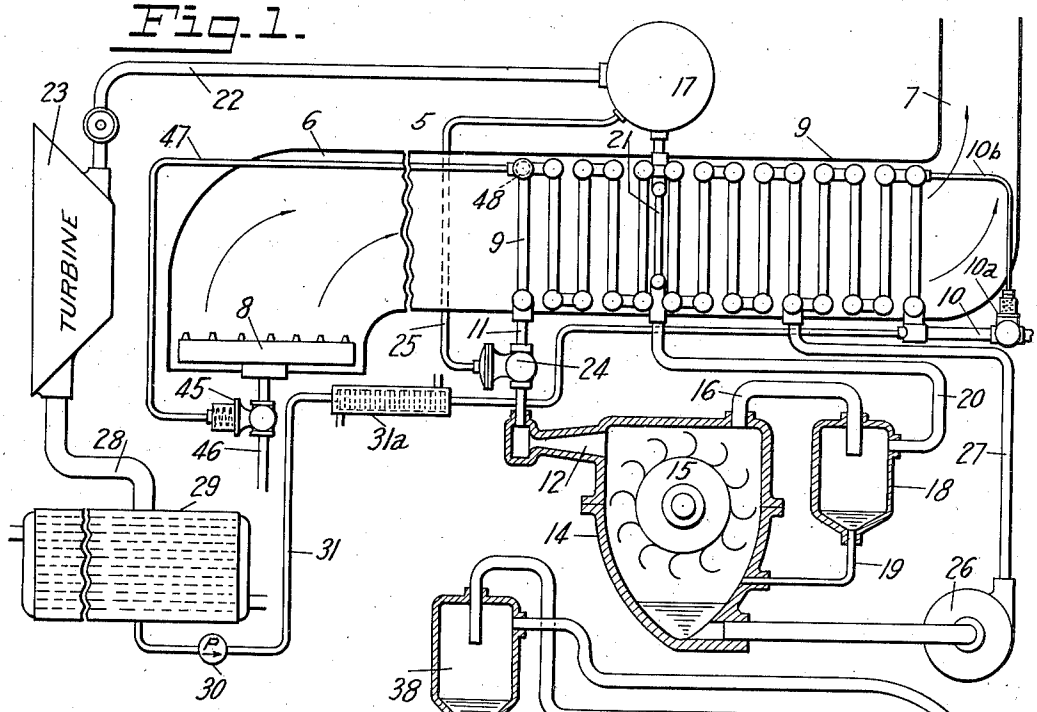
May 14, 1940. E. T. TURNER 2,200,759

STEAM GENERATOR

Filed Oct. 12, 1938

Fig. 1.



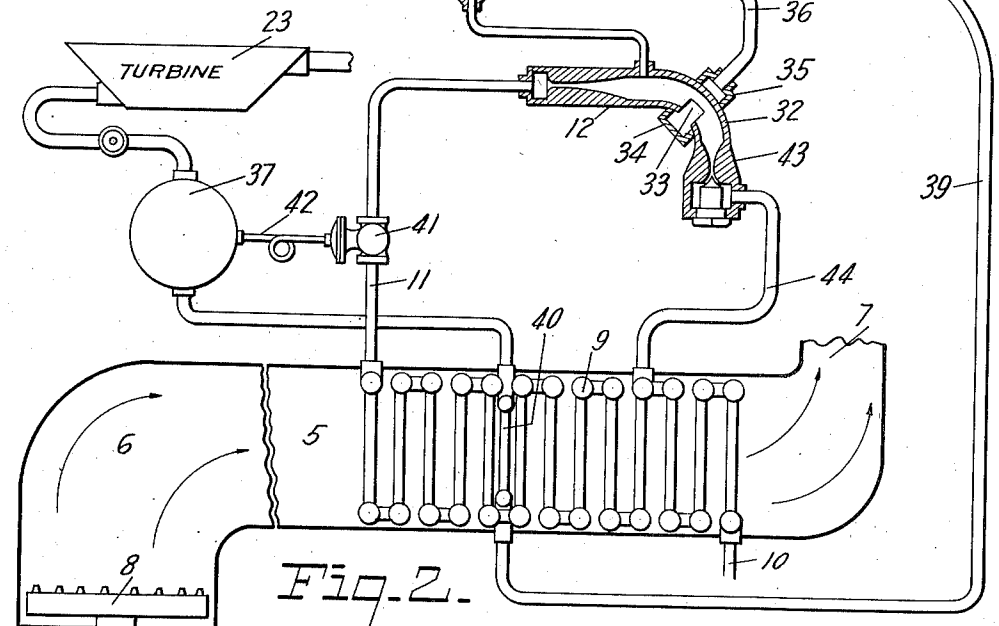


Fig. 2.

