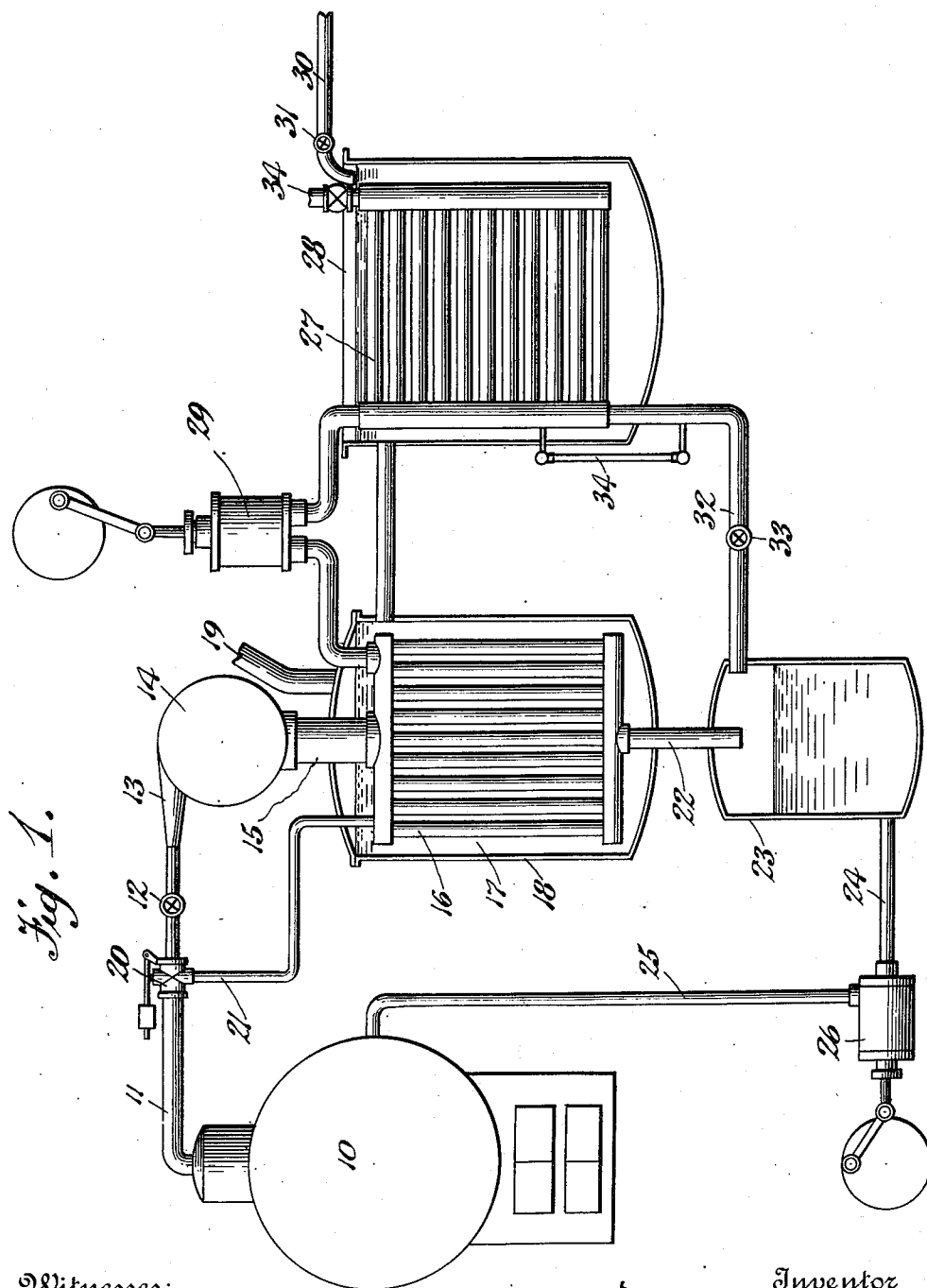


C. S. BRADLEY.
METHOD OF AND APPARATUS FOR OPERATING TURBINES.
APPLICATION FILED MAY 25, 1911.

1,015,777.

Patented Jan. 30, 1912.

2 SHEETS—SHEET 1.



Witnesses:
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Emanuel M. Fenster.

