

1

2,757,618

THERMOPUMP

Nils Erland af Kleen, North Stonington, Conn., assignor to Jet-Heet, Inc., Englewood, N. J., a corporation of New York

Application September 26, 1952, Serial No. 311,694

7 Claims. (Cl. 103—255)

This invention relates to improvements in pumps, and particularly to an improved thermally actuated pump, referred to herein as a thermopump.

The usual elements of a thermopump of the type with which the present invention is concerned comprise a heating or vapor generating chamber in which liquid may be vaporized, and a condensing chamber connected to the generator chamber by a vapor conduit to provide an area in which to condense vapor produced in the generator chamber. The condenser and generator chambers also are connected by a conduit permitting the flow of liquid therebetween. For simplicity and economy of parts, it is customary to use ordinary metal tubes for the various chambers and conduits.

In operation, the various tubes comprising the pump are initially filled with liquid. Heat is then applied continuously to a portion of the generator. The liquid vaporized within the generator creates pressure within the pump system and forces a portion of the liquid from the system through a check valve. When vapor completely fills the vapor conduit and reaches the relatively cool liquid in the condenser, condensation of the vapor immediately commences, ultimately resulting in a drop in the pressure within the system. The liquid which has been discharged from the pump system through the check valve cannot be drawn back into the pump to restore the equilibrium. With the system connected to a supply of liquid through a second check valve, the pressure reduction accompanying condensation will cause the system to refill through this second check valve.

Accordingly, the pumping cycle is started by the pressure of vaporization which forces liquid from the pump. When the vapor flows out of the generator through the vapor tube, liquid flows through the generator into the vapor tube, with the result that further vaporization does not take place during condensation. As the condensation continues, a pressure drop occurs which causes fresh liquid to be drawn into the system to replace that forced out during the vaporization stage. When equilibrium is once again established and the flow of liquid through the system ceases, the generator again vaporizes more liquid and the cycle is repeated.

At one time, the utility of such pumps was seriously impaired by the fact that they would generally cease functioning in an unpredictable period of time; usually a matter of hours. Non-functioning appeared to be the result of the generator running dry due to failure of condensation.

In U. S. Patent No. 2,553,817, I have shown how the operation of a thermopump may be so prolonged as to operate indefinitely without failure, by interposing a reservoir adapted to hold a body of the liquid in the connection between the lower end of the condenser tube and generator tube. In the same patent, I have also shown how further improvement in thermopump operation can be obtained by immersing the above-mentioned reservoir in a body of the liquid being pumped.

I have now discovered that this latter immersion prin-

2

ciple can be utilized to much greater advantage by surrounding a substantial part of the condensing tube itself with a constantly replenished layer of the liquid being pumped. In other words, in accordance with my present invention, what is contemplated is a thermopump condenser arranged as part of a heat exchanger structure wherein the liquid being pumped is utilized to cool the condenser wall, both to insure temperature stability and to provide for very rapid or "shock" condensation of accumulated vapor. With such an arrangement, I have found that it is possible to materially reduce the overall dimensions of a thermopump as well as to considerably simplify its manufacture without adversely affecting the improved operation described in my above-mentioned patent. Rather, a more rapid pumping action results due to more rapid condensation.

A more complete understanding of my present invention can be had by reference to the following description of illustrative embodiments thereof, when considered in connection with the accompanying drawing, wherein

Figs. 1 and 2 are side views, partly in section, of thermopumps arranged in accordance with the present invention, and

Fig. 1a is a fragmentary view of a thermopump corresponding to the pump of Fig. 1, illustrating a modification of the heat exchanger jacket construction.

As shown in Fig. 1, the heat operated pump of my present invention comprises an upright heating tube or generator 10, contacted by a metallic conductor 12 which carries heat from the flame of a burner 14, or other suitable heat source, to the side walls of the generator 10. The conductor 12 is covered with heat insulation 16 in order to insure a relatively high temperature at the unheated end of the conductor which makes contact with the generator.

The upper end of the generator tube is provided with an inverted U-shaped bend 18. The bend serves as a trap to accumulate vapor as it is formed in the heated portion of the generator. The end of the bend 18 communicates with a vapor line 20 which is of considerably smaller cross-section than the heating tube 10 in order to insure delivery of the vapor to the condenser tube as a coherent body rather than as a series of bubbles.

