June 5, 1934. R. C. ROE 1,961,786

BINARY FLUID POWER PLANT

Original Filed March 6, 1931 2 Sheets-Sheet 1

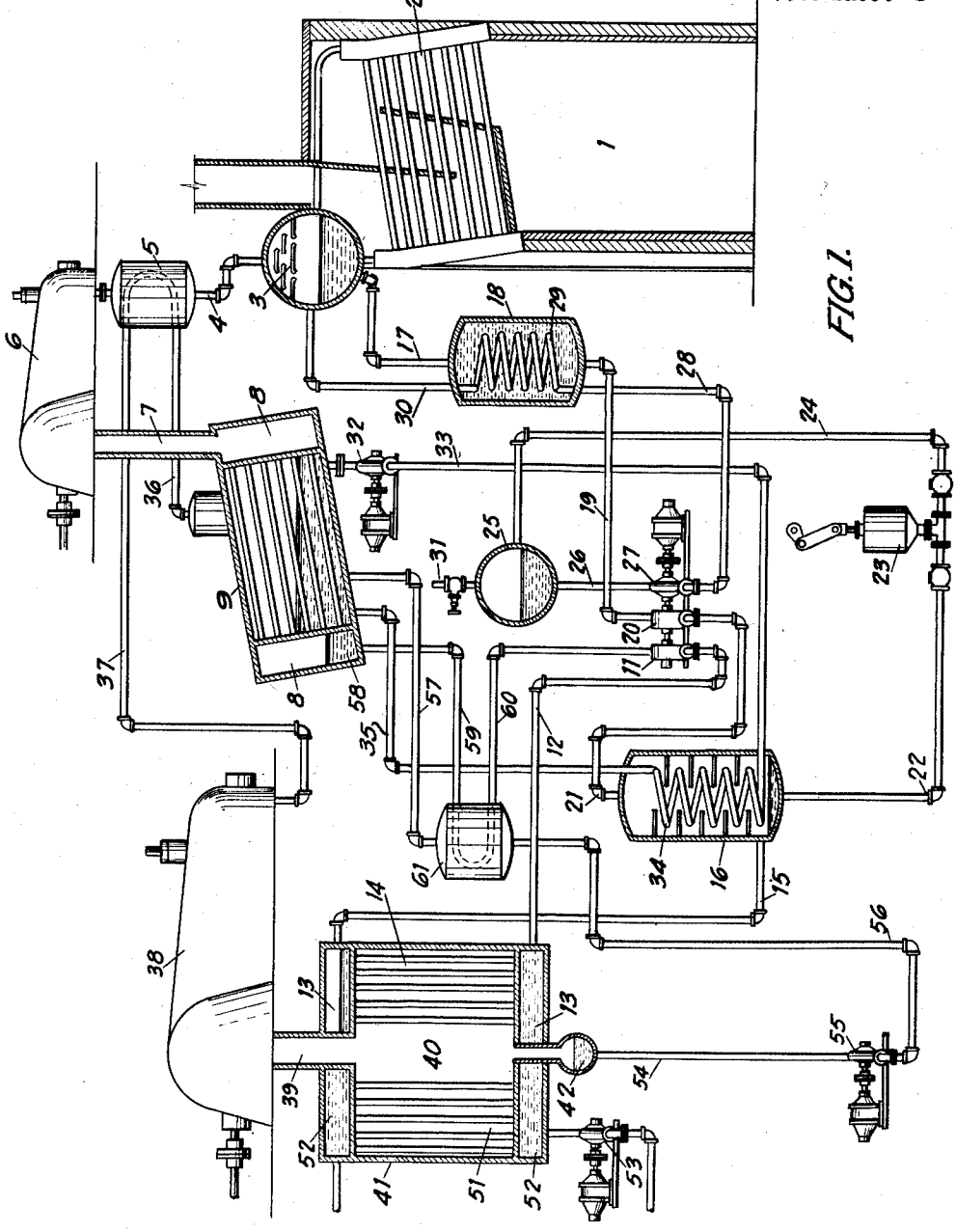


FIG. 1.

