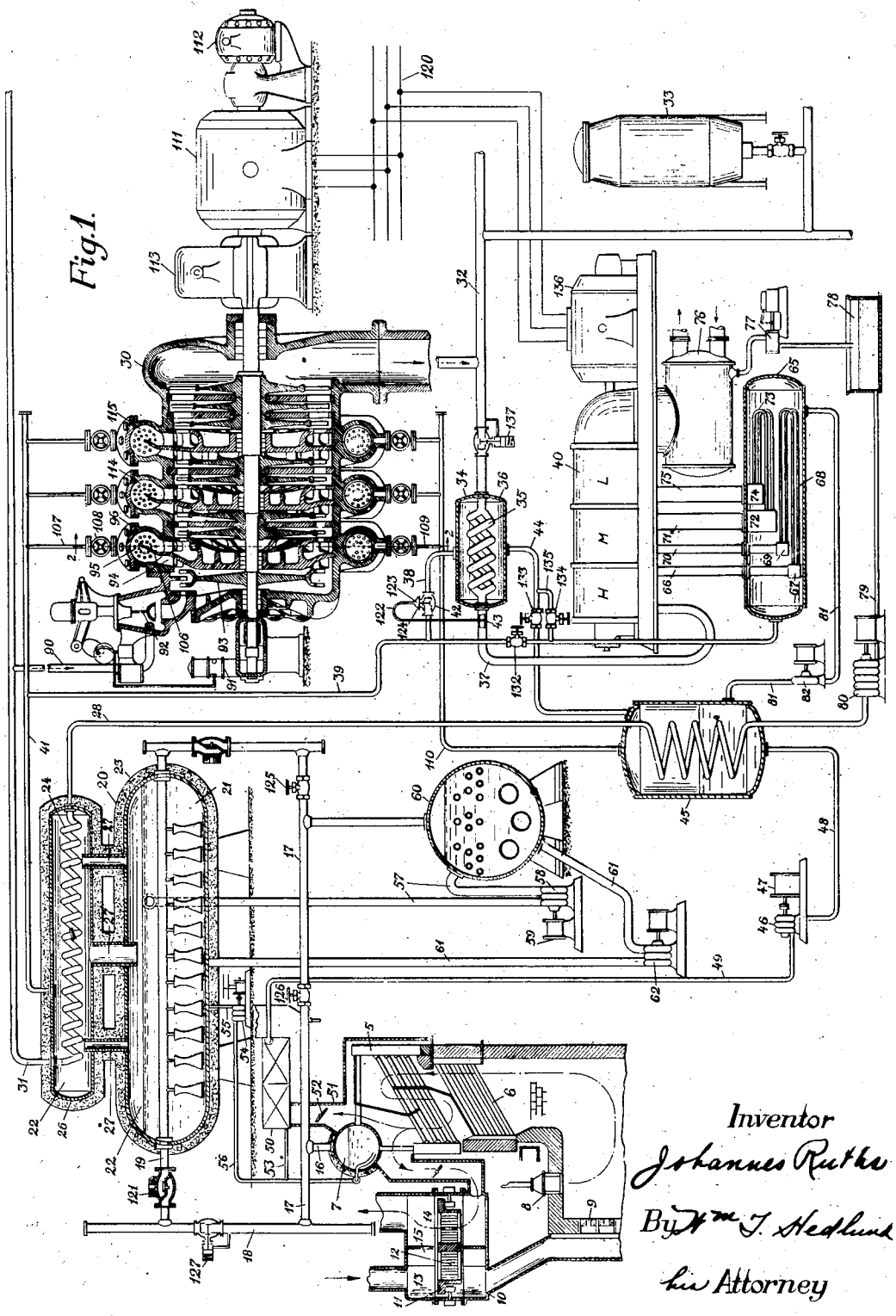
April 17, 1928. 1,666,426

J. RUTHS

STEAM PLANT

Filed Dec. 27, 1924 2 Sheets-Sheet 1

Fig. 1.



