12.

The heated air passing through the conduits 30, 41, 43, 45 and 38 can, if desired, be mixed in a common windbox before or at the combustion apparatus.

During operation of the steam turbine power plant and steam generating unit described above hot gases produced in the furnace chamber of the steam generating unit flow along the path indicated by the line B—B in the direction indicated by the arrowhead. Steam generated in that unit is superheated in the superheater 1, is partly expanded in the steam turbine high pressure stage 5, is reheated in the reheater 2, is further expanded in the turbine low pressure stage 6, and is condensed in the condenser 7. Steam bleed 60 heats air heaters 40 and 32 and feed-water heater 11. Steam bleed 61 heats air heaters 42 and 34 and feed-water heater 12. Steam bleed 62 heats air heaters 44 and 36 and feed-water heater 13. Condensate from condenser 7 is fed through the feed-water heaters 11, 12 and 13 to the economiser 3 and thence to the steam generating parts of the unit (not shown). Air from forced draught fan 20 is heated in the gas heated air heater 4, the steam heated air heaters 32, 34 and 36 and in the superheated steam heated air heaters 40, 42 and 44 and this heated air is fed to the combustion apparatus of the unit.

The feed-water supplied to the inlet of economiser 3 is at a relatively low temperature due to the absence of feed-water heaters fed by steam from the high pressure stage 5 of the steam turbine and due to the fact that the heating steam fed to the feed-water heaters 11, 12 and 13 has given up its superheat in the air heaters 40, 42 and 44. As a result, the furnace gases approach the air heater 4 at a relatively low temperature. The quantity of

air supplied by the fan **20** is determined by the amount of air required for combustion, and the quantity of air which is to pass through the air heater **4** is determined by the reduced temperature of the furnace gases leaving the economiser **3**. Therefore, the distribution at distributor **21** of the air from the fan **20** between the conduits **22** and **31** is determined by the reduction in the temperature of the furnace gases consequent upon the relatively low temperature of the water at the inlet of economiser **3**.

Since it is no longer necessary to withdraw steam from the high pressure stage **5**, all the steam entering the turbine is usefully expanded in the whole of the high pressure stage **5** and thus for every pound of steam leaving the superheater **1** more useful energy is extracted by the turbine than in an arrangement utilising steam bleeds from the high pressure turbine. As a result of the reduction of the quantity of steam required to produce a given power output from the turbine, the area of the heat exchange surfaces of the super-heater **2** and reheater **3** can be reduced and yet calculation shows that no appreciable loss in efficiency is caused by the accompanying use of a lower feed-water temperature.

Further, since the superheated steam extracted through the bleeds **60**, **61** and **62** is utilised in the air heaters **40**, **42** and **44** to heat relatively hot air instead of relatively cold feed-water, this heat is transferred from one medium to another with a much smaller temperature drop, so reducing the degradation of heat involved in the heat transfer. At the same time all the combustion air is heated without overcooling of the furnace gases, and cold air is utilised in the last heat exchanger in the flow of furnace gases, yet all the combustion air is sufficiently heated,

Although the single forced draught fan can be replaced by two fans feeding respectively the conduits **22** and **31**, an economy is effected by the use of a single fan of such size as to be able to handle the maximum amount of combustion air required during operation of the unit. Further, although independent air circuits could be used for each pair of air heaters fed by the same steam bleed, for example, for the pair of air heaters **32** and **40**, and although air heated by desuperheated steam from one bleed could be used for desuperheating steam from another bleed, the arrangement shown has been found to be an economical, compact and efficient arrangement.

Referring now to FIGURE 2, many of the parts shown are equivalent to parts shown in FIGURE 1, and the same numerals have been used for equivalent parts. The dotted line B—B indicates the gas flow through the steam generating and superheating unit and the arrowhead on that line indicates the direction of gas flow. Disposed in that gas flow are a steam superheater **1**, a steam reheater **2**, an economiser **3** and a two stage air heater **4**, suitably of the rotary regenerative type. The steam turbine includes a high pressure stage **5** arranged to receive steam flowing from the superheater **1**, and to discharge partly expanded steam to the reheater **2** and a low pressure turbine stage **6** arranged to receive steam from the reheater **2**, and to discharge steam to a condenser **7**. An extraction pump **8** is arranged to extract condensate from the condenser **7** and to force it through series connected feed water heaters **11**, **12**, **13**, **14** and **15** of the closed type to a feed water pump **10** by which it is forced into the steam generating unit through the economiser **3**.

A forced draught fan **20** is arranged to supply air through a conduit **22** to a first stage **23** of the air heater **4**, which stage is provided with an intermediate tapping from which extends a conduit **24** the flow through which is controlled by a damper **25**, the outlet of the stage **23** being connected by a conduit **26** through a distributor **27** to the inlet of a second stage **28** of the air heater **4**, the outlet of that stage being connected through a distributor **29** to a conduit **30** leading to combustion apparatus of the furnace associated with the steam generating unit.