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HEAVY LIQUID, GLYCERINE ($C_3H_8O_3$)
LIGHT LIQUID, WATER (H_2O)

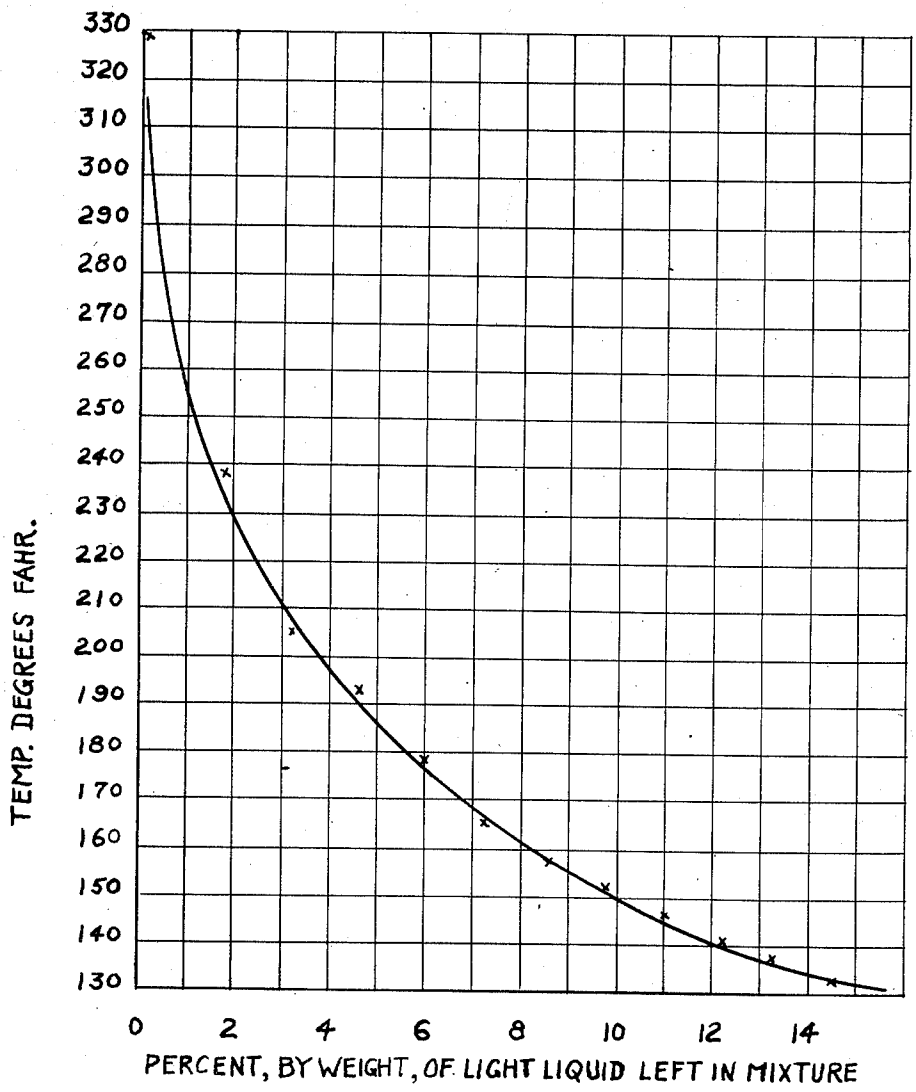


Fig. 2

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UNITED STATES PATENT OFFICE

1,961,786

BINARY FLUID POWER PLANT

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Application March 6, 1931, Serial No. 520,557
Renewed March 17, 1934

12 Claims. (Cl. 60—38)

This invention pertains to improvements in binary fluid power plants employing a regenerative heat cycle and more particularly to such plants employing compound turbines.

The object of this invention is to provide a plant employing regenerative heat, by means of a binary fluid absorption system, in which a standard type of prime mover may be utilized without necessarily being modified for use in the system and in which binary fluids which are easily available and relatively cheap may be used and in which the other pieces of equipment are all of well known design and easily obtainable.