The vapor tube 20 slopes upwardly from the end of the heating tube to the upper portion of an upright condensing tube 22. The condensing tube is of substantially the same cross-sectional size as the generator 10 and is adapted to hold a body of liquid in communication with the liquid in the generator. Since a reservoir such as is described in my above-mentioned patent is not required in the thermopump of my present invention, the heating tube 10 and the condensing tube 22 advantageously can be of one-piece construction, formed by suitably bending a continuous length of tubing to the shape illustrated. The upper end of the condenser is connected to an inlet-outlet tube 24 communicating with a valve assembly 26 which includes an outlet valve 34 and an inlet valve 36 for controlling the discharge of liquid from and the delivery of liquid to the pump system. The lower end of the condenser 22 is joined to the generator 10 by a connecting portion 23.

In accordance with an important feature of the present invention, a heat exchanger structure is provided for controlling the temperature of the condenser, and particularly for chilling the condenser immediately adjacent the vapor delivery point. In the embodiment of the invention shown in Fig. 1, this heat exchanger structure comprises a jacket 28 enveloping the condenser 22 throughout a substantial part of its length, up to a point just below the vapor delivery tube. Both ends of the jacket 28 are sealed to the condenser tube, so that part of the condenser wall is common to the condenser and

3

heat exchanger chambers. An inlet line 30 is coupled to the jacket 28 at the upper end thereof. From the lower end of the jacket 28, a coupling line 32 leads to the inlet valve 36. It will be understood that the inlet valve 36 can as well be connected in the inlet line 30, rather than between the coupling lines 24, 32 as shown.

Assuming that the pump is completely full of liquid, heat applied to the generator 10 will cause generation of vapor which will collect in the inverted U-shaped portion 18 of the generator tube. The generation of vapor within the pump system will be accompanied by an increase in the pressure within the system. This pressure increase will cause liquid to be forced through the outlet valve 34. The vapor will continue to form and to displace the liquid in the vapor tube 20 until the vapor reaches the body of relatively cool liquid in the upper portion of the condensing tube 22. The resulting contact between vapor and the small cross-sectional mass of liquid will initiate condensation of the vapor. As condensation of the vapor proceeds, the difference in liquid level between the liquid in the upper portion of the condensing tube 22 and the liquid in the heating zone of the generator 10 will cause the liquid to flow upwardly through the heating tube. The resulting ingress of relatively cool liquid into the heating zone will terminate further vaporization momentarily and expedite the condensation taking place in the upper portion of the condensing tube. Thus, once condensation is initiated it will continue rapidly and will quickly establish a partial vacuum in the pump system. Under these conditions, liquid will flow into the pump system through the inlet-outlet 24, the inlet valve 36, the coupling line 32, the jacket 28 and the line 30, with the result that relatively cool liquid will flow into the upper portion of the jacket 28 and on into the condenser chamber until the pressure within the system returns to normal. At this point in the operating cycle, the liquid again will substantially completely fill the pump system. The continued application of heat to the generator 10 once again will establish vaporizing conditions therein and the pump cycle will be repeated.

As compared with the pump described in my above-mentioned patent, wherein cold liquid from the supply source is utilized primarily to cool the coupling line between the generator and the condenser, the arrangement just described wherein a portion of the condenser wall is immersed in the liquid being pumped and thereby chilled immediately adjacent the vapor delivery point appears to provide a marked improvement in operating characteristics.

It has been found that the circulation of relatively cool liquid through the heat exchanger jacket 28 not only assists in keeping the temperature of the condenser 22 below the critical non-condensing value, but has the additional effect of producing what may be termed "shock condensation" by exposing the part of the pump into which the vapor is discharged to a chilling flow of liquid. In other words, as soon as condensation starts, cool liquid will start to flow into the upper end of the jacket 28. At the same time, vapor will be drawn down through the tube 22 by the clockwise rotational liquid flow already described. Therefore, this vapor will be brought into contact with the condenser wall surface that is being chilled by the incoming cool liquid, causing very rapid and positive "collapse" of the accumulated vapor and a consequent rapid and powerful suction stroke.