The conduit **24** is connected to a steam-heated air heater **36** the air outlet of which is connected through a steam-heated air heater **44** to a conduit **45** leading to the combustion apparatus mentioned above. The distributor **27** is connected by a conduit **39** to a steam-heated air heater **40** the air outlet of which is connected through a further steam-heated air heater **50** to a conduit **51** leading to the combustion apparatus. The distributor **29** is connected by a conduit **52** to a steam-heated air heater **42** the air outlet of which is connected to a further steam-heated air heater **53** the air outlet of which is connected to a conduit **54** leading to the combustion apparatus.

The turbine low pressure stage **6** is provided with three steam bleeds **60**, **61** and **62** from different pressure points in the stage, bleed **60** being at the lowest bleed pressure and bleed **62** being at the highest bleed pressure. Bleed **60** heats the steam-heated air heater **40**, and the desuperheated or substantially desuperheated steam heats the feed-water heater **11**, from which condensate is extracted by drain **11A** and is returned to the condenser **7**. Bleed **61** heats the steam-heated air heater **42**, and the desuperheated or substantially desuperheated steam heats the feed-water heater **12**, from which condensate is extracted by drain **12A** and is fed to the heating steam/water space of the feed-water heater **11**. Bleed **62** heats the steam-heated air heater **44**, divides in a distributor **65** into two streams one of which heats the feed water heater **13** and the other of which heats the steam-heated air heater **36**. Condensate from heaters **13** and **36** is extracted by drains **13A** and **36A** respectively and fed to the heating steam/water space of the feed-water heater **12**.

The turbine high pressure stage **5** is provided with two steam bleeds **70** and **71** from different pressure points in the stage, bleed **70** being at the lower bleed pressure. Bleed **70** heats the steam-heated air heater **50** and the desuperheated or substantially desuperheated steam heats the feed-water heater **14**, from which condensate is extracted by drain **14A** and is fed to the heating steam/water space of the feed-water heater **13**. Bleed **71** heats the steam-heated air heater **53** and the desuperheated or substantially desuperheated steam heats the feed-water heater **15**, from which condensate is extracted by drain **15A** and is fed to the heating steam/water space of the feed-water heater **14**.

The heated air passing through the conduits **30**, **45**, **51** and **54** can, if desired, be mixed in a common windbox before or at the combustion apparatus.

During operation of the steam turbine power plant and steam generating unit described above, hot gases produced in the furnace chamber of the steam generating unit flow along the path shown by the line B—B in the direction indicated by the arrowhead. Steam generated in that unit is superheated in the superheater **1**, is partly expanded in the steam turbine high pressure stage **5**, reheated in the reheater **2**, further expanded in the turbine low pressure stage **6** and is condensed in the condenser **7**. Steam bleed **60** heats air heater **40** and feed-water heater **11**. Steam bleed **61** heats air heater **42** and feed-water heater **12**. Steam bleed **62** heats air heaters **44** and **36** and feed-water heater **13**. Steam bleed **70** heats air heater **50** and feed-water heater **14**. Steam bleed **71** heats air heater **53** and feed-water heater **15**. Condensate from condenser **7** is fed by pump **8** through the feed water heaters **11**, **12**, **13**, **14** and **15** to pump **10**, passing to the economiser **3** and thence to the steam generating parts of the unit (not shown). Air from forced draught fan **20** is heated in the gas heated air heater **4**, and parts of the air are further heated in the steam-heated air heater **36** and the superheated-steam heated air heater **44**, in the superheated-steam heated air heaters **40** and **50**, and in the superheated-

steam-heated air heaters **42** and **53** respectively, and this heated air is fed to the combustion apparatus of the unit.

The damper **25** and dampers in the distributors **27** and **29** are suitably controlled with the aid of the control devices usually associated with a turbine plant and steam generating plant in order that the division of the air flow between the various heaters shall be such as to maintain the overall efficiency of the plant as nearly as possible at a maximum value.

It has been found by calculation that by the utilisation of combustion air for the desuperheating of steam bled from the turbine, before that bled steam is utilised in feed water heaters, it is possible to obtain a gain in overall efficiency.

Although only one air heater **36** heated by desuperheated or substantially desuperheated bled steam is shown, if desired several such air heaters may be used, for example, one such air heater may be arranged in series with each air heater heated by superheated steam, such as the air heater **40** and, further, independent air flows could be utilised for each steam bleed. Furthermore, a single air flow may pass through more than two superheated steam-heated air heaters, for example, had a further bleed of steam been provided, a third air heater could be provided in series with heaters **42** and **53**. If the temperature of the flue gases renders it desirable, the conduit **24** may be connected directly to the pipe **22**, so reducing the flow of cold air into the gas heated air heater **4**.

