July 13, 1937. F. H. ROSENCRANTS 2,086,781

POWER PLANT

Filed June 2, 1933 3 Sheets-Sheet 1

Fig. 1.

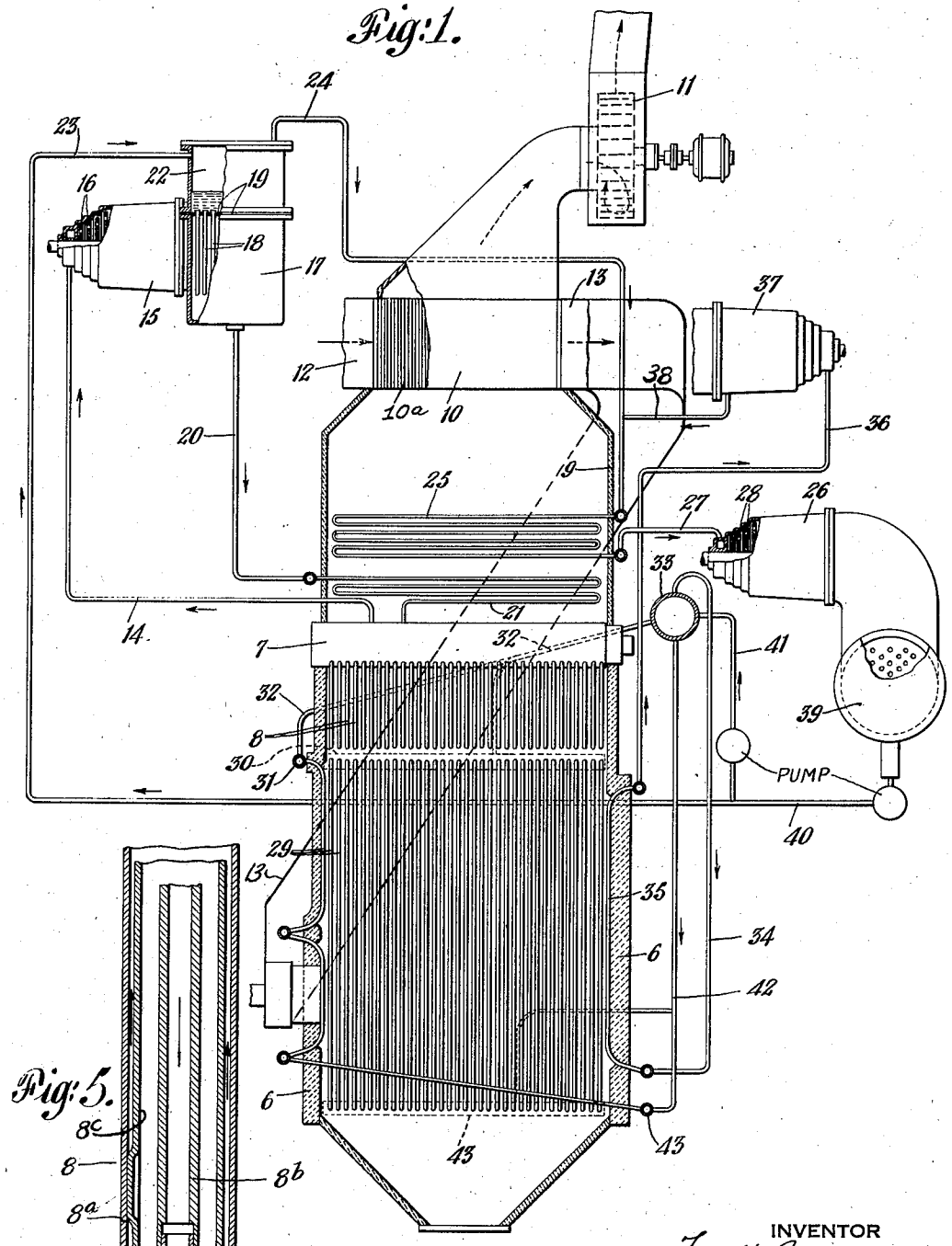


Fig. 5.