This application is a continuation in part of my co-pending application Serial #508,068, the principal difference consisting in the placing of the high pressure turbine between the combustion boiler and the heat exchanger.

The general principles of absorption refrigeration may be formed in such works as Kent's and Mark's handbooks of mechanical refrigeration and in "Refrigeration" by Moyer and Fittz, 1928.

The general principle of recovering heat from the turbine exhaust and re-introducing it into the heat cycle by means of a binary fluid absorption system is described in my co-pending applications Serial Nos. 508,068 and 522,214.

The terms used herein 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 one, of the two liquids of a binary fluid, which has the lower boiling point.

Heavy liquid—that one, of the two liquids of a binary fluid, which has the higher boiling point.

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

The following nomenclature has been adopted, in both the specification and claims, for the sake of clearness. The boiler used for producing vapor for the high pressure element has been termed "combustion boiler" and the boiler for producing vapor for the low pressure element "condenser boiler". The fluid leaving the absorber, when consisting of substantially normal proportions of its two constituent fluids, is termed "binary fluid". The constituent element having the lower boiling point is termed "light liquid" and vapor produced therefrom under high pressure in the boiler is termed "light liquid vapor" and vapor produced therefrom under vacuum in the condenser evaporator is termed "light liquid evaporate". The other of the two constituents of the binary fluid is termed "heavy liquid". These terms are applied even though one of the constituent liquids may be water. The fluid which is heated in the condenser boiler for supplying the vapor for the low pressure element of the turbine is referred to throughout as "water" and the vapor thereof as "steam" although it is to be understood that other liquids may be used for that purpose, and that "water" and "steam" as herein used are intended to include such liquids and their vapors.

In the drawings, which are schematic, Fig. 1 represents a binary fluid regenerative plant employing a compound turbine. Fig. 2 is a distillation-temperature-pressure curve for a binary fluid consisting of glycerine and water in a 28" vacuum.

Referring to Fig. 1 of the drawings: 1 is a furnace or other source of heat for boiler 2 which contains a mixture of heavy and light liquids, 3 represents a rectifier or purifier of any conventional type, 4 a conduit, 5 a superheater, 6 the high pressure element of a compound prime mover, 7 an exhaust conduit, 8 the vapor space of a condenser boiler 9, 11 a liquid turbine or other pressure reducing device, 12 a conduit, 13 the vapor chamber of a condenser evaporator 14, the condenser evaporator being one portion of a combination evaporator condenser 41, 15 a conduit, 16 an absorber, 17 a conduit, 18 a heat exchanger, 19 a conduit, 20 a liquid turbine or other pressure reducing device, 21 and 22 conduits, 23 pump for removing vapor and liquid, 24 a conduit, 25 an air vent drum, 26 a conduit, 27 a pressure pump, 28 a conduit, 29 a heat exchanger element, 30 a conduit, 31 a vent pipe, 32 a pump, 33 a conduit, 34 a cooling coil, 35, 36 and 37 conduits, 38 the low pressure element of a prime mover, 39 an exhaust conduit, 40 the steam chamber of the combination evaporator condenser 41, 42 a hot well, 51 a water cooled steam condenser and one portion of the combination evaporator condenser 41, 52 the water chamber of the condenser 51, 53 a pump or other means of maintaining and regulating a flow of cooling water through chamber 52. 54 is a conduit, 55 a combination hot well and boiler feed pump, 56 and 57 conduits, 58 light liquid condensate, 59 and 60 conduits and 61 a heat exchanger.

In the form of my invention herein illustrated and described, the prime mover is a compound

steam turbine of conventional design. The rest of the equipment is all of conventional design and the operation and construction thereof, including the necessary calculations as to size, etc., are well understood in the steam power and refrigerating arts.

