Sept. 24, 1935. E. SCOTT-SNELL ET AL 2,015,240

THERMALLY ACTUATED PUMP

Filed May 18, 1934 2 Sheets-Sheet 1

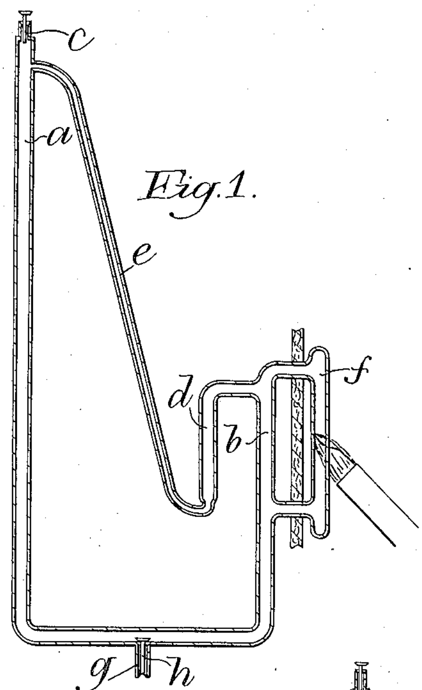

Fig.1.

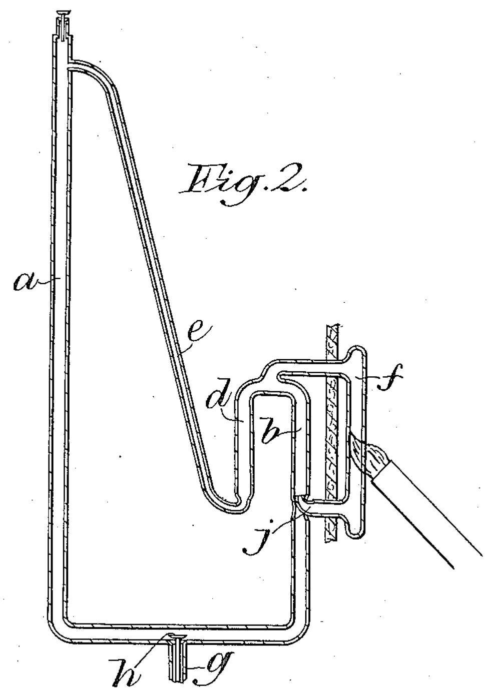

Fig.2.

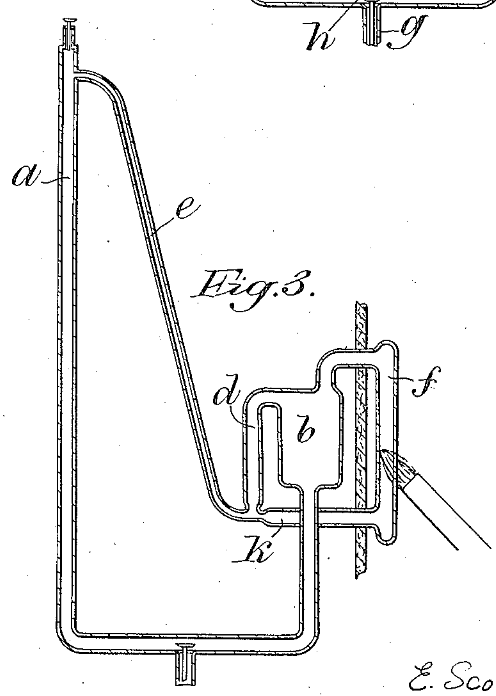

Fig.3.

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THERMALLY ACTUATED PUMP

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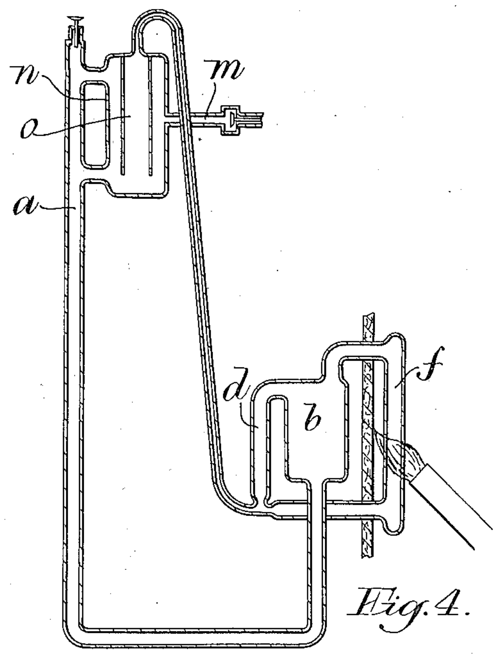

Fig. 4.