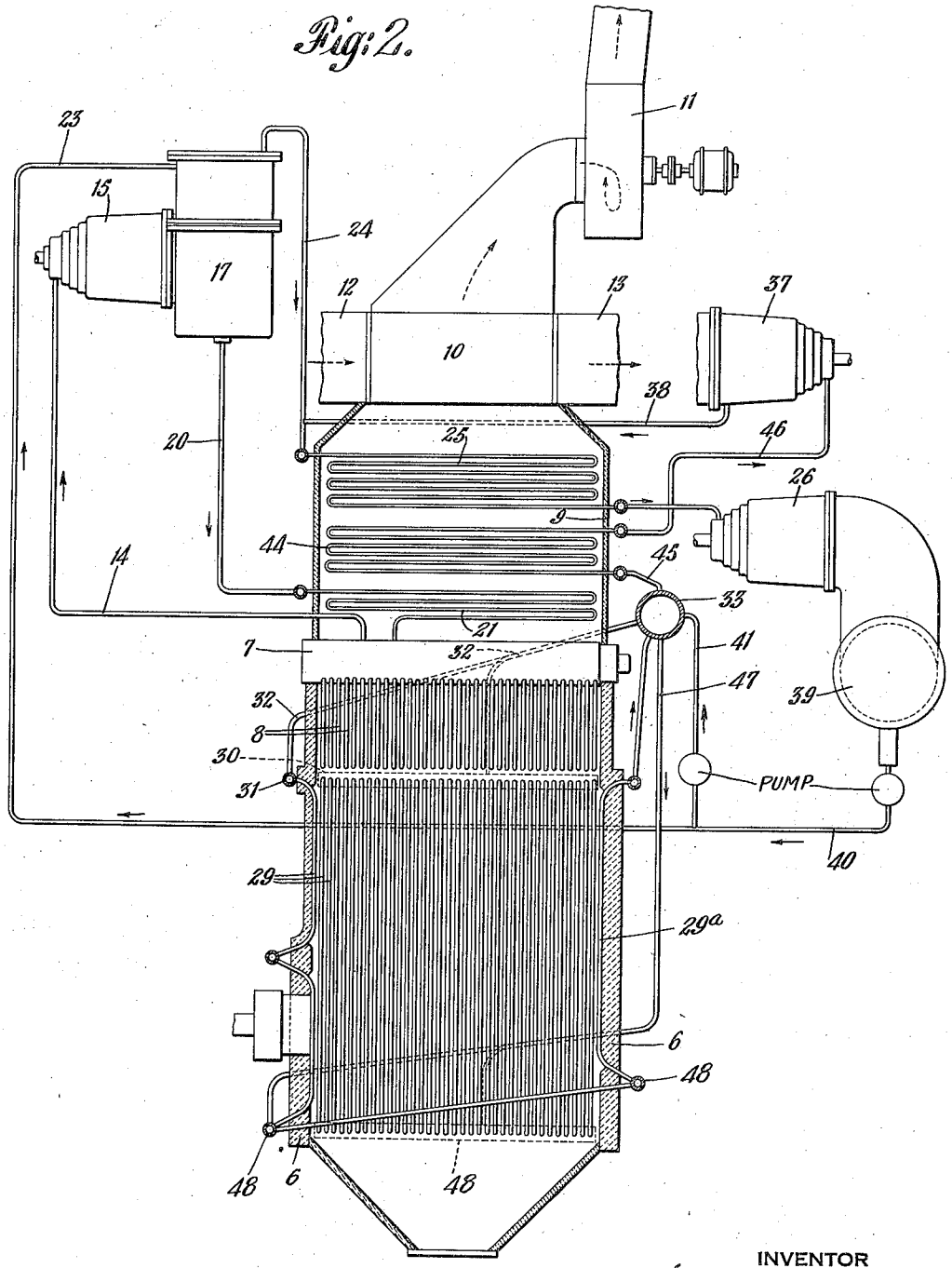
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Filed June 2, 1933 3 Sheets-Sheet 2

Fig. 2.



