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HEAT CYCLE

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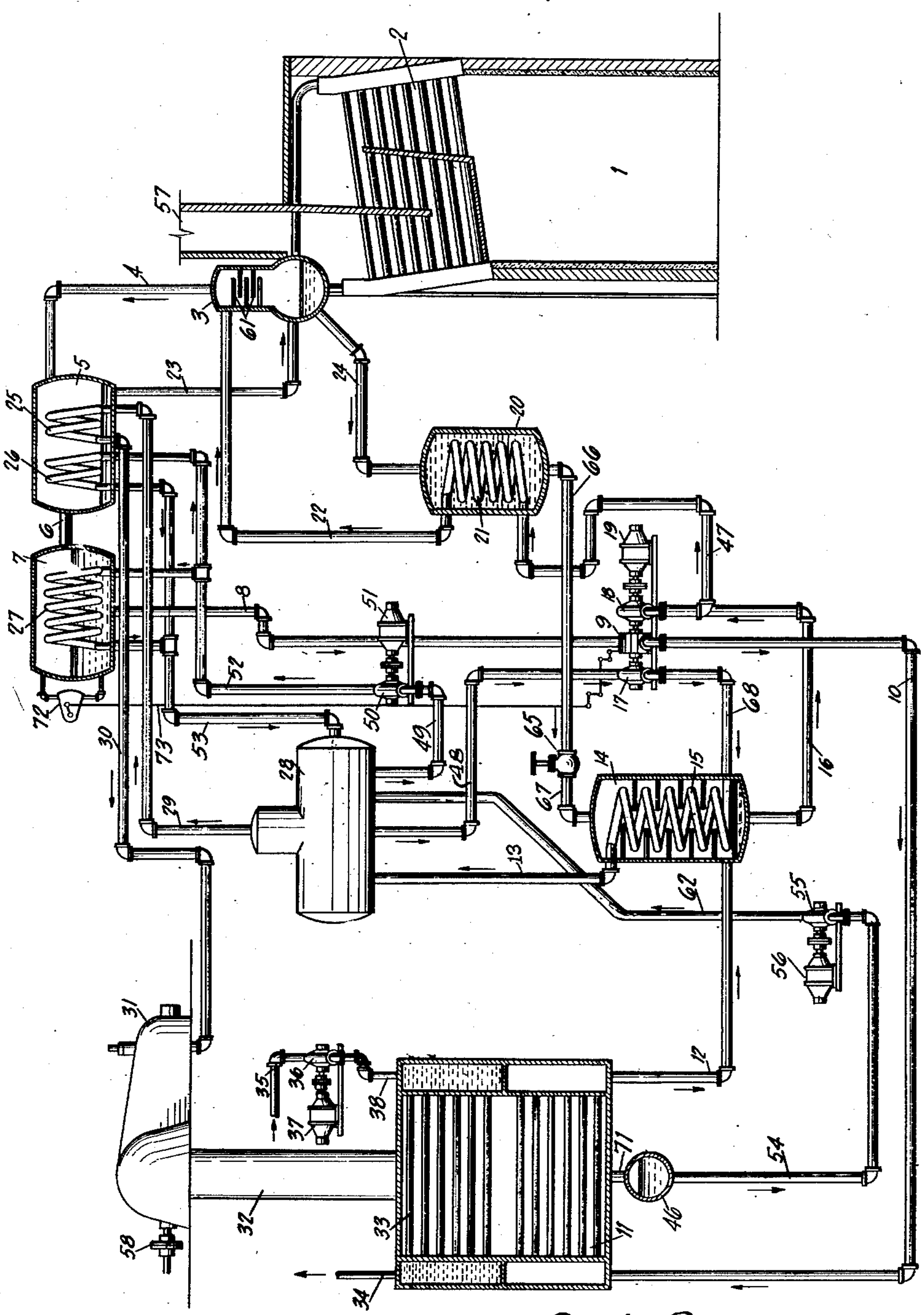

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HEAT CYCLE

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This invention pertains to improvements in methods of making low temperature heat available for high temperature work and more particularly to heat cycles involved in the production of work from an elastic fluid and still more particularly to steam power plants.

The object of this invention is to improve the efficiency of power plants and such heat cycles, the improvement being obtained by conserving more or less of the heat which is now customarily rejected to condenser cooling water. Another object is to reduce the amount of condenser cooling water required.

The drawing is schematic only and illustrates my invention as incorporated in an elastic fluid power plant.