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STEAM GENERATOR

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7 Claims. (Cl. 122—356)

This invention relates to a method and apparatus for generating steam.

One object of the invention is to provide a simple and efficient method and apparatus whereby steam may be produced for industrial purposes at a low cost.

A further object of the invention is to provide a method and apparatus for generating steam for industrial purposes without the use of a steam boiler.

A further object of the invention is to provide a method and apparatus whereby flash steam may be separated from the water and stored under pressure for use.

A further object of the invention is to provide such a method and apparatus in which the amount of water which is flashed into steam will be automatically controlled by the pressure of the stored steam.

A further object of the invention is to provide such a method and apparatus comprising a closed cycle in which the steam which has been withdrawn from storage and used for operating a power element, or otherwise, may be condensed and again used in the generation of steam.

Other objects of the invention may appear as the invention is described in detail.

In the accompanying drawing Fig. 1 is a schematic view, partly in elevation and partly in section, and partly broken away, of an apparatus for carrying out my method; and Fig. 2 is a similar view of a slightly modified form of such an apparatus.

In performing my method, in its preferred form, water is passed in counterflow heat exchange relation to products of combustion, as by the use of a suitable heat exchanger, in such a manner that the water is heated to a high temperature and high pressure. The heated water is caused to flow from its initial high pressure to a lower pressure, as by passing the same through an expansion chamber, such as an expansion nozzle, whereby a portion of the water is converted or "flashed" into steam. The steam mixes with the water in the expansion chamber and by its expansion therein converts pressure energy into velocity energy. After the mixture of steam and water leaves the expansion chamber the steam is separated from the water and delivered to a storage chamber, herein referred to as a steam chest. Preferably the separated steam is passed through the products of combustion in the heat exchanger to superheat the same before it is delivered to the steam chest. The steam which is thus stored in the steam chest under pressure may be withdrawn for use as required and the flow of water to the expansion chamber is regulated by the pressure in the steam chest to control the amount of steam generated in accordance with the demands made on the steam chest. The water from which the steam has been separated is returned to the heat exchanger and again heated to a high temperature. If desired, the mixture of water and steam which is discharged from the expansion chamber at a high velocity may be utilized to develop mechanical power prior to the separation of the steam and water. The steam which is withdrawn from the steam chest and used in the performance of work may thereafter be condensed and the condensate returned to the heat exchanger and again used in the generation of steam.

The apparatus employed for performing this method may take various forms and in the drawing I have illustrated two forms of apparatus which differ slightly one from the other. In each form the apparatus includes a heat exchanger adapted to utilize products of combustion to heat water to a high temperature and high pressure. As here shown, this heat exchanger comprises a conduit 5 connected at one end with a combustion chamber 6 and connected at its other end with a stack 7 or other suitable point of discharge. In the arrangement here shown the conduit 5 is connected directly with the combustion chamber of a gas burner 8 but the products of combustion may be taken from any suitable source and products of combustion which would otherwise be wasted may be used, as for example, by interposing the conduit 5 between a steam boiler and the stack. Arranged within the conduit 5 it a second or water conduit 9 which is connected at its inlet end, that is the end remote from the combustion chamber, with a source of water supply, as by means of a pipe 10. The water flows through the conduit 9 in counterflow heat exchange relation to the products of combustion in the conduit 5 and is heated to a high temperature and high pressure before it reaches the discharge end of the conduit 9. If desired, the water delivered to the water conduit 9 may be preheated, as by means of an ordinary feed water heater.

The water is discharged from the water conduit 9 of the heat exchanger through a conduit 11 which includes an expansion nozzle 12 in which a portion of the highly heated water will be converted or flashed into steam and the expansion of this steam in and about the water will convert a portion of the pressure and heat

energies of the steam and water into velocity energy, so that the mixture will be discharged from the nozzle at high velocity.