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POWER PLANT

Filed June 2, 1933 3 Sheets-Sheet 3

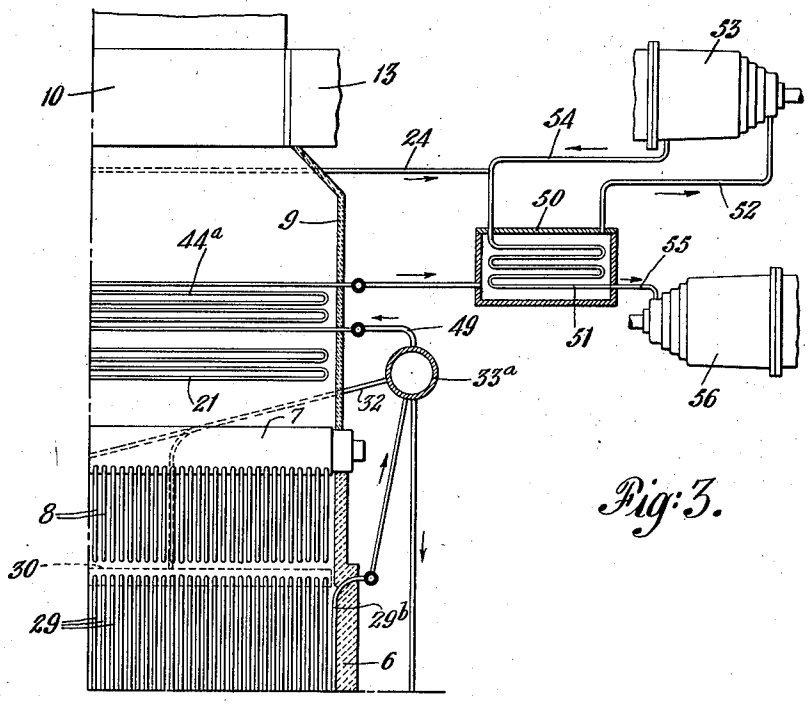


Fig. 3.

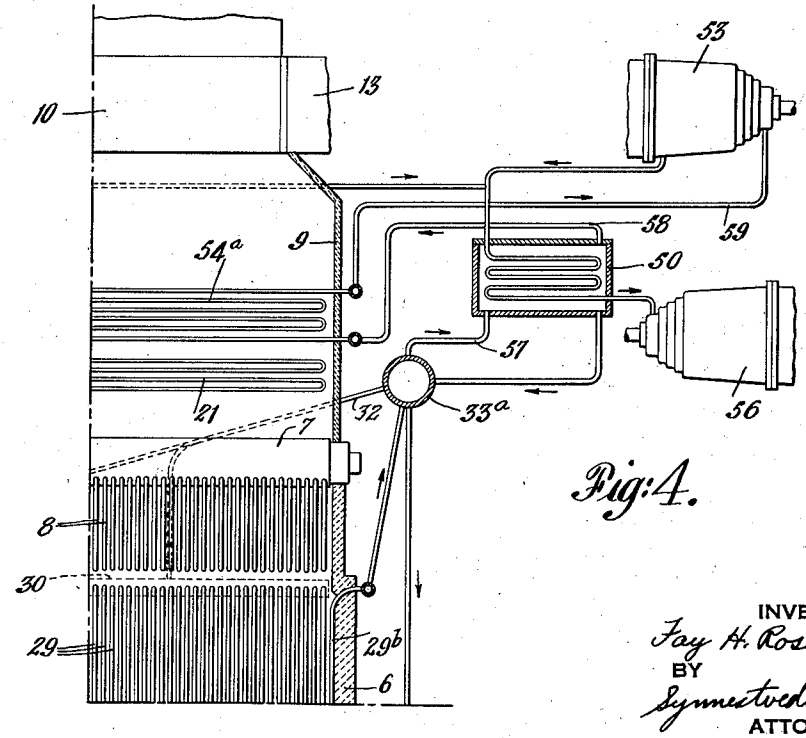


Fig. 4.

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UNITED STATES PATENT OFFICE

2,086,781

POWER PLANT

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Application June 2, 1933, Serial No. 673,953

3 Claims. (Cl. 60—38)

This invention relates to power plants, especially to that type of plant which involves a binary-vapor cycle. Still further, and as will appear more fully hereinafter, the invention is particularly advantageous in connection with the so-called mercury-steam cycle.

The purposes, objects and advantages of the invention will appear to better advantage after a consideration of the following comments regarding power plants of this general type which have been employed or contemplated heretofore.

It is known that materially increased efficiencies are obtainable by the use of the mercury steam cycle as compared with power plants operating on the straight steam cycle. However, heretofore practical difficulties have been encountered in the operation of mercury boilers especially when equipped with refractory furnaces, which may be analyzed as follows:

In view of the extremely high temperature of the mercury within the boiler under operating conditions the temperature of the offtake gases is correspondingly high. To overcome the resultant excessive heat loss it is necessary to employ an air preheater as well as other auxiliaries beyond the mercury boiler with respect to the flow of the gases so as to reduce the offtake temperature. The highly preheated air is, of course, used in the furnace for combustion purposes. The furnace temperature resulting from the use of highly preheated air has been proved in practice to result in a prohibitive amount of furnace maintenance when such furnace is of refractory construction.