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Charles S. Bradley
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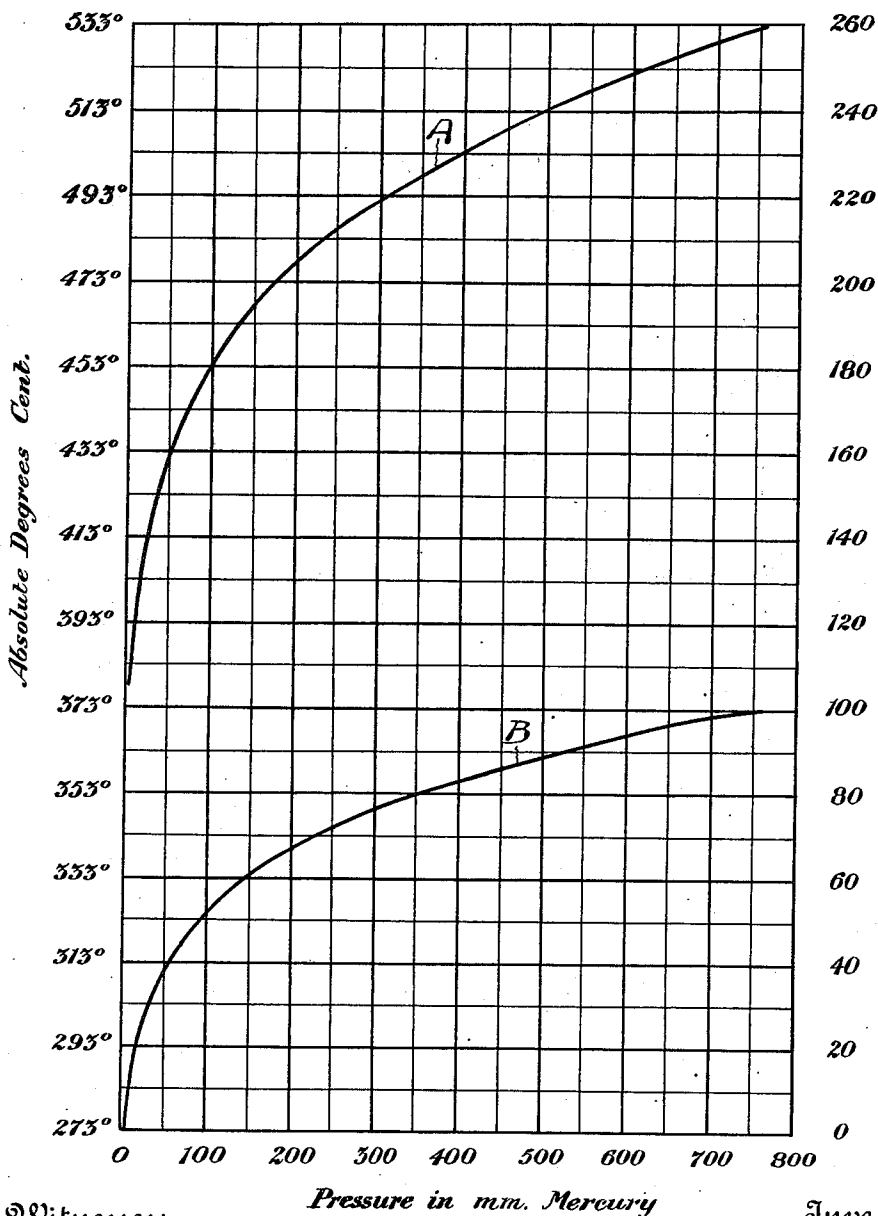
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2 SHEETS—SHEET 2.

Fig. 2.



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CHARLES S. BRADLEY, OF NEW YORK, N. Y.

METHOD OF AND APPARATUS FOR OPERATING TURBINES.

1,015,777.

Specification of Letters Patent.

Patented Jan. 30, 1912.

Application filed May 25, 1911. Serial No. 639,437.

To all whom it may concern:

Be it known that I, CHARLES S. BRADLEY, a citizen of the United States, and a resident of the borough of Manhattan, city, county, and State of New York, have invented certain new and useful Improvements in Methods and Apparatus for Operating Turbines, of which the following is a specification.

My invention relates to a method and apparatus for operating turbines for converting heat into mechanical power.

The invention forming the subject of my present application is especially adapted to those situations where condenser water is scarce and it is further intended to replace with economy the present so-called high pressure steam engine, that is to say, those steam engines which of necessity must exhaust the steam into the atmosphere.

All condensing steam engines require a relatively large amount of water to operate the condenser, for the reason that they utilize in the condensing operation only the specific heat of the water through a range of say for example 35° of temperature centigrade, or 35 gramscalories or therms per gram of water used. According to my invention the specific heat of the water between ordinary temperature and the boiling point is used and in addition thereto the 537 therms of latent heat, making in all say 572 therms per gram of water evaporated.

In addition to the economical use of the condenser water my invention provides a much more efficient operation within the turbine itself, as will appear from a consideration of some of the characteristics of this type of prime mover.