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STEAM PLANT

Filed Dec. 27, 1924 2 Sheets Sheet 2

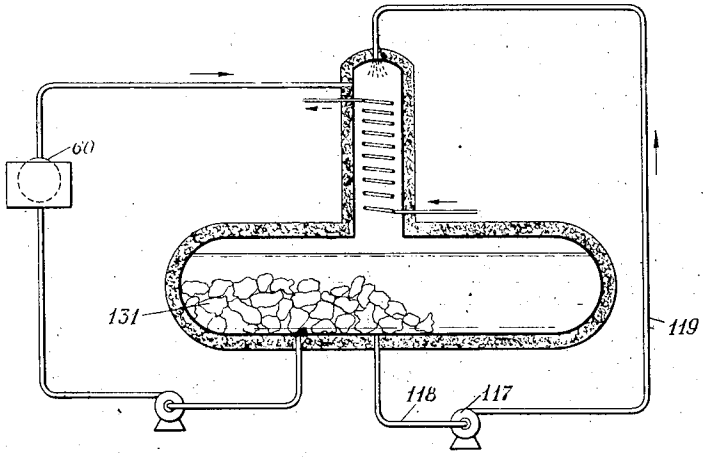


Fig. 3.

Fig 4

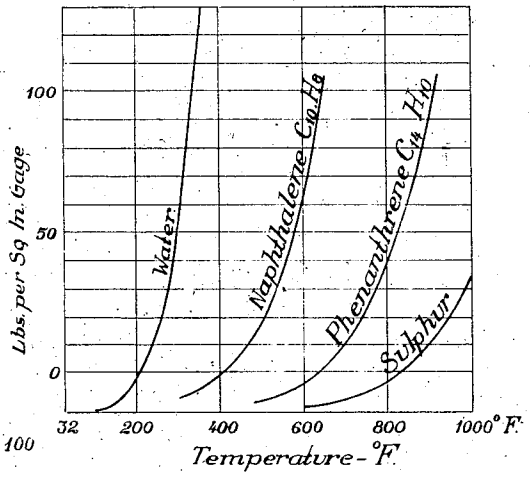
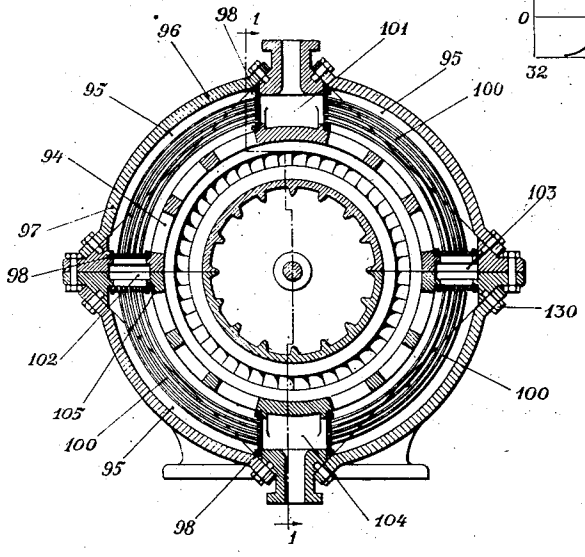


Fig 2



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Patented Apr. 17, 1928. 1,666,426

UNITED STATES PATENT OFFICE.

JOHANNES RUTHS, OF DJURSHOLM, SWEDEN.

STEAM PLANT.

Application filed December 27, 1924, Serial No. 758,438, and in Germany and Sweden January 14, 1924.

My invention relates to steam plants and more particularly to steam plants wherein there is a variable steam consumption.

My invention involves a novel manner of generating steam of high pressure, for example from 1500 to 3000 pounds per square inch, or higher, and to generate steam substantially in proportion to the demand, and at any desired temperature, but independently of heat supplied to the plant in the form of fuel so that the generation of heat is independent of steam consumption. For example, by this means, a constant firing of boilers may be obtained while at the same time the steam generation and steam consumption vary considerably.

Another purpose of my invention is to produce a novel means for superheating steam, and to provide a highly efficient system wherein high pressure steam is used and superheated for different purposes.