From the standpoint of simplicity of construction, the embodiment of the invention shown in Fig. 1 constitutes a preferred arrangement. As already stated, the generator and condenser 18, 10, 22 may comprise a single length of tubing bent to the desired shape. In the reservoir-type pump shown in my above-mentioned patent, such an arrangement is somewhat impractical because of the relatively long tube that would be required to provide a reservoir or cooling element, of sufficient volume between the generator and condenser proper.

4

To keep the construction as simple as possible, the upper end of the jacket 28 terminates just below the vapor tube connection to the condenser. On the other hand, chilling and condensation can be improved by extending the heat exchanger above the vapor delivery point. Such a construction is illustrated in Fig. 1a, wherein only the upper part of the condenser and heat exchanger elements 22, 28 are shown with the associated tubes 20, 24, 30. In the Fig. 1a construction, the jacket 28 extends above the vapor delivery point, with the vapor tube 20 passing through the wall of the jacket 28 to open into the condenser 22. This arrangement somewhat improves the shock condensation effect, although is slightly more complicated to assemble.

A further alternative arrangement is shown in Fig. 2, wherein the parts also are arranged so that the cool liquid flowing into the heat exchanger structure can be brought into contact with the condenser walls both above and below the point of vapor delivery, but without complicating the connection of the vapor tube to the condenser.

To this end, the pump shown in Fig. 2 comprises a generator tube 10 and vapor tube 20 identical to the corresponding parts in Fig. 1. In Fig. 2, however, the lower end of the generator tube communicates with a condenser jacket 42, surrounding a heat exchanger tube 44. The vapor tube 20 is accordingly connected to the upper portion of the condenser jacket 42, and an inlet-outlet tube 24 communicates between the upper end of the jacket 42 and the check valves 34, 36.

From the inlet check valve 36, a coupling line 32 extends to the bottom of the heat exchanger tube 44, and an inlet line 30 is connected to the top of the tube 44. The lower end of the generator tube 10 communicates with the bottom of the condenser jacket 42.

An alternative arrangement for supplying heat energy to the pump also is shown in Fig. 2, wherein the heating means comprises a high resistance electrical conductor 46, wound on a thin coating or layer of insulation 48, such as mica or the like, on the upright portion of the generator 10, and covered by a layer of heat insulating material 50, such as glass wool.

With the arrangement just described, the functioning of the apparatus will be substantially the same as that of the pump shown in Fig. 1, except that the cool incoming liquid will flow past the inside wall of the condenser 42, rather than the outside wall. Of course, the single tube generator-condenser structure of the Fig. 1 pump cannot be utilized in the Fig. 2 construction, but in some instances it may be found that the benefits of increased cooling about the point of vapor delivery to the condenser will entirely justify the slight structural complication. Moreover, with the Fig. 2 arrangement, additional cooling of the condenser jacket can readily be provided by fins 52 extending along the outside surface thereof.

From the foregoing, it can be seen that the present invention provides an improved thermopump wherein the relatively cool liquid drawn in on each intake stroke of the pump is utilized to effect extremely rapid cooling and condensation of vapor in a simple and efficient manner.

I claim:

1. In a thermally actuated pump capable of delivering a liquid under pressure, a closed system including a vapor generator chamber provided with means for heating liquid in the chamber to a vaporizing temperature, a condenser chamber adapted to contain liquid for condensing vaporized liquid produced in said generator chamber and conveyed to said condenser chamber, a vapor tube connecting the upper portion of said generator chamber to the upper portion of said condenser chamber for conveying vapor produced in the upper portion of said generator chamber to the upper portion of said condenser chamber, connection means providing liquid communication between the lower portions of the generator and condenser chambers, and a heat exchanger structure com-

5

6

prising a chamber providing a path for liquid being drawn into the pump to flow in contacting heat exchange relation with said condenser chamber, said condenser chamber and said heat exchanger chamber having a common wall immediately adjacent the area of contact between said vapor delivery tube and said condenser chamber.