The steam turbine for mechanical and physical reasons is essentially a low pressure, large volume and high speed device. To be efficient it must operate between two pressures low on the scale as will be apparent, in the first place in order that the wheel may rotate in vacuum to reduce the "windage"; secondly, in order that the difference between the initial and final temperatures may be as great as possible (the temperature drop with any given difference in pressures being greater at low pressure), thereby increasing the thermodynamic efficiency with differences of pressure; thirdly as mechanical construction calls for passages so large

that only a part of them are brought into use at any one time; therefore the large volumes of low pressure gas or vapor are more easily handled than the high pressure gas or vapor; and fourthly, in order that the vapor issuing from the nozzles should not be retarded and thus lose energy by issuing into a dense medium.

Among other advantages of my invention is the low cost of mechanical construction for a given amount of power developed. Furthermore the boiler or heater is at very low pressure and therefore requires a small amount of material and the danger of bursting is minimized.

The improved method consists, generally speaking, in using in a boiler a substance which boils under atmospheric pressure at such a temperature above the boiling point of water that it may be expanded a maximum amount and condensed after operating the turbine by keeping a surface condenser at the boiling point of water under atmospheric pressure. For example, if the working fluid were admitted to the interior of the tubes of a surface condenser surrounded with water open to the atmosphere, it is evident that the tubes would be kept at the temperature of boiling water, and if the turbine is operated by a vapor which has been boiled at 260° C. while the condenser is at 120° C. (allowing for 20° drop through the walls of the condenser tubes), then the operating difference of temperature will be 140° C. This temperature range indicates a thermodynamic efficiency of a little more than 26%, and a large part of this may be realized in practice. While choosing a vapor of these desirable qualities, I prefer also that the substance utilized as a working fluid shall, when in the state of vapor or gas, have a relatively high density in order that its issuing velocity may be as low as possible and thus the turbine have as low a velocity as it is possible to obtain. An example of such a substance is found in the case of monochlor-naphthalene, the density of which is 5.5 referred to air, or nine times that of steam, which will give an issuing velocity of about 1333 feet per second or about $\frac{1}{3}$ of that of steam. This substance having a boiling point of about 260° C. at ordinary pressure and a little under 120° C.

at 10 mm. pressure, offers a temperature range of 140° C. which will give a thermodynamic efficiency

$$\frac{533 - 393}{533} = 26\%$$

Since the boiling point at 10 mm. pressure is 118.6° C. while the water at atmospheric pressure boils at 100° C., it is apparent that a good working difference of temperature is maintained in the condenser.

While I have set forth the above thermodynamic conditions as the most simple case and involving the most simple construction, I may, where high efficiency is absolutely necessary, operate the boiler above the atmospheric pressure and thus increase the thermodynamic efficiency beyond 26%. It will also be apparent that the steam coming from the condenser may be utilized to operate a low pressure steam turbine, similarly to the present practice of adding a low pressure turbine to a high pressure reciprocating engine.

In place of the monochlor-naphthalene, some other substance having similar characteristics may be employed, such as for example nitro-benzole or tetra bromid of tin. Those skilled in this art will understand that the details of the apparatus will vary according to the substance utilized and 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 drawings and describe the same with reference to the use of monochlor-naphthalene.

In said drawings, Figure 1 is a diagrammatic view of a system embodying the principles of my invention, and Fig. 2 represents the boiling-point-pressure curves of water and monochlor-naphthalene in degrees centigrade and millimeters of mercury.

Referring to Fig. 1, 10 indicates the boiler from which leads a pipe 11 controlled by hand valve 12 for conducting the vapor of monochlor-naphthalene generated in boiler 10 into an expanding nozzle 13 which directs the vapor into turbine 14. From turbine 14, the spent vapor is drawn through exhaust pipe 15 into the condenser tubes 16 which are surrounded by a body of water 17 in container 18 open to the atmosphere or to a low pressure turbine by pipe 19. A safety valve 20 is provided in the vapor pipe 11 and discharges excess vapor from pipe 11 through discharge pipe 21 directly into the condenser tubes 16 instead of into the atmosphere, so as to avoid loss of operating fluid from the system.

From the condenser tubes 16, the condensed operating fluid is delivered through a discharge pipe 22 into a reservoir 23 from

which it is pumped back through return pipes 24 and 25 by pump 26 to the boiler 10.

A second or auxiliary condenser, having condenser tubes 27 and an open water receptacle 28, receives the uncondensed exhaust vapor from the first mentioned or primary condenser, pumped out by the pump 29, which thus maintains the reduced pressure in the primary condenser. Its water receptacle is supplied with water by supply pipe 30 controlled by hand valve or the like 31, and discharges the overflow into the water receptacle or container 18 of the primary condenser. From the secondary condenser tubes, the condensed fluid is delivered from time to time to the above mentioned reservoir 23, through the return pipe 32 by opening the hand valve 33. An indicator tube 34 is preferably provided in the secondary condenser to disclose the quantity of condensed fluid contained. Condenser tubes 27 open into the atmosphere through outwardly opening check valve 34 so as to discharge air which may have leaked into the system.