More recent installations employ a furnace completely or substantially completely lined with water tubes the steam from which is used separately as in a turbine. In accordance with this practice, after use of the mercury vapor, as in a mercury turbine, the vapor is condensed in the mercury-steam condenser-boiler in order to transfer the heat of the vapor to steam at relatively low pressure. This steam is combined with the steam produced in the water walls of the furnace and employed in a steam turbine, usually after being superheated.

The net overall efficiency of a power plant of the type just above outlined is substantially lower than one employing a furnace uncooled by water tubes. The principal reason why is accounted for by the relatively very large amount of heat absorbed by such tubes, which is utilized at an efficiency no better than that obtained in a normal steam plant operating at the same pressure. In such a plant only that portion of the heat which is absorbed by the mercury boiler itself is utilized at an efficiency higher than that secured in a plant operating on a normal steam cycle.

In addition to the above proposal to line the furnace with water tubes the steam from which is combined with the steam produced in the mercury-steam condenser-boiler, it has heretofore been suggested to line the combustion chamber for a mercury boiler with mercury tubes, but this proposal is also open to a number of serious difficulties which need not be discussed herein.

With the foregoing in mind, the present invention, in its broad aspect, has in view as its primary object the arrangement of a power plant of the general type hereinbefore referred to in such manner as to increase the efficiency thereof to a point which justifies the additional complication.

More specifically, this invention contemplates a power plant arrangement having a mercury boiler and a mercury-steam/condenser-boiler in which fluid containing walls producing relatively high pressure are employed in the combustion chamber. Still more specifically, the necessary increase in efficiency is obtained in accordance with the present invention by so relating the pressures and temperatures carried in the several elements of the plant that the heat absorbed in the tubular walls of the combustion chamber may be utilized in two stages. For example, high pressure steam may be produced in the wall tubes and delivered to a high pressure turbine, and thereafter combined with the steam produced in the mercury-steam/condenser-boiler to operate a low pressure turbine or the like.

The manner in which the foregoing objects and advantages are accomplished, and also additional objects and advantages, will appear to better advantage after a consideration of the following description of the accompanying drawings, in which—

Figure 1 is a vertical sectional view of a furnace constructed in accordance with the present invention, the view also including a showing of the associated steam and vapor utilizing engines or the like, together with the connections between the several parts of the entire installation;

Figure 2 is a view similar to Figure 1 but illustrating a slightly modified layout;

Figure 3 is a fragmentary view similar to the showing of Figures 1 and 2 but illustrating a modification in the manner of use of the heat absorbed in the tubes in the combustion chamber;

Figure 4 is a view similar to Figure 3 but illustrating still another modification; and

Figure 5 is a fragmentary sectional view of a mercury tube illustrating the general construction thereof.

In referring to the drawings, reference is first made to Figure 1 in which the outside refractories or wall of the furnace are designated by the numeral 6. The mercury boiler is preferably positioned at the top of the combustion chamber and may include a drum-like structure 7 and a plurality of depending tube elements 8 adapted to be contacted by the gases in the flow thereof upwardly from the combustion chamber through the off-take 9. The structure of the tubes 8 may suitably be substantially as indicated in Figure 5, which shows a tube, in longitudinal section, as including an outer tube 8*a* and inner tubes 8*b* and 8*c*. The mercury descends from the drum 7 through the central tube 8*b* and thereafter returns to the drum through the annular cavity provided between tubes 8*a* and 8*c* so as to absorb heat and produce the vapor. The annular space between tubes 8*b* and 8*c* is sealed from access to mercury.

At the top of the off-take 9 I have shown an air preheater 10, having heat transfer elements 10*a* the specific construction of which need not be considered in detail herein. After passing through the heater 10 the gases are withdrawn to be discharged through a stack or the like as by means of fan 11. The heater 10 has an air inlet 12 and a discharge pipe 13 which, of course, is extended to the combustion chamber to supply preheated air thereto. This may be done by connection of pipe 13 with the fuel delivery device as shown in Figure 1.

The vapor liberated in the drum 7 may be conducted through the pipe 14 to the mercury turbine generally indicated at 15. The turbine 15, of course, may be of any desired construction such as one including blades 16 as shown in the portion of the turbine which is broken away in Figure 1. After use in the turbine 15, the mercury vapor is preferably directly passed into the mercury-steam/condenser-boiler generally indicated at 17 in which it flows around tubes 18 which, as shown, may have closed lower ends and therefore only one tube sheet 19 at the upper end thereof. The mercury, after condensation, may be conducted as by means of the connection 20 back to the drum 7. I prefer to employ a mercury preheater 21 located in the off-take just beyond the mercury boiler itself.