2. In a thermally actuated pump capable of delivering a liquid under pressure, a closed system comprising a continuous tube having a first upright portion terminating in on inverted U and provided with means for heating liquid in said first portion to a vaporizing temperature, a second and longer upright portion adapted to contain liquid for condensing vaporized liquid produced in said first portion and conveyed to said second portion, a lateral portion connecting the lower ends of said upright portions, and a vapor tube portion extending from said inverted U to the upper part of said second upright tube portion for conveying vapor collected in said U-shaped tube portion to the upper part of said second upright tube portion, and a heat exchanger jacket surrounding a section of said second upright tube portion adjacent said vapor tube.

3. In a thermally actuated pump capable of delivering a liquid under pressure, a closed system including an inverted U-shaped vapor generator tube, a substantially vertically disposed vapor condenser tube adapted to contain liquid for condensing vaporized liquid produced in said generator tube and conveyed to said condenser tube, one leg of the inverted U being provided with heating means adapted to substantially continuously heat liquid contained in said generator tube, connection means providing liquid communication between the lower end of said heated leg of said generator tube and the lower portion of said condenser tube, a vapor tube for conveying vapor produced in said generator tube to said condenser tube, said vapor tube communicating between the lower end of the other leg of said generator tube and a portion of said condenser tube located above the level of the top of said inverted U-shaped tube, and a heat exchanger structure comprising a jacket enclosing said condenser tube from said connection means at least up to a point just below the point of delivery of vapor to said condenser tube.

4. A pump as defined in claim 3 wherein said jacket encloses said condenser tube both above and below said point of vapor delivery.

5. In a thermally actuated pump capable of delivering a liquid under pressure, a closed system including an inverted U-shaped vapor generator tube, a substantially vertically disposed heat exchanger tube, a condenser chamber comprising a jacket enclosing said heat exchanger tube and adapted to contain liquid for condensing vaporized liquid produced in said generator tube and conveyed to the condenser chamber, one leg of the inverted U being provided with heating means adapted to substantially continuously heat liquid contained in said generator tube, connection means providing liquid communication between the lower end of said heated leg of said generator tube and the lower portion of said condenser chamber,

a vapor tube for conveying vapor produced in said generator tube to said condenser chamber, said vapor tube communicating between the lower end of the other leg of said generator tube and a portion of said condenser chamber located above the level of the top of said inverted U-shaped tube, and connection means communicating between the upper portion of the condenser chamber and the lower portion of the heat exchanger tube.

6. A thermally actuated pump capable of delivering a liquid under pressure comprising a closed system including a vapor generator chamber provided with means for heating liquid in the chamber to a vaporizing temperature, a condenser chamber adapted to contain liquid for condensing vaporized liquid produced in said generator chamber and conveyed to said condenser chamber, a vapor conduit connecting the upper portion of said generator chamber to the upper portion of said condenser chamber for conveying vapor produced in the upper portion of the generator chamber to the upper portion of the condenser chamber, connection means providing liquid communication between the lower portions of the generator and condenser chambers, a heat exchanger structure comprising a chamber providing a path for liquid being drawn into the pump to flow in contacting heat exchange relation with said condenser chamber, said heat exchanger and condenser chambers having a common wall immediately adjacent the point of connection of said vapor delivery tube to said condenser chamber, and valve means in said system adapted to permit discharge of the liquid from the system by the pressure produced within the system upon vaporization of the liquid in the generator chamber and adapted to permit drawing of additional liquid into the system through said heat exchanger chamber upon a lowering of the pressure within the system by condensation of said vapor in said condenser chamber.

7. In a thermally actuated pump of the type comprising a liquid filled system within which to generate and condense vapor and including walls defining a condenser comprising a generally vertically disposed chamber, a vapor tube communicating with the upper portion of said chamber for delivering vapor thereto, liquid supply means communicating with said chamber for conducting liquid thereto upon condensation of vapor in said chamber, the improvement which comprises a heat exchanger structure forming a part of said liquid supply means, said heat exchanger structure comprising a chamber having a wall portion common to that portion of said condenser chamber defining wall which is immediately adjacent the point of delivery of vapor to said condenser chamber so that liquid flowing into said system through said heat exchanger structure will contact said common wall portion to chill said common wall portion.

References Cited in the file of this patent

UNITED STATES PATENTS

2,015,240	Scott-Snell	Sept. 24, 1935
2,553,817	Kleen	May 22, 1951