I claim:

1. Steam turbine power plant including a steam turbine; a steam generating and superheating unit arranged to supply superheated steam to the steam turbine; first combustion air heating means; second combustion air heating means; means leading air through the first and second combustion air heating means in succession and supplying the air as combustion air to the steam generating and superheating unit; bleed means for bleeding steam from the turbine and supplying the bled steam to the second combustion air heating means to become at least largely desuperheated by heat exchange with air in the second combustion air heating means; feed water heating means; means for passing feed water through the feed water heating means and supplying it as motive fluid to the steam generating and superheating unit; and means for leading bled steam that has been at least largely desuperheated in the second air heating means through the feed water heating means to heat feed water passing through said feed water heating means.

2. Steam turbine power plant including a steam turbine; a steam generating and superheating unit arranged to supply superheated steam to the steam turbine; first combustion air heating means including a heat exchanger; second combustion air heating means; means leading air through the first and second combustion air heating means in succession and supplying the air as combustion air to the steam generating and superheating unit; bleed means for bleeding steam from the turbine and supplying the bled steam to the second combustion air heating means to become at least largely desuperheated by heat exchange with air in the second combustion air heating means; feed water heating means; means for passing feed water through the feed water heating means and supplying it as motive fluid to the steam generating and superheating unit; means for leading bled steam that has been at least largely desuperheated in the second air heating means through the feed water heating means to heat feed water passing through said feed water heating means; and means for supplying bled steam that has been at least largely desuperheated in the second combustion air heating means through the heat exchanger of the first combustion air heating means as a heating fluid.

3. Steam turbine power plant including a steam turbine; a steam generating and superheating unit arranged

to supply superheated steam to the steam turbine; first combustion air heating means; second combustion air heating means; third combustion air heating means; means leading air successively through the first, second and third combustion air heating means in succession and supplying the air as combustion air to the steam generating and superheating unit; bleed means for bleeding steam from the turbine and supplying the bled steam to the second combustion air heating means to become at least largely desuperheated by heat exchange with air in the second combustion air heating means; bleed means for bleeding steam from the turbine at a pressure higher than the pressure at which steam is bled from the turbine and supplied to the second combustion air heating means and for supplying said steam bled at the higher pressure to the third combustion air heating means as a heating fluid; feed water heating means; means for passing feed water through the feed water heating means and supplying it as motive fluid to the steam generating and superheating unit; and means for leading bled steam that has been at least largely desuperheated in the second air heating means through the feed water heating means to heat feed water passing through said feed water heating means.

4. Steam turbine power plant including a steam turbine; a steam generating and superheating unit in which heat is generated by burning fuel in combustion air with the production of flue gases and arranged to supply superheated steam to the steam turbine; first combustion air heating means including a heat exchanger; means for supplying flue gases to said heat exchanger as a heating fluid; second combustion air heating means; means leading air through the first and second combustion air heating means in succession and supplying the air as combustion air to the steam generating and superheating unit; bleed means for bleeding steam from the turbine and supplying the bled steam to the second combustion air heating means to become at least largely desuperheated by heat exchange with air in the second combustion air heating means; feed water heating means; means for passing feed water through the feed water heating means and supplying it as motive fluid to the steam generating and superheating unit; and means for leading bled steam that has been at least largely desuperheated in the second air heating means through the feed water heating means to heat feed water passing through said feed water heating means.

5. Steam turbine power plant as claimed in claim 4, in which said heat exchanger includes a first stage and a second stage through which air passes in succession; and control means is provided between the stages for supplying a variable portion of the air that has been heated in the first stage to the second stage and for supplying the remainder to the second combustion air heating means.

6. Steam turbine power plant; including a steam generating and superheating unit arranged to supply superheated steam to the steam turbine; first combustion air heating means; a plurality of second combustion air heaters; bleed means for bleeding steam from the turbine at different pressures and supplying the bled steam to the second combustion air heaters so that each heater is supplied with steam at a different pressure; means for leading combustion air through the first combustion air heating means and then through the second combustion air heaters so that the steam supplied to the second combustion air heaters becomes at least largely desuperheated by heat exchange with the air in the second combustion air heaters; feed water heating means including a plurality of water heat exchangers, there being as many water heat exchangers as there are second combustion air heaters; means for leading bled steam that has been at least largely desuperheated in any one of the second combustion air heaters through one of the water heat exchangers as a heating fluid; means for passing feed water through the

water heat exchangers in such a succession that of any two water heat exchangers through which the feed water passes, the pressure of the bled steam by which the water heat exchanger through which the feed water passes first is heated is less than the pressure of the bled steam by which the water heat exchanger through which the feed water passes next is heated; and means for supplying feed water from the water heat exchangers as motive fluid to the steam generating and superheating unit.

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