I have discovered that it is possible to build a practical high pressure boiler operating at pressures higher than those yet acquired in practice by means of an indirect system of generating the high pressure steam with the help of a medium of high boiling point and having high temperature at low pressure, the said medium consisting of phenanthrene, or a similar liquid. I utilize such liquids also to store heat as set out herein.

I utilize these liquids also to superheat steam and more particularly as shown herein to superheat steam between stages of a turbine.

With these and other objects my invention consists in the matter herein described and more particularly pointed out in the appended claims, reference being had to the accompanying drawings which illustrate some forms of my invention.

In the drawings, Fig. 1 shows a steam plant illustrating several phases of my invention part of which is taken substantially on line 1—1, Fig. 2.

Fig. 2 is a section through a turbine taken on the line 2—2. Fig. 1, showing details of the preferred manner of superheating steam between stages.

Fig. 3 shows diagrammatically a modified form of accumulator for carrying out the present invention.

Fig. 4 is a diagram showing corresponding boiling points and pressure of various liquids illustrating advantages of the present combination.

In Fig. 1, 5 indicates a boiler of any suitable construction which may utilize any desired means of heating.

For the purpose of illustration I have shown what is ordinarily termed a "water-tube" boiler comprising water tubes 6, and a transverse "steam-and water-drum" 7. The boiler, which may be termed a primary boiler, is shown as fired by means of pulverized fuel supplied by means of burner 8. Air is supplied through ports 9, and in the illustration shown is preheated by means of a rotary air preheater 10 of known construction, and comprising a rotor 11 filled with regenerative material 12, which rotor rotates partly in a passage 13 for fresh air to be heated, and partly in a passage 14 for the hot products of combustion, said products of combustion giving off heat to the rotor, the two passages 13 and 14 being separated by partition walls 15.

In this boiler 5 the above-mentioned liquid of high boiling point, in referring to which, for convenience I will herein-after use the name of the preferred liquid, phenanthrene, is vaporized in a manner similar to that which steam is generated from water, and the vapor generated is conducted through conduits 16, 17, 18 and 19 into the liquid space of the accumulator 20. Check valve 121 is provided to prevent return of liquid from the accumulator into the primary boiler piping. Phenanthrene boils under atmospheric pressure at 640° F. wherefore it is seen that a very high temperature in the liquid and vapor in boiler 5 and accumulator 20 is obtained.

The accumulator 20 consists of a large receptacle having a liquid space 21 and a vapor space 22 and is well insulated as indicated at 23.

This accumulator is designed with respect to the heat consumption of the plant and it is built of such size that it can store sufficient heat, and give off sufficient heat, so that the supply of heat, as for example the fuel supply to boiler 5, can be made independent of the steam consumption.

In the vapor space of the accumulator is

arranged one or more elements 24 which constitute the high pressure steam generator of the plant. I have found that a greatly improved heat transfer is effected with the high pressure elements placed in the vapor space than if they are submerged in the liquid.

In the form shown these elements, which might be termed a secondary boiler, consist of a series of pipe-coils placed in a vapor drum 26, which is connected to the main body of the accumulator by means of connections 27.

Water is supplied to the high pressure elements 24 through conduit 28 at substantially the pressure at which steam is to be generated. The relatively cold water entering the elements 24 absorbs heat through the walls of the elements and condenses the phenanthrene vapor in the vapor drum 26, the condensate returning to the liquid space of the accumulator.

In operation, phenanthrene vapor is continually formed from the liquid in the lower part of the accumulator, due to a slightly lower pressure prevailing in the vapor space 22 than corresponds to the temperature of the liquid, which lower pressure is caused by the cooling effect of the water in coils 24. The vapor formed disengages itself at the liquid surface, rises through the outer connections 27, is condensed on coils 24, falls down into the lower part of drum 26 and is returned to the liquid space 21 through central connection 27. From elements 24 steam is conducted through conduit 31 to means for consuming steam such as turbine 30.