Referring to the drawing: 1 is a furnace or other source of heat for boiler 2 which contains binary fluid, 3 is an analyzer, 4 a conduit, 5 a high pressure condensing rectifier, 6 a conduit, 7 a high pressure vapor condenser, 8 a conduit, 9 a fluid turbine, 10 a conduit, 11 a condenser evaporator, 12 and 13 conduits, 14 a vapor absorber, 15 a heat absorbing coil, 16 a conduit, 17 and 18 are pumps, 19 a pump motor, 20 a heat exchanger, 21 an exchanger coil, 22, 23 and 24 are conduits, 25, 26 and 27 pipe coils, 28 a steam generator, 29 and 30 conduits, 31 a prime mover, 32 an exhaust connection, 33 a water cooled condenser, 34 and 35 conduits, 36 a circulating pump, 37 a motor for the pump, 38 a conduit, 46 a hot well, 47, 48 and 49 conduits, 50 a pump, 51 a pump motor, 52, 53 and 54 conduits, 55 a pump, 56 a pump motor, 57 a gas flue, 58 connection to power consuming device, 61 trays in analyzer, 62 a conduit, 65 a valve, 66, 67 and 68 are conduits, 71 a conduit, 72 a float in a chamber and 73 a means of transmitting motion from the float to the governor on turbine 9.

The boiler 2 is not necessarily heated by products of combustion but the fluid therein may be heated by any convenient and suitable source of heat brought into heat transfer relation therewith by any known means.

The condenser evaporator 11 and condenser 33, the feed water heaters 41 and 42, the absorber 14, the heat exchanger 20, the analyzer 3, the steam generator 28, the rectifier 5 and the vapor condenser 7 are all of the conventional type of similar equipment used in either steam or refrigerating plants. The pumps, motors and liquid turbines are all conventional equipment and involve nothing new in the way of construction or principle of operation. Their operation and construction, including the necessary calculations as to size, etc., are well understood in the steam power and refrigerating arts.

In the interest of simplicity, the prime mover 31 will be herein considered as a steam turbine exhausting into condenser 33 and condenser evaporator 11, the turbine delivering its power through coupling 58. The steam for the turbine is generated in coils 15, 26 and 27, separated from the water in generator 28 and superheated in coil 25. The boiler 2 is used for the vaporization of the light liquid of a binary fluid as later explained.

Steam from the generator 28 passes through conduit 29 and through coil 25, where it is superheated, through conduit 30 to turbine 31, which it leaves through the exhaust connection 32 entering condenser 33 and condenser evaporator 11. A portion of the heat from the exhaust steam may be extracted therefrom by condenser 33 through which water from an outside source is circulated. The water enters via conduit 35, is pumped by pump 36 to conduit 38 and thence through the condenser leaving by conduit 34.

In the conventional steam plant, all the heat remaining in the steam, after it has passed the last stage of the turbine, except the heat of liquid in the condensate, is absorbed by the condenser circulating water and carried away thereby and even in the best designed plants the heat thus carried away and wasted is of the order of two or three times the amount of heat which is converted into work by the turbine. In the system herein described, only a portion of the heat is carried away by the condensing water, the rest of the heat passing into condenser evaporator 11 from which it is reclaimed for further use in the turbine.

While it would be feasible to reclaim, by my process, all the heat ordinarily rejected to the condenser water in a straight condensing plant, there is nothing to be gained thereby since there is no place to use it inasmuch as, in addition to the heat regained in absorber 14, there must be added the heat required for distillation in boiler 2 and the sum of these two heats is much greater than that which the turbine can convert into work. If we attempt to use the excess heat in an additional turbine, we are simply doing the equivalent of increasing the size of turbine 31 which does not help matters any. By regulating the speed of motor 37 or by other suitable means, the amount of water circulating through condenser 33, and therefore the amount of heat which will be extracted from the steam by condenser 33, may be controlled within proper limits so that there will be neither an excess or a deficiency of reclamation, thus keeping the necessary size of the reclaiming apparatus at a minimum.

The terms used herein are to be understood to have the following meanings.

Binary fluid.—An absorptive, thermal-binary fluid consisting of two liquids in certain normal proportions, one of which has a lower boiling point, at any pressure, than the other and the latter liquid having the property of absorbing, under certain conditions, vapor of the former liquid.

Light liquid.—That liquid of a binary fluid which has the lower boiling point.

Heavy liquid.—That liquid of a binary fluid which has the higher boiling point.

Either or both liquids may consist of a solution of two or more substances.