For illustrating the general principle of the operation of the system, it will be assumed that the binary fluid employed is a solution of glycerine and water containing 4 per cent glycerine as it leaves the absorber and that water is used as the liquid for the low pressure element and reference is had to the drawings. By applying heat to boiler 2 the water is distilled from the glycerine at a suitable pressure, say 215 pounds absolute and 404 degrees Fahr., and passes, in the form of superheated steam, through the purifier 3, where any entrained particles of glycerine are taken out and returned to the boiler. The steam then passes through the conduit 4 and superheater 5 to high pressure turbine 6. Leaving the turbine by way of exhaust conduit 7, the steam enters the steam space 8 of condenser boiler 9, at a selected temperature, say 192 degrees Fahr. and 9.8 pounds absolute, where it is condensed, forming light liquid condensate 58, which flows through conduit 59, heat exchanger 61, conduit 60 and turbine 11, where its pressure is reduced the desired amount, into chamber 13 of condenser evaporator 14, chamber 13 being maintained under vacuum by means of pump 23. Exhaust steam from low pressure turbine 38 enters the steam chamber 40 of condenser evaporator 14 which results in vaporizing the light liquid condensate therein and the light liquid evaporate passes through conduit 15 into the absorber 16.

Returning now to combustion boiler 2. Heavy liquid passes through conduit 17, heat exchanger 18 where its temperature is greatly reduced, conduit 19, reducing turbine 20 and conduit 21 to the absorber. In the absorber the heavy liquid is brought into intimate contact with the light liquid evaporate entering through conduit 15 with the result that the evaporate is absorbed by the heavy liquid, the two re-forming into the original binary fluid which is drawn off by conduit 22, vacuum pump 23 and conduit 24 to vent drum 25 where any entrained gas may be vented through conduit 31. From 25 the binary fluid passes through conduit 26, pump 27, heat exchanger 29 and conduit 30 back to the boiler 2 thus completing the circuit of the binary fluid and its two constituent elements.

In the absorber 16 "heat of absorption" is liberated and the heat is taken up by coil 34 through which water from the boiler condenser 9 is circulated via pump 32, conduits 33 and 35, the coil 34 generating steam at a temperature of about 185 degrees Fahr. and 8.4 pounds absolute. A portion of the heat from absorber 16 passes, in the form of heat of liquid, via pump 27 back to boiler 2. The binary fluid at this point will have a temperature of about 187 degrees Fahr. which will be the operating temperature of the absorber.

In condenser boiler 9 the water receives heat from the exhaust steam from turbine 6 and the heat of absorption via coil 34 providing steam at say 185 degrees Fahr. and 8.4 pounds absolute. The steam generated in boiler 9 passes through conduits 36 and 37 to turbine 38 and it may be superheated by passing it through superheater 5 where it will receive sufficient superheat from the superheated steam entering turbine 6. Leaving turbine 38 the exhaust steam passes through conduit 39 into the steam chamber 40 where it is condensed, partly by means of the light liquid in chamber 13 and partly by means of cooling water in chamber 52. The steam condensate flows into hot well 42 and is returned to boiler 9 by feed water pump 55 via heat exchanger 61.

The wet vacuum pump 23 produces a vacuum which may be as high as 28½" of mercury and which extends back into chamber 13 and this vacuum determines the temperature of the light liquid evaporate and therefore places certain limitations on the temperature and vacuum in chamber 40 and since not less than a 10° difference is usually required to supply a suitable heat head, it follows that the temperature in chamber 40 must be at least 10° higher than that in chamber 13. If the light liquid is water, the vacuum in chamber 40 may be as high as 28" but not higher which, of course, detracts from the efficiency of the low pressure turbine but this disadvantage may be easily offset by the advantage of using turbines of standard construction and especially so where the turbines may be available as in the case of a remodeled plant.

Since the processes in the combustion boiler and the absorber are the same except that one is the reverse of the other, and since the heat of absorption or the heat of vaporization in the binary fluid always contains the latent heat of condensation or vaporization and in addition may contain other heats, such as heat of solution, and since the latent heat varies with the pressure, it follows that for each heat unit furnished to the turbine via heat of absorption, that is to say for each regenerated heat unit, there must be a large portion of another heat unit furnished by the fuel boiler for the purposes of vaporization, the exact ratio depending on the comparative pressures of the two.