Referring now to some additional features of the mercury-steam/condenser-boiler, it is noted that at the upper ends of the tubes 18 a chamber 22 is provided, this chamber serving as a steam and water drum, the water inlet to which is shown at 23 and the steam off-take from which appears at 24. The pressure of this steam in an arrangement where the pressure of the mercury vapor at the exhaust side of the turbine 15 is approximately one pound absolute (with a corresponding temperature of about 458° F.) will be about 350 to 400 pounds absolute. This steam supply, as clearly seen in Figure 1, is conducted through the pipe 24 to a low pressure superheater 25, after which it is passed to a low pressure turbine 26 through a connection 27. The specific construction of the turbine 26 is not of importance herein, although it may include blades or buckets 28 of substantially the usual arrangement.

Turning now to the heat absorbing tubes employed to line the walls of the combustion space, in the first place these tubes, as indicated at 29, substantially completely define the walls of the combustion space proper. The upper headers 30 and 31 for the wall tubes are provided with connections 32 extended to the drum 33. The steam may be carried away from the drum through a connection 34 and passed through a high pressure superheater 35 which, in accordance with the showing of Figure 1, serves to define at least a portion of one wall of the combustion space. After passing through the superheater 35 the high pressure steam is conducted through pipe 36 to the high pressure turbine 37, the construction of which may be essentially similar to that suggested in connection with the low pressure turbine 26. Upon discharge of the steam from the turbine 37 it is carried through connection 38 to join the steam withdrawn from the mercury-steam/condenser-boiler through pipe 24. The point of juncture is preferably in advance of the low pressure superheater 25, and at this point it is to be observed that I contemplate an arrangement wherein the exhaust pressure of the steam leaving turbine 37 approximates the pressure of the steam produced in the mercury-steam/condenser-boiler. In view of this, it will at once be apparent that the tubular elements defining the combustion chamber carry very high pressure. This may be in the neighborhood of from 600 to 2000 pounds.

After use of the steam delivered from the low pressure superheater 25 (in turbine 26) this steam may be condensed in condenser 39 and the water returned to the high pressure steam boiler unit as through connections 40 and 41 and also to the steam and water space of the mercury-steam/condenser-boiler through connections 40 and 23. It might also be mentioned that as shown in Figure 1, downcomers such as that indicated at 42 may extend from the high pressure drum 33 downwardly to the headers 43 at the lower ends of tubes 29.

Turning now to the showing of Figure 2, it will at once be apparent that numerous features of this modified arrangement are entirely similar to those already described. The following discussion of Figure 2 will therefore be limited to the features of distinction which are briefly as follows:—

In the first place, in Figure 2, the high pressure superheater has been interposed between the mercury preheater 21 and the low pressure superheater 25. This high pressure superheater, which is indicated by the numeral 44, is again fed from the drum 33 of the high pressure boiler unit as by means of connection 45, and connection 46 serves to conduct the high pressure superheated steam to the high pressure turbine 37. As before, the exhaust from the high pressure turbine 37 passes through the pipe 38 and joins the low pressure steam supply in pipe 24 prior to entrance thereof into the low pressure superheater 25.

As shown in Figure 2, there are also some slight modifications in the arrangement of the downcomers 47 and bottom headers 48 in order to supply the tubes 29*a* in the rear wall of the furnace which, in this instance, replace the high pressure superheater 35 of Figure 1 and discharge into drum 33.

With regard to the showing of Figure 3, it is to be observed that in accordance with this layout the high pressure heat absorbing elements 29, 29*b* of the combustion chamber discharge into drum 33*a*. The high pressure steam is carried to

the high pressure superheater 44*a* through connection 49 and is thereafter utilized in a steam heater generally indicated at 50. This steam heater includes tubular elements 51 round which the high pressure steam passes to be conducted through connection 52 to the high pressure turbine 53 which, again, may be of the same construction as hereinbefore suggested. The exhaust from turbine 53 passes through connection 54 and joins the low pressure steam supply in pipe 24 to mingle therewith and pass through the tubular elements 51. Upon discharge of the steam from the elements 51 through connection 55, the steam is utilized in low pressure turbine 56. The exhaust from turbine 56 may be condensed in the manner hereinbefore referred to and the condensate returned to the drum 33*a* and also the mercury-steam/condenser-boiler.