The general principles of absorption refrigeration may be found in such standard reference works as Kent's and Mark's handbooks of mechanical engineering and in "Refrigeration" by Moyer and Fittz, 1928. Therein will be found a description of the operation of absorbers by means of which heat is extracted from one substance at one temperature and transferred to another substance at a higher temperature, as well as drawings and descriptions of the operation of rectifiers, analyzers, heat exchangers, binary fluid boilers etc., as applied to absorption refrigeration systems.

The heat from the exhaust steam entering condenser evaporator 11 is reclaimed in the following manner. Boiler 2 initially contains a binary fluid. It is not material, for this particular system, whether the binary fluid be a true chemical combination or merely a suitable soluble mixture of the light and heavy liquids.

Those skilled in this art will understand that the details of the apparatus and the binary fluid used will vary according to the particular requirements attending the use of which the system is to be put, but for the purposes of illustration I shall refer to an apparatus shown in the accompanying drawing and describe the same with reference to the use of the following binary fluid. A heavy liquid consisting of substantially 20% diphenyl ($C_6H_5.C_6H_5$), 40% diphenyl oxide ($C_6H_4.C_6H_4.O$) and 20% diphenyl oxide oil, medium fraction (chemical symbol undetermined at this time), to which is added a light liquid consisting of benzene (C_6H_6), sometimes called benzol, to the extent of about 2.5% of the total mixture by weight. This is the composition of the binary fluid as it leaves the absorber. The effect of any variation in the percentage is shown by Fig. 2.

The pressures and temperatures which will be developed in the various parts of the system will be as follows, no allowance being made for friction or radiation losses. The location numbers are the reference characters of Fig. 1.

Sufficient heat being applied to boiler 2, a vapor is formed by the evaporation of light liquid, which will be distilled off and pass in vapor form through analyzer 3 and conduit 4 to the high pressure condensing rectifier 5, leaving nearly pure heavy liquid in the boiler. This vapor at times will carry some entrained particles of the heavy liquid. The vapor given off by boiler 2, in practically all cases, will be superheated, this being a characteristic of the distillation of binary fluids. The temperature of this vapor is lowered in rectifier 5, due to heat absorption by coils 25 and 26, the function of which will be explained later, to a point where any strained portion of the heavy liquid which may have been carried over will be condensed and will return to the boiler by gravity through conduit 23. The temperature of the vapor in rectifier 5 is reduced nearly to the saturation point after which it passes through conduit 6 to the high pressure vapor condenser 7 where it gives up its latent heat to coil 27 and is condensed to a liquid.

The condensed liquid in condenser 7 passes through conduit 8 to the liquid motor 9, where it performs work on pumps 17 and 18 and where its pressure is reduced (to an extent later explained), and thence through conduit 10 to the condenser evaporator 11 where it absorbs heat from the turbine exhaust and by which heat it is partially or wholly vaporized. The vaporized mixture flows through conduit 12 to absorber 14. The reduction of temperature by turbine 9 is very slight and since the temperature must drop to 79 degrees, since its pressure is now only 1.93 lbs. absolute, about 6.5% of the liquid in conduit 10 will be evaporated in producing this drop in temperature.

Turning to boiler 2; some of that portion of the binary fluid, which is now nearly pure heavy liquid, due to the evaporation of light liquid from the boiler, flows through conduit 24 to heat exchanger 20, where its temperature is greatly reduced, thence through conduit 66, regulating expansion valve 65 and conduit 67 to absorber 14. The valve 65 reduces the pressure of the liquid to that of the beforementioned vapor entering the absorber through conduit 12.

From generator 28 water flows through conduit 48, the pump 17, the heat exchanger coil 15 in absorber 14 where it is partially converted into steam, thence through conduit 13 back to the generator 28.

In absorber 14, the pressure of the vapor and heavy liquid being equal, the liquid is cooled and the vapor is superheated until their temperatures become equal, after which the vapor is absorbed by the liquid, in which process it gives up heat, known in the art as "heat of absorption", to coil 15, which heat is conveyed back to the generator by the circulation of water through the coil as previously described.