Turbine 30 is a high pressure non-condensing multiple stage turbine operating for example between 2000 and 300 lbs. per square inch, and discharging into intermediate pressure conduit 32 from which consumers as, for example, digester 33 may receive steam. This turbine is provided with novel means for inter-stage superheating more fully described hereinafter.

Connected to the conduit 32 is a heat-exchanger 34 comprising an inner coil of pipe 35 and a casing 36. Steam passes from the conduit 32 through the coil 35 and into conduit 37, which supplies steam to a multiple stage condensing turbine 40 operating from about 300 lbs. to condenser pressure.

Phenanthrene vapor is supplied to the casing 36 from the vapor space of accumulator 20 by means of conduits 38, 39 and 41, and, surrounding the coil 35, heats the same to raise the temperature of the steam passing through so that said steam is superheated. To regulate the supply of phenanthrene vapor passing into exchanger 34 I have shown a valve 42, which may be controlled by means of a thermostat 43 placed in the conduit 37, and operating to maintain a constant temperature in conduit 37.

The thermostatic control may, for example, consist of a bulb filled with liquid and connected with a tube 122 which is also connected with a diaphragm chamber 123, so that when the temperature rises, the liquid expands and moves diaphragm 124 downwards so that valve 42 more or less closes, limiting the flow of phenanthrene vapor into casing 36. Phenanthrene leaves exchanger 34 through conduit 44 and enters the water economizer 45 in which feed water for the high pressure elements 24 is preheated. In this economizer 45 I preferably decrease the temperature so that the phenanthrene is a liquid of low temperature, for example 250° F.

Pump 46 driven by motor 47 withdraws phenanthrene from economizer 45 through conduit 48 and pumps the same through conduit 49 into the phenanthrene economizer 50 which is heated by means of products of combustion leaving the boiler 5 through flue 51 controlled by the damper 52. From economizer 50 the phenanthrene passes through conduits 53 and 56 into the liquid space of drum 7.

The low pressure phenanthrene which is conducted to the accumulator 20 and therein condensed is returned from the liquid space of the accumulator to the liquid space of the primary boiler by means of motor driven pump 54 and conduits 55 and 56. The pump 54 may be controlled in any manner so that a proper level of liquid is maintained in boiler 7. The liquid level in the accumulator may vary quite considerably depending on the difference between consumption and generation.

Several boilers may supply one accumulator. To illustrate this I have shown a second primary boiler 60 supplying phenanthrene vapor to conduit 17. In this case I have shown a horizontal return tubular boiler. It is, of course, understood that the present invention is independent of the type of primary boiler used. If valve 125 is closed and valve 126 open the primary boilers 5 and 60 supply the accumulator through the same piping. If valve 126 is closed and valve 125 open the supply from these boilers is independent. I have shown this to illustrate a slightly different mode of operation of these different types of boilers which might be preferable in some cases. Where the pressure changes in the accumulator are rather large, it is preferred to place an overflow valve, indicated at 127, between the small liquid space boiler 5 and the accumulator which valve will operate to maintain a constant pressure in boiler 5. However, with a boiler of large cubic contents such as 60, the pressure may more readily vary with the pressure in the accumulator, in which case the overflow valve may be omitted.

Furthermore, since it requires less time to fire up the type of boiler shown at 5, it may be advantageous to operate one or more boilers like 60 continually and hold one or more boilers of the type of boiler 5 in reserve.

Means are shown whereby liquid can be kept in constant circulation between the accumulator and boiler 60. This comprises a conduit 57 including a pump 58 driven by motor 59 and a conduit 61 including a motor driven pump 62. The first conduit with its pump are designed to conduct liquid phenanthrene from the boiler to the liquid space of the accumulator. The second conduit with its pump are designed to conduit liquid from the accumulator to the liquid space of the boiler. By this means a uniform distribution of heat and a better operation of the accumulator may be obtained. The conduit 57 with its pump is also extremely useful in firing up the boiler 60, especially when a liquid such as phenanthrene is used, since phenanthrene expands very rapidly as its temperature is raised. Thus, in firing up a boiler, it has been found necessary to gradually remove phenanthrene from the boiler as the temperature rises in order to maintain a proper level within the boiler. This may be done as shown in the present instance by conducting the liquid through conduit 57 and into the accumulator.