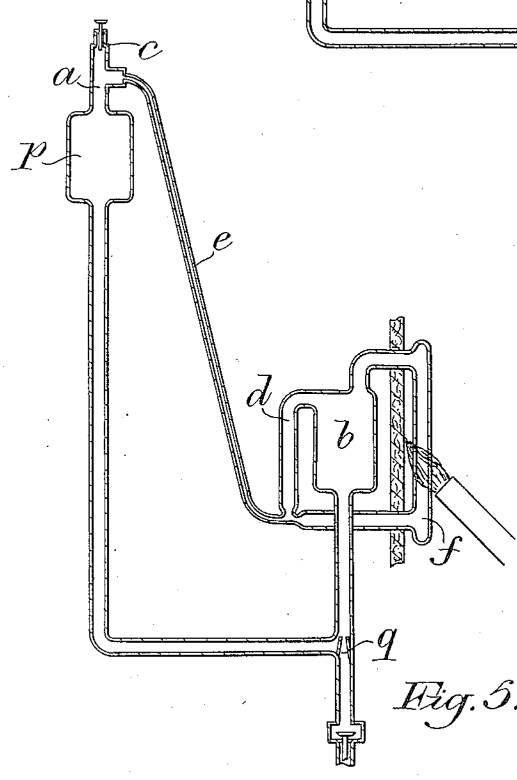

Fig. 5.

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THERMALLY ACTUATED PUMP

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Application May 18, 1934, Serial No. 726,362
In Great Britain July 11, 1933

6 Claims. (Cl. 103—255)

This invention relates to thermally actuated pumps of the kind wherein cyclic pulsations are produced entailing the expulsion of vapor through a vapor outlet duct from liquid in a constantly heated envelope vapor generator accompanied by delivery of liquid displaced by such vapor past a non-return outlet valve followed by the inspiration of liquid into a cool inlet duct past a non-return inlet valve.

Examples of such pumps are disclosed in Patents Nos. 1,773,551 and 1,848,226.

In pumps of this kind as hitherto constructed the generator with its whole contents is heated at each stroke thus entailing a high working temperature throughout the pump because, although only a small amount of liquid need be heated to boiling point to produce the necessary vapor for a stroke, in actual fact a great deal more than this is heated and consequently circulated through the pump thus entailing a higher working temperature than is fundamentally necessary.

Now it has been found as a result of experiment and in practice that the reliability and continued action of such pumps depends to a very marked extent on the temperature of the pump system as a whole. A criterion of success is in fact the heat content (i. e. the product of volume, specific heat and temperature) of the liquid left in the system at the end of the expulsion stroke (i. e. just before intake).

It is of first importance, therefore, if reliability and pumping against considerable pressure are to be attainable, to ensure that heat is applied in such a manner as to ensure the generation of the maximum amount of working vapor for the minimum rise in temperature of the liquid in the cylinder and the achievement of this result is the main object of the present invention.

It is also of importance to introduce the incoming liquid at such a point that it will have a high cooling effect on the vapor generator.

In pumps of this kind we have also observed that a delayed action in condensing is in many cases desirable as, for example, as described in Patent No. 1,848,226.

In the simplest form of pump, generation of vapor in the generator during the intake stroke, i. e. suction period, is prevented by the "quenching" or cooling action resulting from the hydraulic swing.

It should be realized that steam or other vapor is always generated at the point where heat is applied. Thus, if a quantity of water exists in a receptacle above the point of heat application, it is obviously necessary before steam can be released above the surface of the liquid that the whole of the liquid above the point of heat application be raised to a temperature corresponding to the boiling point of the liquid. (At temperatures of liquid below boiling point, the steam bubbles generated will merely pass into the liquid and be condensed therein, but at the boiling point the steam bubbles will be able to pass through the liquid).