Location	Pressure in lbs. abs.	Temp. in degrees F.	Location	Pressure in lbs. abs.	Temp. in degrees F.
2, 3, 4 and entering 5	54.6 622		30	37.5	600
Leaving 5, 7, 8	54.6 266		32	.575 (28.8"HG)	84
10 and 12	1.93 (26"HG)	79	47	54.6	266
13	37.5	263	62	37.5	84
14, 15 and 16	1.93	266	63	54.6	86
22	54.6	620	64	37.5	263
24	54.6	622	66	54.6	267
25, entering	37.5	263	67	1.93	266
25, leaving	37.5	600	68	37.5	263
26, 27, 28, 29	37.5	263	74	1.93	79

The heavy liquid and light liquid vapor in absorber 14, having now combined and formed binary fluid, is conducted by conduit 16, pump 18 and conduit 47 through coil 21 of the heat exchanger 20, where it absorbs heat from the heavy liquid as previously mentioned, cooling the heavy liquid and increasing its own temperature, and thence through conduit 22 to analyzer 3.

In analyzer 3 the binary fluid passes down over the trays 61 and in so doing comes into intimate contact with the superheated vapor passing from boiler 2 into conduit 4. This intimate contact between the fluid and vapor condenses a portion of any entrained particles of heavy liquid contained in the outgoing vapor, causing the same to drop back into the boiler, while at the same time it tends to desuperheat the outgoing vapor of the light liquid and to evaporate a portion of the light liquid in the incoming binary fluid.

Turning now to generator 28: The generator is partially filled with water, a portion of which is circulated through conduit 49, pump 50, conduit 52, coils 26 and 27 where it is partially vaporized, and conduit 53 back to the generator where the steam entrained in the partially vaporized water is released. This steam, together with the steam from coil 15, travels through conduit 29 to coil 25, where it is superheated and thence through conduit 30 to turbine 31 as previously explained. The condensate from hot well 46 passes through conduit 54, pump 55 and conduit 62 to generator 28.

The amount of heat given off in absorber 14 will be that amount of heat which the fluid in condenser evaporator 11 extracts from the exhaust steam when the fluid vaporizes, plus a small amount which will be added by surface radiation. This heat will be largely absorbed by the water in coil 15 and the remainder will pass back, as heat of liquid, through conduit 16 to boiler 2. In boiler 2 such additional heat is added as is required to produce sufficient re-evaporation to maintain the necessary steam pressure in generator 28, irrespective of the load on turbine 31.

Pump 18 will control the pressure in absorber 14 and in condenser evaporator 11 inasmuch as pump 18, being designed for a larger capacity than turbine 9 and regulating valve 65, will never permit the pressure to build up beyond the desirable point. The quantity through turbine 9 is controlled by a suitable admission valve responsive to the level of the condensate in condenser 7. The constant speed motor 19 furnishes any additional power required for the operation of pumps 17 and 18 and at the same time maintains the turbine and the pumps at constant and equal speeds. The supply of steam for the turbine may be maintained in accordance with the turbine demand by varying the amount of heat applied to boiler 2, which may be done automatically by any of the methods known to the art.

When the turbine requires additional steam the additional heat applied to boiler 2 causes an increase in the vapor through conduit 4 to condensers 5 and 7 where it furnishes additional heat to coil 25 for superheating the steam and additional heat to coils 26 and 27 which heat is transferred to the steam generator 28. The additional condensate in condenser 7 causes the float valve 72 to act on the governor of turbine 9 in such manner as to permit a greater flow of condensate therethrough thus increasing the liquid flowing through conduit 10 to condenser evaporator 11, which in turn allows condenser evaporator 11 to condense the increased amount of exhaust steam and the increased amount of vapor flowing through conduit 12 and absorbed in 14 creates additional heat which is transferred by coil 15 to boiler 28.

The vaporization point of the binary fluid appearing in the absorber after absorbing the gas therein, determines the maximum temperature permissible in the absorber and therefore the maximum temperature of coil 15 and therefore substantially the maximum temperature and pressure available in steam generator 28. The light liquid, when condensed in condenser 7, must be capable of giving up, by such condensation, a considerable quantity of heat (largely latent) since this coil must transfer to the turbine steam a large part of the heat supplied by boiler 2.

The pressure in the absorber depends upon the pressure in the evaporation chamber 74 of condenser evaporator 11, which pressure must be low enough to permit the pure light fluid entering from conduit 10 to vaporize at a temperature consistent with the proper condensation of the steam from the turbine. In cases where it is desired to extract steam for industrial purposes, at the exhaust pressure, this temperature may be comparatively high as the steam would then be condensed at the pressure required for industrial use but where a low vacuum is desired, this temperature should be in the neighborhood of 45° to 50° F. By the choice of a suitable binary fluid, the turbine exhaust pressure may be made high where steam is required for process use or it may be made low when it is to be condensed.