With a system designed as herein set out it becomes very practical to effect interstage superheating by means of the low pressure high boiling point phenanthrene.

I have shown two different ways of doing this. In the instance of the turbine 40 phenanthrene vapor is conducted to a superheat chamber 65 in which superheat tubes are arranged to be heated by means of the vapor or by the liquid formed by condensation of the same. From the high pressure stage H of turbine 40 the steam passes through conduit 66 and into header 67 from which it passes through U-tubes 68 into header 69 and through conduit 70 into the intermediate stage M. From the intermediate stage M the steam passes through conduit 71, into header 72, through U-tubes 73 into header 74 and through conduit 75 into the low pressure section L. From the low pressure section steam is conducted to condenser 76 from which the condensate is conducted by means of pump 77 into hot-well 78. From the hot-well 78 water is conducted through conduit 79 and pump 80 into the water space of the economizer 45. The superheat tubes 68 and 73 are, as is thus seen, arranged to be fed in parallel by the phenanthrene. In the superheat chamber the phenanthrene may be partly condensed. The phenanthrene, whether vapor or liquid is conducted from the superheat chamber through conduit 81 to economizer 45 where the last heat is extracted in raising the temperature of feed-water. If necessary or desirable, pump 82 may be inserted in conduit 81 to help in obtaining this result.

In the instance of the turbine 30 the interstage superheating is effected in chambers forming a part of the turbine, which chambers are arranged around the outer casing of the turbine and preferably contain tubes through which phenanthrene circulates.

Steam is supplied to the turbine from conduit 31 through conduit 90. Admission to the first wheel 93 is controlled by a mechanism 92 comprising a series of valves operating successively in response to speed of the turbine acting through the agency of centrifugal governor 91, this control being known. As is obvious, other forms of control may be used in accordance with this invention. Steam after passing through the blades of the first wheel enters channels 94 which communicate with chambers 95. (Fig. 2.) Each of these chambers is bordered by circular portions 96 of the main turbine casing. Part of these circular portions 96 comprises covers 97 which are secured by means of studs bolts 130 so that they may be readily removed to gain access to chambers 95. Each of the chambers 95 is also bordered by two tube plates 98 between which and through holes of which tubes 100 extend and into which the tubes are expanded or otherwise secured as by welding. Between tube plates 98 are formed an upper inlet chamber 101, two side chambers 102, 103 and a lower discharge chamber. Chambers 101, 102, 103 and 104 are in communication through the inside of tubes 100. The turbine casing is made in parts which are coupled together at the sides. Tube plates 98 are secured to ledges 105 forming part of the casing. The whole is arranged so that there is no communication or leakage between the space comprising chambers 101, 102, 103, 104 and the insides of tubes 100 on the one hand and the space chambers 95 surrounding tubes 100 on the other hand.

The parts are so arranged that the covers 95 may be removed and the tubes 100 and tube plate 98 removed as units for purposes of cleaning and repair.

The steam in passing through chambers 95 around tubes 100, is caused to be deflected by baffle plate 106 to assure an intimate contact of the steam with tubes 100.

Phenanthrene vapor is admitted to chamber 101 through pipe 107 controlled, for example by valve 108. This vapor then passes to both sides of the turbine, through upper tubes 100, through chambers 102 and 103, in parallel, through the lower groups of tubes 100 and into chamber 104 from which the phenanthrene passes through conduits 109 and 110 into economizer 45.

The phenanthrene, as is understood from

the above description superheats the steam as it passes from the one wheel to the next.

The turbine is shown as driving a generator 111, with exciter 112 through reduction gear 113, although it may drive any apparatus.

Other superheating chambers 114 and 115 are shown between other stages of the turbine. The arrangement of these may be varied according to circumstances.

By means of this invention I am able to produce steam of hitherto unacquired pressure and produce the same without having that part of the boiler which is under high pressure in contact with flames while at the same time heat is accumulated in liquid of low pressure so that the heat production must follow the curve of heat consumption and the mode of heat production is simplified.