If we omit the high pressure turbine unit, as in Serial #508,068, then of the total heat going to the turbine something less than 50% must come from the fuel boiler or, in other words, the amount of regeneration which can be utilized is equal to approximately 50%, of the total heat entering the turbine. In the instant case, the above ratio is not governed entirely by the vaporization pressure, but also by the exhaust pressure of the high pressure turbine and by whether the high pressure turbine exhausts in a superheated or saturated condition and the tendency is generally to improve the ratio or, in other words, to increase the amount of regeneration which can be utilized.

Whatever heat is used by the high pressure turbine must be furnished by the fuel boiler and inasmuch as the high pressure unit is thermally nearly 100% efficient, because all of the remaining heat in its exhaust is used for the low pressure unit, it therefore follows that in some cases there is a gain in efficiency by using the high pressure unit in the manner shown. This is particularly true when the initial pressure is very high. In this respect the effect of super-imposing the high pressure unit is substantially the same as that produced by doing the same thing in a conventional steam plant. Any gain in efficiency from this cause is in addition to any gain which may be produced by an improvement in the regenerative ratio.

If too much heat from the exhaust steam of the low pressure unit, be used for regeneration, there will be produced an excess of steam in the condenser boiler 9 and unless this can be used to advantage, as for process work or other heat-

ing requirements, there is no object in burdening the regenerative equipment with this extra work and the balance of the heat must be disposed of which is the function of the water cooled condenser 51. The amount of heat disposed of in the water cooled condenser may be regulated by varying, in any conventional manner, the amount of water flowing therethrough.

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 mentioned, but that the scope of invention is to be gauged by the accompanying claims taken in connection with the state of the prior art.

What I claim is:—

1. A binary fluid power plant which includes— an elastic fluid compound prime mover having high and low pressure elements; a combustion boiler producing light liquid vapor for the high pressure element; a condenser boiler receiving the exhaust from the high pressure element and producing steam for the low pressure element; a condenser evaporator receiving exhaust steam from the low pressure element and producing light liquid evaporate which is conveyed to an absorber; an absorber for the light liquid evaporate, the absorber being in heat exchange relation with the condenser boiler; a first conduit line for conducting heavy liquid from the combustion boiler to the absorber, said conduit line including pressure reducing means; a second conduit line for conducting binary fluid from the absorber to the combustion boiler, said conduit line including a pump; a third conduit line for conducting steam condensate from the condenser evaporator to the condenser boiler, said conduit line including a pump and a fourth conduit line for conducting light liquid condensate from the condenser boiler to the condenser evaporator said conduit line including temperature and pressure reducing means together with means for conducting vapor from the combustion boiler to the high pressure element and from the high pressure element to the condenser boiler, means for conducting steam from the condenser boiler to the low pressure element and from the low pressure element to the condenser evaporator and means for conducting evaporate from the condenser evaporator to the absorber.

2. A power plant according to claim 1 characterized by the further fact that the first conduit line includes one element of a heat exchanger, the second element of which is included in the second conduit line.

3. A power plant according to claim 1 characterized by the further fact that the second conduit line includes means for venting the same.

4. A power plant according to claim 1 which is characterized by the addition of a water cooled condenser for condensing steam from the low pressure element of the prime mover, said condenser being arranged to discharge the steam condensate into a chamber which receives also the steam condensate from the condenser evaporator.

5. A power plant according to claim 1 characterized by the further fact that the third conduit line includes a pump and one element of a heat exchanger, the other element of which is connected in the fourth conduit line.

6. A power plant according to claim 1 characterized by the fact that the second conduit line includes, in addition to the pump specified, means for removing vapor and liquid from the absorber and condenser evaporator.

7. A power plant according to claim 1 characterized by the fact that the pressure reducing means in the first conduit line is a liquid turbine.

8. A power plant according to claim 1, characterized by the fact that the means for conducting vapor from the combustion boiler to the high pressure element includes one element of a superheater, the other element of which is included in the means for conducting steam from the condenser boiler to the low pressure element.