Where a process use requires a high pressure steam, a greater proportion of the heat in the turbine exhaust may be reclaimed in condenser evaporator 11 (and less rejected in condenser 33), the additional heat being projected back in added heat in generator 28 and this may, in some cases, be carried to an extent where the steam available out of generator 28, for process use, is substantially equal to that required by the turbine, condenser 33 being greatly reduced in size or omitted.

The excess heat, assuming full reclamation, can be economically used directly from generator 28 for process work or other heating purposes providing the pressure required for such purposes is substantially as high as that of the generator. When this is not the case, turbine 31 should be designed to supply bleeder steam at the pressure required for process or other work and the reclamation apparatus should be proportioned to make this extra steam in steam generator 28, and the steam used in turbine 31 down to the point required for process work. The economical capacity of the reclamation apparatus may be anything up to 100% reclamation.

If a binary fluid having a constituent of low boiling point is selected, boiler 2 may be indirectly heated as by a steam water boiler or by the exhaust of a high pressure steam turbine.

The liquid motor 9 serves to reduce to suitable pressure the liquid in conduit 10 while at the same time it performs useful work. A reducing valve might be substituted for motor 9 but in that case the work otherwise done by motor 9 would have to be reclaimed through the reclamation cycle and would therefore increase its size accordingly. The power consumed by pump 18 appears partly in the form of increased pressure in the system, and is later recovered when the pressure is reduced, and partly in the form of heat in the liquid in conduit 47. The reclamation cycle is substantially 100% efficient in the sense that substantially all of the heat extracted from condenser evaporator 11 is eventually returned to the turbine for further use.

The amount of heat released in absorber 14 and the amount of heat released in binary boiler 2 are respectively dependent upon the heat of absorption and the heat of vaporization of the binary fluid, one of these properties being the reverse of the other. The amounts of heat are approximately equal when the composition and pressure of the fluid is the same in each case. However, for the arrangement herein shown, the pressure in boiler 2 is higher than the pressure in absorber 14 and therefore the heat of vaporization will be less than the heat of absorption. The relation between the two amounts of heat is slightly affected also by the amount of heat carried over in superheat and heat of liquid in condenser 7 and absorber 14 but in general it may be said that by the foregoing process, the amount of heat which it is possible to reclaim and return to the turbine is approximately equal to one-half the sum of the heat rejected by the turbine, plus the heat converted to energy by the turbine, plus the radiation losses, or, in other words, equal to one-half the heat entering the turbine.

While I have shown and described one embodiment of my invention in accordance with the patent statutes, it will be understood that my invention is capable of embodiment in a variety of forms of apparatus and that I am not limited to the specific arrangement or structural parts shown and described, nor to the particular binary fluid specified, but that the scope of the invention is to be gauged by the accompanying claims taken in connection with the state of the prior art.

What I claim is:—

1. Equipment for transferring heat from the exhaust steam of a prime mover to a steam generator from which the prime mover receives its steam, said generator receiving heat from a binary fluid containing two constituent liquids the second of which has a higher boiling point than the first, which includes; a boiler for distilling the first constituent liquid from the second; a vapor condenser for condensing the vapor thus distilled, the condenser being arranged in heat exchange relation with the generator; means for conducting vapor from the boiler to the vapor condenser; a steam condenser evaporator receiving exhaust steam from the prime mover and condensate from the vapor condenser to be evaporated therein by the exhaust steam; a conduit for conveying the condensate from the vapor condenser to the steam condenser evaporator and means associated with said conduit for reducing the pressure of the condensate; an absorber for absorbing vapor formed in the condenser evaporator; means for conducting vapor from the condenser evaporator to the absorber; a conduit line for conducting second constituent liquid from the boiler to the absorber and means associated with the conduit for reducing the pressure of the liquid therein; means in the absorber for causing an intimate mixture of the second constituent liquid and the vapor of the first constituent liquid; means in the absorber for absorbing the heat of absorption produced by the absorption of the vapor by the liquid; means for conveying the absorbed heat from the absorber to the generator; and means for conveying the binary fluid, formed in the absorber, back to the boiler.