In that form of the apparatus shown in Fig. 1 the expansion nozzle 12 is connected with and discharges into a casing 14 in which is mounted a power element, such as a Pelton wheel 15, so arranged that it will be actuated by the mixture of steam and water discharged from the nozzle into the casing. The steam will separate from the water in the casing 14 and it may be withdrawn from the upper end of the casing by means of a conduit 16 and is then delivered to a storage chamber or steam chest 17. Due to the turbulation within the casing 14 small quantities of water are apt to escape along with the steam through the conduit 16 and in order that substantially dry steam will be delivered to the steam chest I have interposed between the casing 14 and the steam chest a separator 18, here shown as an upright casing, into which the discharge end of the conduit 16 projects. Any water entering the separator 18 along with the steam will, due to its weight, fall to the bottom of the separator and may be withdrawn therefrom in any suitable manner. In the present instance, such water is returned through a pipe 19 to the casing 14. The steam, which is now substantially free from water is discharged from the upper end of the separator 18 through a conduit 20 to the steam chest 17 and preferably this conduit is passed through the conduit 5 of the heat exchanger, as shown at 21, so as to superheat the steam before it is delivered to the steam chest. The steam is stored in the steam chest under pressure and may be withdrawn therefrom for use in any suitable manner. As shown, the steam chest is connected by a pipe 22 with a turbine 23.

The flow of water from the water conduit of the heat exchanger to the expansion nozzle is automatically regulated to cause the generation of steam in quantities determined by the amount of steam withdrawn from the steam chest. For this purpose the pressure operated regulating valve 24 is interposed in the conduit 11 in advance of the expansion nozzle 12. This valve is connected by a tube 25 with the steam chest so that it regulates the flow of water to the expansion nozzle in accordance with the pressure in the steam chest.

Water in the casing 14, from which the steam has been separated, is withdrawn from that casing by a pump 26 and returned to the water conduit 9 of the heat exchanger through a pipe 27, the pump providing the water with sufficient pressure to enable it to enter the conduit against the pressure therein. If desired, the pump 26 may be driven by the power element 15. Inasmuch as this water which is withdrawn from the casing 14 has a high temperature it is preferably introduced into the water conduit 9 at a point between the ends of the latter where the water in the conduit 9 will be at approximately the same temperature as the water which is returned through the conduit 27.

In Fig. 1 I have also shown means whereby the used steam, in the present instance the exhaust from the turbine 23, may be condensed and returned to the heat exchanger for further use in the generation of steam. For this purpose the exhaust pipe 28 of the turbine is connected with a condenser 29 in which the exhaust steam is condensed, and the condensate is withdrawn from the condenser by a pump 30 and delivered through a conduit 31 to the intake end of the water conduit 9 of the heat exchanger. Preferably the condensate is passed through a heater, such as the feed water heater 31*a*, to impart additional heat thereto before it is delivered to the heat exchanger. In this manner I not only save steam which would otherwise go to waste but I also provide the water conduit 9 of the heat exchanger with water having a relatively high temperature. When the condensate is thus returned to the heat exchanger the water supply pipe 10 would be required merely to compensate for such losses as might occur in the cycle.

If desired, means may also be provided for automatically controlling the temperature and pressure of the water in the conduit of the heat exchanger. The pressure in the conduit 9 may conveniently be controlled by interposing in the supply pipe 10 a pressure operated regulating valve 10*a* and connecting the same with the conduit 9 by a tube 10*b*. The temperature of the water in the conduit may be controlled by thermostatically regulating the supply of products of combustion. In the arrangement illustrated a pressure operated regulating valve 45 is interposed in the gas supply pipe 46 and is connected by a tube 47 with a bulb or container for a volatile fluid which is inserted in the conduit 9 near the discharge end thereof, thus automatically controlling the amount of heat generated in the combustion chamber.