The advantages of high pressure are well known. High pressure gives a more economical plant since practically no more heat need be applied to obtain higher pressure. Fuel consumption is less per k. w. h. at higher pressure. The advantage of the inter-stage superheating in raising the efficiency of turbines and the longer life of turbine parts thereby acquired are known. The value of heat accumulation so that heat generation is independent of heat consumption is known. I have herein described novel means for producing these advantages and for combining them in a manner that gives greater efficiency than has hitherto been possible.

Boilers have previously been built of pressures up to 1200 and 1500 pounds per sq. inch pressure but in these constructions all of the boiler has been at the pressure of generated steam giving an undesirable arrangement liable to leakage and other faults. My high pressure boiler is confined to one or more small elements preferably coils which give great strength without parts liable to leakage since if there are joints, the type of joint necessary can be made tight without difficulty. Furthermore I place the high pressure element in the vapor space of the accumulator thus taking advantage of the higher rate of heat transfer obtained by the condensation of the vapor. Phenanthrene vapor condenses on the tubes, falls down into the liquid space and further vapor is drawn to the tubes to be condensed, thus obtaining a constant circulation of heat transmitting medium past the condensing tubes. In this manner I am able to reduce the high pressure steam generating surface to a very small percentage of the heating surface of the primary boilers 5 and 60.

The operation of the plant is obvious from the above description. Suppose, for example, that the load in circuit 120 increased. Turbine 30 being the one equipped with a speed governor, will feel the increased load and operate to add power to the circuit by opening valve mechanism 92 to receive more steam and convert the same into power. More water must then be supplied to high pressure generating elements 24 to compensate for the increased demand.

This condenses more phenanthrene vapor in the accumulator. If more vapor is condensed than the quantity entering the accumulator, the pressure in the phenanthrene space thereof falls in a manner similar to a steam accumulator filled with water. However, there are many advantages in the accumulator of the present application over the ordinary steam accumulator. Here the pressure of steam supplied can be constant regardless of varying pressure in the accumulator. Furthermore the heat accumulated per cubic foot is about double that of the accumulator containing water. This is evident from the showing in Fig. 4 which is a diagram showing the corresponding temperature and pressure values of boiling of various liquids. Suppose no vapor is led from boiler 5 to the accumulator and only the accumulated heat in the accumulator is utilized and that the pressure in the accumulator is 100 pounds per square inch. The corresponding temperature is about 900° F. Now water is led into coils 24 and phenanthrene vapor condensed until the pressure in the accumulator is atmospheric. The temperature drop is then about 250° F. The temperature drop in water between the same values of pressure is about 125° F. Consequently it is seen that for these pressure values only one half as large an accumulator is necessary with phenanthrene as with water. No accumulators are built outside the pressures here indicated wherefore this advantage may be said to be present in all cases.

In many cases it will make a cheaper construction, especially with the use of media which are more expensive than phenanthrene if the accumulator or the boilers are not only filled with a suitable liquid but also with solid material such as castiron. Ores, slacks of blast furnaces and certain kinds of stones can also be used for this purpose. This is indicated by reference character 131 in Fig. 3.

Further in the embodiment illustrated in Fig. 3 the steam generated in boilers 5 or 60 is directly supplied to the vapor space of the accumulator and condensed by the liquid of the accumulator which for this purpose is drawn from the lower part of the accumulator by pump 117 through conduit 118 and forced through conduit 119 into the vapor space.

In Fig. 1 are shown valves 132, 133 and 134 and a bypass conduit 135, illustrating

that the phenanthrene may heat or superheat in series or in parallel. When valve 134 is closed, phenanthrene is supplied in parallel to heat-exchanger 34 and superheat chamber 65. When valve 134 is open and valves 132 and 133 are closed phenanthrene passes in series through heat exchanger 34 and superheat chamber 65. The latter arrangement offers some advantages in some cases in obtaining more heat from the phenanthrene especially in case it is inconvenient to couple cooling apparatus such as the economizer 45 to the heat-exchanger.