In the operation of the above described apparatus, the vapor is preferably produced in the boiler at about normal atmospheric pressure, or if it is desired the pressure may be maintained a little higher than atmospheric to gain higher initial temperature with consequent increased temperature range, and thermodynamic efficiency. It will be observed, however, with reference to the boiling point pressure curves hereinafter referred to, that the elevation of the boiling temperature for a given increase in pressure is relatively small at the higher pressures. The pressure in the condenser, on the other hand, is maintained as low as practicable, as the depression of the condensation temperature becomes relatively greater and greater as the pressure becomes lower. Another point of view would be that the lower end of the curve is the place where the greatest gain in efficiency is offered.

Referring now to Fig. 2 of the drawings, A indicates the boiling-point-pressure curve for water, and B indicates the boiling-point-pressure curve for monochlor-naphthalene. In the diagram, the abscissæ indicate pressure in millimeters of mercury, and the ordinates indicate temperature in degrees centigrade. Absolute temperature is shown at the left of the diagram. The monochlor-naphthalene being a very much heavier vapor than the steam, I am able to operate it at a very much lower pressure and still have a considerable mass of material in the condenser, that is, there will be more material in the condenser with the monochlor-naphthalene at ten millimeters pressure than with water at fifty millimeters pressure. Furthermore, the water vapor cannot be car-

ried to its ultimate practical vacuum on account of not being able to get as low a temperature in the condenser as would be necessary to reduce it to its lowest possible pressure. The monochlor-naphthalene being higher on the scale it can be readily cooled to a vacuum corresponding to ten millimeters pressure and even lower. A comparison of the two curves shows that at working pressures curve B has a much greater temperature range than curve A and, whereas between the normal pressure of 760 mm. and 50 mm. the boiling point of water has a temperature range of 62°, the working temperature range of monochlor-naphthalene is in the neighborhood of 155°; consequently the thermodynamic efficiency between these pressures is very much greater in the case of monochlor-naphthalene than in the case of water. With regard to the condensation of the monochlor-naphthalene by transfer of its heat to water at normal atmospheric pressure, it will be seen from the relative positions of the two curves that the pressure of the monochlor-naphthalene may be maintained as low as say 10 mm. and leave a satisfactory operating difference of temperature to permit the latent heat, given off from the vapor in changing to liquid, to be taken up by the water in the form of latent heat of evaporation. Again the temperature range of the monochlor-naphthalene, under the conditions of operation, will be seen to be about 155°, or taking the initial and final temperatures in degrees absolute, the thermodynamic efficiency equals say

$$\frac{533 - 393}{533} = 26 + \%$$

I claim:

1. The method of operating power turbines, which comprises boiling a substance having a vapor heavier than steam and which at condenser pressures lower than practical with steam has a boiling point higher than water at atmospheric pressure, driving the turbine with the vapor thus produced, and condensing the vapor by the evaporation of a condenser fluid at atmospheric pressure.
2. The method of operating power turbines, which comprises boiling a substance having a vapor heavier than steam and which at condenser pressures lower than practical with steam has a boiling point higher than water at atmospheric pressure,

driving the turbines with the vapor thus produced, and condensing the vapor by absorbing heat therefrom as latent heat of water at atmospheric pressure.

3. The method of operating power turbines, which comprises boiling a substance having a vapor heavier than steam and which at condenser pressures lower than practical with steam has a boiling point higher than water at atmospheric pressure, driving the turbine with the vapor thus produced, and condensing the vapor by absorbing heat therefrom as latent heat of water at atmospheric pressure, while maintaining a material margin of temperature between the working vapor and the boiling water in the condenser.

4. The method of operating power turbines, which comprises vaporizing monochlor-naphthalene, driving the turbine therewith, and condensing the spent vapor, in cyclic manner.

5. The method of operating power turbines which comprises driving the turbine with a working fluid of suitable boiling point and condensing the fluid with boiling water.

6. The method of operating power turbines which comprises driving the turbines with a working fluid of suitable boiling point and condensing the fluid with boiling water at about 100° C.

7. A power turbine system comprising in combination a boiler for fluid of high boiling point relative to steam, a turbine, a condenser for the spent fluid from said turbine, and a safety valve between said boiler and said turbine discharging into said condenser for avoiding loss of operating fluid.

8. A power turbine system comprising in combination a boiler for fluid of high boiling point relative to steam, a turbine operated thereby, a primary condenser in which the working fluid is condensed at vacuum pressure, a secondary condenser and an air pump for pumping uncondensed vapor from the primary condenser into the secondary condenser at atmospheric pressure, whereby total condensation is assured and loss of working fluid avoided.

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