In that form of the apparatus shown in Fig. 2 the velocity of the mixture of water and steam discharged from the expansion nozzle 12 is not utilized in the development of power but that mixture is discharged directly into a steam separator. This separator may be of any suitable character but preferably I employ a centrifugal separator which is here shown as a curved tube 32 connected at one end with the discharge end of the expansion nozzle 12. The inner wall of the curved tube 32, which has the shorter radius, is provided with a discharge opening 33 which communicates with an exterior discharge chamber 34. In the present arrangement this chamber is in the form of an annular casing 35 mounted about the tube 32 and enclosing the discharge opening 33. The mixture of water and steam is discharged from the expansion nozzle 12 into the centrifugal separator at high velocity and due to this velocity and the greater weight of the water the latter will tend to follow the outer wall of the curved tube 32, that is, the wall having the longer radius, while the steam will tend to follow the inner wall and will escape through the discharge opening 33. A discharge pipe 36 is connected with the discharge chamber 34 and the steam escaping from the tube is delivered to a steam chest 37. Preferably a second separator 38 is interposed between the centrifugal separator and the steam chest for the purpose of removing from the steam any water which may have passed therewith from the centrifugal separator and the steam is conducted from the second separator 38 through a conduit 39 to the steam chest, this conduit passing through the conduit 5 of the heat exchanger, as shown at 40, to superheat the same. The flow of heated water from the heat exchanger to the expansion valve is controlled by a pressure operated regulating valve 41 which is connected with the steam chest 37 by a tube 42 in the same manner as shown in Fig. 1.

The water is discharged from the tube 32 of the centrifugal separator through a compression nozzle 43 which converts a portion of the velocity energy thereof into pressure energy and the pres-

sure thus imparted to the water is sufficient to force the same through a pipe **44** and into the water conduit **9** of the heat exchanger without the use of a pump. The compression nozzle **43** may be of any suitable character but, in the present instance, is of the type shown and described in my pending application Serial No. 176,506, filed November 26, 1937. In this form of apparatus the exhaust or used steam may, if desired, be condensed and returned to the heat exchanger in the manner shown in Fig. 1.

The method and apparatus herein described enable steam to be generated in quantities and at pressures suitable for industrial purposes at a cost much lower than it can be produced in corresponding quantity and pressure by an ordinary steam boiler plant. An apparatus of the type here illustrated can be constructed and installed at a cost much lower than would be required to construct and install a steam boiler plant capable of producing steam in the same quantities and at the same pressure. The efficiency of the apparatus is high. The products of combustion are utilized much more fully than they are in a steam boiler. By passing the water in counterflow relation to the products of combustion, in the manner described, the water is caused to absorb a very large part of the available heat in the products of combustion so that the latter are discharged to the stack at a relatively low temperature, and the water is heated to a correspondingly high temperature and pressure at the discharge end of the water conduit **9**. The pressure drop in the expansion nozzle **12** is relatively small. For example, if the water at the discharge end of the water conduit **9** had a pressure of 550 pounds the pressure drop in the nozzle would be approximately 50 pounds so that the water would be delivered to the casing **14** of the power element at approximately 500 pounds pressure. The steam is delivered from the casing **14** to the steam drum **17** with very small loss in pressure and therefore the steam is maintained in the steam chest at approximately the pressure in the casing **14**, the automatic regulating valve **24** serving to regulate the amount of steam generated in accordance with the withdrawals from the steam chest. The method of utilizing the discharged water and the exhaust steam further increases the efficiency of the apparatus and serves to reduce the cost of operation.

While I have described my preferred method and have shown one form of apparatus for performing that method, together with a minor modification thereof, I wish it to be understood that I do not desire to be limited to the details of either the method or apparatus as various modifications thereof may occur to a person skilled in the art.

Having now fully described my invention, what I claim as new and desire to secure by Letters Patent, is:

1. In a steam generator, a conduit adapted to be connected with a source of products of combustion, a second conduit adapted to be connected with a source of water supply and arranged to conduct water in counterflow heat exchange relation to the products of combustion in the first mentioned conduit to heat said water to a high temperature and high pressure, a third conduit to receive said water from said second conduit and including an expansion chamber to convert a portion of said water into steam and to expand said steam to convert pressure energy into velocity energy, means arranged beyond said expansion chamber to separate the steam from the water, a steam chest, means for delivering the separated steam to said steam chest, and means for returning the separated water to said second conduit at a point therein where the water in said second conduit is at a temperature approximating the temperature of the returned water.