Turbine 40 drives generator 136 coupled to circuit 120 in parallel to generator 111.

Overflow valve 137 controls delivery of steam to turbine 40. Turbines 30 and 40 may be regarded as one machine with an extraction to digester 33, turbine 40 taking the steam not used by the extraction consumer and being so constructed that it can receive all steam delivered to the same and convert it into power. When consumer 33 draws a large quantity of steam, the supply to turbine 40 is momentarily decreased wherefore the power delivered by the same to circuit 120 is decreased, wherefore the decreased revolutions of turbine 30 will cause a response of governor 91 to send more steam through turbine 30.

Although I have described phenanthrene as the preferred liquid, it is to be understood that the invention is not limited thereto but may also use other liquids such as naphthalene.

While I have described what is to my mind the preferred means for carrying out my invention, it is to be understood, that my invention is not limited to the arrangement of parts herein shown nor the operations therein involved but by the scope of the appended claims considered in light of the prior art.

What I claim and desire to secure by Letters Patent of the United States is:

1. In a steam plant, in combination, a boiler containing a medium of high boiling point, said boiler generating vapor therefrom at a rate corresponding to the rate of supply of heat thereto, an accumulator, means to conduct vapor from said boiler to said accumulator, said accumulator operating independently of the supply of vapor thereto and under variations of pressure corresponding to variations in state of charge, a steam generating element situated in said accumulator and means to conduct water to said steam generating element.

2. In a steam plant, in combination, a boiler containing a medium of high boiling point, said boiler generating vapor therefrom, an accumulator receiving vapor from said boiler, and condensing the same, a steam generating element heated by vapor formed in said accumulator and means to supply water to said steam generating element.

3. In a steam plant, in combination, a boiler containing a fluid of high boiling point relative to water, an accumulator, means to conduct said fluid from said boiler to said accumulator, means to conduct said fluid from said accumulator to said boiler, a steam generating element situated in said accumulator, and means to conduct water to said steam generating element.

4. In a steam plant, in combination, a boiler containing a fluid of high temperature at low pressure and operating at a rate corresponding to the rate of supply of heat thereto, an accumulator, means to conduct said fluid from said boiler to said accumulator, said accumulator operating independently of the rate of supply of fluid thereto and under variations of pressure corresponding to variations in state of charge thereof, means to conduct said fluid from said accumulator, a steam generating element heated by vapor formed in said accumulator and means to supply water to said steam generating element.

5. In a steam plant, in combination, a boiler containing a fluid of high boiling point, said boiler generating vapor therefrom at a rate corresponding to the rate of supply of heat thereto, means to maintain constant pressure in said boiler, an accumulator receiving vapor from said boiler, said accumulator operating independently of supply of vapor thereto and under variations of pressure corresponding to variations of state of charge thereof, a steam generating element situated in said accumulator, and means to circulate said fluid through said boiler and said accumulator.

6. In a steam plant, in combination, a boiler containing a medium of high boiling point, said boiler generating vapor therefrom at a rate corresponding to the rate of supply of heat thereto, an accumulator having a liquid space and a vapor space, means to conduct vapor from said boiler to the liquid space of the accumulator, said accumulator operating independently of supply of vapor thereto and under variations of pressure corresponding to variations of state of charge thereof, a steam generating element situated in the vapor space of said accumulator and means to supply water to said steam generating element.

7. In a steam plant, in combination, a boiler containing a medium of high boiling point, said boiler generating vapor therefrom at a rate corresponding to the rate of supply of heat thereto, an accumulator having a liquid space and a vapor space, means to conduct vapor from said boiler to said accumulator, said accumulator operating independently of supply of vapor thereto and under variations of pressure corresponding

to variations in state of charge thereof, a steam generating element situated in the vapor space of said accumulator, and means to conduct water to said steam generating element.