9. A binary fluid power plant which includes— an elastic fluid compound prime mover having high and low pressure elements; a combustion boiler producing light liquid vapor for the high pressure element; a condenser boiler receiving the exhaust from the high pressure element and producing steam for the low pressure element; a condenser evaporator receiving exhaust steam from the low pressure element and producing light liquid evaporate which is conveyed to an absorber; an absorber for the light liquid evaporate, the absorber containing a cooling coil connected by a conduit line, which includes a pump, to the condenser boiler, said conduit line and pump being arranged to circulate water from the condenser boiler through the cooling coil; a first conduit line for conducting heavy liquid from the combustion boiler to the absorber, said conduit line including pressure reducing means; a second conduit line for conducting binary fluid from the absorber to the combustion boiler, said conduit line including a pump; a third conduit line for conducting steam condensate from the condenser evaporator to the condenser boiler, said conduit line including a pump and a fourth conduit line for conducting light liquid condensate from the condenser boiler to the condenser evaporator said conduit line including temperature and pressure reducing means together with means for conducting vapor from the combustion boiler to the high pressure element and from the high pressure element to the condenser boiler, means for conducting steam from the condenser boiler to the low pressure element and from the low pressure element to the condenser evaporator and means for conducting evaporate from the condenser evaporator to the absorber.

10. A binary fluid power plant which includes— an elastic fluid compound prime mover having high and low pressure elements; a combustion boiler producing light liquid vapor for the high pressure element; a condenser boiler receiving the exhaust from the high pressure element and producing steam for the low pressure element; a condenser evaporator receiving exhaust steam from the low pressure element in a single steam chamber, said evaporator including a cooling chamber for the reception and evaporation of a light liquid and a second separate chamber for receiving cooling water; an absorber for the light liquid evaporate, the absorber being arranged in heat exchange relation with the condenser boiler; a first conduit line for conducting heavy liquid from the combustion boiler to the absorber, said conduit line including pressure reducing means; a second conduit line for conducting binary fluid from the absorber to the combustion boiler, said conduit line including a pump; a third conduit line for conducting steam condensate from the condenser evaporator to the condenser boiler, said conduit line including a pump and a fourth con-

duit line for conducting light liquid condensate from the condenser boiler to the condenser evaporator said conduit line including temperature and pressure reducing means together with means for conducting vapor from the combustion boiler to the high pressure element and from the high pressure element to the condenser boiler, means for conducting steam from the condenser boiler to the low pressure element and from the low pressure element to the condenser evaporator and means for conducting evaporate from the condenser evaporator to the absorber.

11. A power plant according to claim 10 characterized by the fact that the pressure reducing means in the first conduit line is a liquid turbine.

12. A binary fluid power plant which includes—an elastic fluid compound prime mover having high and low pressure elements; a combustion boiler for producing light liquid vapor for the high pressure element from a binary fluid, one liquid of which is water; a condenser boiler receiving the exhaust from the high pressure element and producing steam for the low pressure element; a condenser evaporator receiving exhaust steam from the low pressure element and producing light liquid evaporate which is conveyed to an absorber; an absorber for the light liquid evaporate, the absorber being in heat exchange relation with the condenser boiler; a first conduit line for conducting heavy liquid from the combustion boiler to the absorber, said conduit line including pressure reducing means; a second conduit line for conducting binary liquid from the absorber to the combustion boiler, said conduit line including a pump; a third conduit line for conducting steam condensate from the condenser evaporator to the condenser boiler, said conduit line including a pump and a fourth conduit line for conducting light liquid condensate from the condenser boiler to the condenser evaporator said conduit line including temperature and pressure reducing means together with means for conducting vapor from the combustion boiler to the high pressure element and from the high pressure element to the condenser boiler, means for conducting steam from the condenser boiler to the low pressure element and from the low pressure element to the condenser evaporator and means for conducting evaporate from the condenser evaporator to the absorber.

RALPH C. ROE.