The arrangement of Figure 4 resembles that of Figure 3 as to the general layout thereof, although it is to be observed that the connections 57, 58 and 59 provide for the flow of the high pressure steam through the heater 50 prior to the time it is superheated in the high pressure superheater 54*a*.

Various features of the foregoing several embodiments of the present invention are disclosed herein with a view to illustrating the manner in which variations may be made, for example, in order to compensate for differences in pressure and temperature which may be employed in the high pressure boiler unit of the combustion space and to bring the temperature and pressure of the high pressure steam down to points approximating the temperature and pressure of the steam produced in the mercury-steam/condenser-boiler. However, it is to be observed that in all instances the arrangement is such that relatively very high pressure and temperature is carried in the fluid tubes which line the combustion space. This feature is of very great importance for reasons more or less briefly referred to hereinbefore. More specifically, by employing pressure in the tubular elements defining the combustion space which is sufficiently high to permit of the use of the high pressure steam produced (as in a turbine) prior to the time this steam joins the steam produced in the mercury-steam/condenser-boiler, the overall efficiency of the installation is increased to a point which amply justifies the additional complication involved in employing the mercury cycle, and this, in turn, makes it practicable and economical to employ a mercury-steam cycle.

Obviously, if desired, some other fluids may be employed in place of the mercury and water hereinbefore referred to. By way of example, diphenoloxide or the like may be circulated in the tubes which line the combustion chamber either in whole or in part. As a further example, attention is again directed to Figure 1 which includes a showing of a high temperature superheater, at one wall of the combustion space. If desired, steam only may be circulated in all of the tubes defining the combustion space. These ramifications, of course, are well within the scope and broad aspect of the invention since one of the most important features contemplated is the use, in a binary-vapor system, of relatively high pressure tubes defining the combustion chamber so as to avoid excessive heat absorption from the fuel and flame stream prior to the time the mercury boiler or its equivalent is reached.

This application is in part a continuation of my prior application, Serial No. 539,473, filed May 23rd, 1931, now abandoned.

I claim:—

1. Equipment of the character described including, in combination with a boiler and furnace installation having a combustion chamber; two heat absorption systems associated with said installation; one of said systems comprising a mercury-steam cycle having a mercury boiler associated with the installation adjacent the off-take of the combustion chamber, having a mercury turbine receiving mercury vapor from the boiler, having means for producing steam by condensation of mercury vapor received thereby from the turbine; and the other of said systems including fluid containing heat absorption tubes at the walls of the combustion chamber and having first stage means for utilizing the heat of said fluid delivered thereto from the tubes; the boiler of said first system and the tubes of said second system both being constructed and arranged to operate at high temperature; and means for utilizing the heat of said fluid in a second stage and for utilizing the heat of the steam produced in the mercury-steam cycle.

2. Power plant equipment including a boiler and furnace installation having a combustion chamber, a mercury boiler adjacent the off-take from the combustion chamber, a mercury turbine receiving mercury vapor from the boiler, a condenser-boiler receiving exhaust mercury vapor from the turbine, means for utilizing steam produced in the condenser-boiler, fluid containing tubes at the walls of the combustion chamber and constituting the heat absorption elements of a high pressure steam generator, a steam heater for heating the steam produced in the condenser-boiler, said heater receiving high pressure steam from said tubes, whereby said high pressure steam serves as a heating medium for the steam produced in the condenser-boiler, and means receiving the high pressure steam from said heater and for further utilizing it.

3. Power plant equipment including a boiler and furnace installation having a combustion chamber, a mercury boiler adjacent the off-take from the combustion chamber, a mercury turbine receiving mercury vapor from the boiler, a condenser-boiler receiving exhaust mercury vapor from the turbine, the condenser-boiler producing steam, fluid containing tubes at the walls of the combustion chamber and constituting the heat absorption elements of a high pressure steam generator, a steam heater for heating the steam produced in the condenser-boiler, said heater receiving high pressure steam from said tubes, whereby said high pressure steam serves as a heating medium for the steam produced in the condenser-boiler, and multi-stage means for utilizing the steam produced by said generator, said multi-stage means receiving the steam from said heater and a succeeding means of said multi-stage means receiving exhaust from the first and also receiving the steam heated by said steam heater.

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