2. In a steam generator, a conduit adapted to be connected with a source of products of combustion, a second conduit arranged to conduct water in counterflow heat exchange relation to said products of combustion in the first mentioned conduit to heat said water to a high temperature and a high pressure, an expansion chamber connected with said water conduit to receive the heated water therefrom, convert a portion thereof into steam and expand said steam to impart velocity energy to the mixture of steam and water, means to separate the steam from the water, means to deliver the separated steam under pressure to a point of use, means to return the separated water under pressure to said water conduit, and means to supply make-up water to said water conduit, said returned water and said make-up water being delivered to said water conduit at separated points so arranged that the products of combustion in the first mentioned conduit will act first on said return water and thereafter on said make-up water, thereby utilizing a relatively large part of the heat of the products of combustion.

3. In a steam generator, a conduit adapted to be connected with a source of products of combustion, a second conduit arranged to conduct water in counterflow heat exchange relation to said products of combustion in the first mentioned conduit to heat said water to a high temperature and a high pressure, means for connecting said water conduit near that end thereof which is remote from said source of said products of combustion with a source of water supply, means connected with said water conduit to receive said heated water therefrom, convert a portion of said water into steam and expand said steam to impart velocity energy to the mixture of steam and water, means for separating the steam from the water and delivering said steam to a point of use, and means for returning the separated water under pressure to said water conduit at a point spaced from said means for connecting said water conduit with said source of water supply in the direction of flow of the water in said water conduit.

4. In a steam generator, a conduit adapted to be connected with a source of products of combustion, a second conduit arranged to conduct water in counterflow heat exchange relation to said products of combustion in the first mentioned conduit to heat said water to a high temperature and a high pressure, means connected with said water conduit to receive said heated water therefrom, convert a portion of said water into steam and expand said steam to impart velocity energy to the mixture of steam and water, a steam chest, means for separating the steam from the water and delivering the separated steam under pressure to said steam chest, means for returning the separated water under pressure to said water conduit at a point between the ends thereof, and means for supplying make-up water to said water conduit near that end thereof which is remote from said source of said products of combustion.

5. In a steam generator, a conduit adapted to

be connected with a source of products of combustion, a second conduit arranged to conduct water in counterflow heat exchange relation to said products of combustion in the first mentioned conduit to heat said water to a high temperature and a high pressure, an expansion chamber connected with said water conduit to receive heated water therefrom, convert a portion thereof into steam and expand said steam to impart velocity energy to the mixture of steam and water, a centrifugal separator connected at one end with said expansion chamber to receive said mixture and separate the steam from the water and having at its other end a compression nozzle to convert velocity energy of said separated water into pressure energy, means for connecting said compression nozzle with said water conduit at a point between the ends of the latter, means for supplying make-up water to said conduit in advance of the point of connection of said compression nozzle with said water conduit, and means for delivering the separated steam to a point of use.

6. In a steam generator, a conduit adapted to be connected with a source of products of combustion, a second conduit arranged to conduct water in counterflow heat exchange relation to said products of combustion in the first mentioned conduit to heat said water to a high temperature and a high pressure, a tubular device connected with said water conduit to receive therefrom water at high temperature and high pressure and having at its intake end a part forming an expansion nozzle to convert a portion of said water into steam and expand said steam to impart velocity energy to a mixture of steam and water, said device having an intermediate arcuate portion provided in its inner side with an outlet to separate the steam from the water, and said device also having at its other end a compression nozzle to convert velocity energy of the separated water into pressure energy, means for connecting said compression nozzle with said water conduit, and means for delivering steam from said outlet to a point of use.

7. In a steam generator, a conduit adapted to be connected with a source of products of combustion, a second conduit arranged to conduct water in counterflow heat exchange relation to said products of combustion in the first mentioned conduit to heat said water to a high temperature and a high pressure, a tubular device connected with said water conduit to receive therefrom water at high temperature and high pressure and having at its intake end a part forming an expansion nozzle to convert a portion of said water into steam and expand said steam to impart velocity energy to a mixture of steam and water, said device having an intermediate arcuate portion provided in its inner side with an outlet to separate the steam from the water, and said device also having at its other end a compression nozzle to convert velocity energy of the separated water into pressure energy, means for connecting said compression nozzle with said water conduit, a steam chest, means for delivering the separated steam to said steam chest, means for withdrawing steam from said steam chest and using the same in the performance of work, means for condensing the steam and returning the same to said water conduit, and means for supplying make-up water to said water conduit at a point in advance of the point at which said separated water is delivered to said water conduit.

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