2. That combination which includes; a steam prime mover; a steam generator for supplying steam to the prime mover; a binary fluid boiler; a vapor condenser for condensing light liquid vapor and supplying heat for the prime mover steam; a condenser evaporator for condensing expanded steam from the prime mover and evaporating light liquid with heat from the expanded steam; and an absorber for absorbing the light liquid vapor and supplying heat for the prime mover steam; means for conducting vapor from the boiler to the vapor condenser; separate means, including a pressure reducing device, for conducting condensate from the vapor condenser to the condenser evaporator; means for conducting vapor from the condenser evaporator to the absorber; means, including a pump, for conducting condensate from the condenser evaporator to the steam generator; additional means, including a pressure reducing device, for conducting liquid from the boiler to the absorber; and means, including a pump, for conducting liquid from the absorber to the boiler.

3. In a power plant, means to expel vapor from a solution, means to derive power from the expelled vapor including a high pressure vapor condenser, a low pressure condenser connected to receive vapor from said power means and to receive condensate from the high pressure condenser, an absorber, means to conduct solution from the first mentioned means to the absorber, means to conduct gaseous fluid from the low pressure condenser to the absorber to be absorbed therein, means to conduct enriched absorption liquid from the absorber to the first mentioned means, and means independent of the first mentioned means for transferring heat rejected by the absorber into the power means.

4. That process which includes vaporizing, at the temperature of the expanded steam, light liquid of a binary fluid with heat from steam which has been expanded in a steam prime mover, absorbing the vapor into the heavy liquid of the binary fluid at a temperature in excess of that of the expanded steam thereby releasing its heat of vaporization, previously obtained from the expanded steam, at a temperature suitable for the generation of steam of a higher temperature and pressure than that of the expanded steam, and so utilizing said released heat for generating steam for the prime mover, heating the binary fluid sufficiently to distill off light liquid vapor, condensing the light liquid vapor to provide light liquid for vaporization by the expanded steam, applying the heat extracted from the distilled vapor to the making of steam for the prime mover and reducing the pressure of the condensed light liquid by converting the pressure into work.

5. In a power plant; means to expel vapor from a binary fluid, a steam turbine, a condenser connected to receive exhaust steam from the turbine and to evaporate the light liquid of the binary fluid, an absorber, means to conduct heavy liquid from the first mentioned means to the absorber, means to conduct light liquid evaporate from the condenser to the absorber, means to conduct binary fluid from the absorber to the first mentioned means, and means for transferring heat rejected by the absorber into the steam turbine, including a steam generator arranged in heat exchange relation with the absorber and arranged to condense the expelled vapor, and means for conducting the condensate of the expelled vapor to the condenser evaporator and means to conduct steam from the generator to the turbine.

6. A power plant which includes a steam prime mover; a steam generator supplying steam to the prime mover; a condenser evaporator receiving steam from the prime mover exhaust; an absorber for absorbing vapor from the condenser evaporator, the absorber being arranged in heat exchange relation with the steam generator; a boiler for re-evaporating the absorbed vapor; a high pressure vapor condenser for condensing the vapor evaporated, said condenser being arranged in heat exchange relation with the steam generator; means for conducting vapor from the boiler to the vapor condenser; separate means, including a pressure reducing device, for conducting condensate from the vapor condenser to the condenser evaporator; means for conducting vapor from the condenser evaporator to the absorber; means, including a pump, for conducting condensate from the condenser evaporator to the steam generator; additional means, including a pressure reducing device, for conducting liquid from the boiler to the absorber; and means, including a pump, for conducting liquid from the absorber to the boiler.

7. A power plant according to claim 6 characterized by the addition of a heat exchanger one element of which is included in the said additional means and the other element in the last mentioned means.

8. A power plant according to claim 6 characterized by the addition, to the last mentioned means, of a vapor analyzer for receiving the liquid from the absorber and re-evaporated vapor from the boiler.

9. A power plant according to claim 6 characterized by the addition, to the first mentioned means, of a rectifier for the re-evaporated fluid, said rectifier being arranged in heat exchange relation with the steam generator.

10. A power plant according to claim 6 characterized by the addition, to the first mentioned means, of a rectifier for the re-evaporated vapor, said rectifier including a superheater for the turbine steam.

11. A power plant according to claim 6 characterized by the fact that the condenser evaporator includes a chamber for cooling water and a separate chamber for evaporating light liquid of the binary fluid from the vapor condenser.

12. A power plant according to claim 6 characterized by the fact that the pressure reducing device in the separate means is a liquid turbine.

13. A power plant according to claim 6 characterized by the fact that the pressure reducing device in the separate means is a liquid motor arranged in power exchange relation with the pump in the last mentioned means.

14. A power plant according to claim 6 characterized by the fact that the pressure reducing device in the separate means is a liquid motor arranged in power exchange relation with the pump in the last mentioned means and with an additional motor.

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