8. In a steam plant, in combination, a boiler containing a medium of high boiling point, said boiler generating vapor therefrom at a rate corresponding to the rate of supply of heat thereto, an accumulator having a liquid space and a vapor space, means to conduct vapor from said boiler to said accumulator, said accumulator operating independently of supply of vapor thereto and under variations of pressure corresponding to variations of state of charge thereof, means to return liquid from said accumulator to said boiler, and means to generate steam by condensing the vapor in said accumultator.

9. In a steam plant, in combination, a boiler containing a medium of high boiling point, said boiler generating vapor therefrom at a rate corresponding to the rate of supply of heat thereto, an accumulator having a liquid space and a vapor space, means to conduct vapor from said boiler to said accumulator, said accumulator operating independently of the supply of vapor thereto and under variations of pressure corresponding to variations of state of charge thereof, means to return liquid from said accumulator to said boiler, a pipe-coil situated in the vapor space of said accumulator means to supply water to one end of said coil and means to withdraw steam from the other end of said coil.

10. Accumulator apparatus for steam plants comprising a receptacle containing a medium of high boiling point and having a liquid space and a vapor space and operating under variations of pressure corresponding to variations of state of charge thereof, a drum connected to said receptacle and filled with the vapor thereof, a steam generating element situated in said drum, said steam generating element comprising a coil.

11. Accumulator apparatus for steam plants comprising a receptacle containing a medium of high boiling point and having a liquid space and a vapor space, a steam drum situated above said receptacle, a steam generating element situated in said drum, connections establishing communication between said receptacle and said drum and means to supply water to said steam generating element.

12. In a steam plant, in combination, a boiler containing a medium of high boiling point, said boiler generating vapor therefrom, an accumulator, means to conduct vapor from said boiler to said accumulator, a steam generating element heated by vapor formed in said accumulator, an economizer means to conduct water through said economizer and into said steam generating element and means to heat said economizer by vapor withdrawn from said accumulator.

13. In a steam plant, in combination, a boiler containing a medium of high boiling point, said boiler generating vapor therefrom at a rate corresponding to the rate of supply of heat thereto, an accumulator receiving vapor from said boiler, and condensing the same, said accumulator operating independently of supply of vapor thereto and under variations of pressure corresponding to variations in state of charge thereof, and a superheating element heated by vapor formed in said accumulator.

14. The method of generating high pressure steam which comprises vaporizing a medium of high boiling point at a substantially uniform rate, condensing the vapor produced in liquid of the same medium, storing heat in said liquid and producing vapor therefrom and condensing the same in proportion to steam demand by the cooling effect of water to such an extent that the water is vaporized to form steam of high pressure.

15. The method of generating high pressure steam which comprises storing heat in a medium of high boiling point, producing vapor thereof in proportion to demand for steam by the cooling effect of water and condensing said vapor by said water, thereby producing steam of high pressure.

16. In a steam plant, a receptacle containing a medium of high boiling point and in boiling condition and having a vapor space above the medium of high boiling point, a steam generating element situated in said receptacle in said vapor space, means to supply heat to said medium, means to supply water to said steam generating element, means to withdraw steam from said element, the said receptacle being of such size and containing said medium in such quantity that large variations in pressure may take place by the cooling effect of water in the steam generating element.

17. Accumulator apparatus for a steam plant comprising a receptacle containing a medium of high boiling point and having a liquid space and a vapor space, means to vary the heat content of said medium in accordance with variations in supply of heat to the plant, said receptacle operating under variations of pressure corresponding to variations in state of charge and means to generate steam by condensing the vapor in said receptacle in accordance with demand for steam.

18. Accumulator apparatus for a steam plant comprising a receptacle containing a medium of high boiling point and having a liquid space and a vapor space, means to vary the heat content of said medium in accordance with variations in supply of

heat to the plant, said receptacle operating under variations of pressure corresponding to variations in state of charge and means to generate and superheat steam by condensing the vapor in said receptacle in accordance with demand for steam.

19. The method of generating high pressure steam which comprises storing heat in phenanthrene, producing vapor thereof in accordance with demand for steam by the cooling effect of water and condensing said vapor by said water thereby producing steam of high pressure.

In testimony whereof I hereunto affix my signature.

JOHANNES RUTHS.