The present invention takes account of this physical phenomenon and provides for the heating of only a small portion of the liquid to produce the necessary quantity of vapor, this being achieved by subdividing the generator cylinder into a heated and an unheated portion.

Therefore, according to the main feature of the present invention, we subdivide the vapor generator into a heated and an unheated portion, these portions being connected together in parallel by way of unrestricted conduits, the heated portion being of small volumetric capacity but having a large heating surface, and we provide means ensuring that a considerable cooling of the system is effected at each stroke.

According to a further feature of the present invention, we provide means controlled by hydraulic swing whereby access of the liquid to the generator is delayed for a sufficient period to enable the internal pressure to drop to a value below that of the source of liquid supply to the pump.

Conveniently such means ensure that regeneration of vapor in the generator cannot take place until such time as the pump is completely refilled as a result of the intake stroke by cutting off the liquid supplied to the boiler.

Referring to the accompanying diagrammatic drawings:—

Figure 1 illustrates one convenient arrangement of pump embodying the present invention.

Figure 2 illustrates a modified arrangement, and

Figures 3 to 5 illustrate further modified arrangements.

In carrying the invention into effect in one convenient form illustrated by way of example in Figure 1, we provide a U-shaped tube having limbs *a* and *b* of unequal length, the longer limb *a* terminating in a non-return outlet valve *c* and constituting a condenser and the shorter limb having a downwardly projecting extension *d*, the lower end of which is connected by a small bore pipe *e* with the longer limb *a* at a point in the region of the outlet valve *c*.

The limb *b* is connected at its upper and lower ends with a receptacle *f* of small volumetric capacity constituting a generator proper to which heat is continuously applied and an inlet connection *g* including a non-return inlet valve *h* is made to the U-shaped tube in a section between *a* and *b* preferably the lower position available.

In operation, assuming the device to be entirely filled with liquid, say water, heat is continuously applied to the generator proper *f* and this results in the formation of steam at the upper end thereof which depresses the water levels in the generator *f*, in the limb *b* and in the extension *d*, and, at the same time, causes water to be discharged past the outlet valve *c* owing to the pressure produced. This action continues until the aforesaid water levels drop to that of the lower end of *d* whereupon steam will pass upwards through the small bore pipe *e*. Immediately this occurs hydraulic instability is produced owing to the removal of water from the tube *e* (displaced by steam in an upward direction) with the result that water will flow within the device from the limb *a* to the limb *b* in a downward direction along *a*, thus tending to restore the original water levels therein. This phenomenon is in the nature of a "hydraulic swing" (in a counterclockwise direction in Figure 1). It is desirable that the diameter of this connecting pipe *e* be sufficiently small to ensure that all liquid will be "pistoned" out before the vapor. Moreover, by making the bore of the tube *e* less than that of the tube *a*, *b*, *d*, a magnification of hydraulic head—known as "velocity tube effect"—takes place. As soon as steam reaches the limb *a*, however, condensation takes place accompanied by the reduction of pressure. The generation of vapor in the generator proper is discontinued by the rapid inflow of cold liquid, the coldness having been secured by the previous cold intake stroke, produced by the hydraulic swing. As soon as the pressure is reduced below that acting beneath the non-return inlet valve *h* the latter will open to admit a fresh supply of water from the source of supply to the pump.

With the above arrangement it will be appreciated that considerably less heat is required to produce a complete stroke of the pump than would be required if heat were applied directly to the limb *b* and consequently the temperature throughout the pump is lower and since the limits of pressure between which the pump fluctuates must depend upon the temperature of the condenser and pump system which, in turn depends upon the heat got rid of—

(1) By passing it out as sensible heat in the delivery liquid;

(2) By the reduction of temperature of the remaining liquid and envelope by the incoming cool water,

the less heat actually used to cause the outstroke the greater will be the range of possible fall in temperature upon the hydraulic turnover taking place and consequently the less the possibility of the residual liquid reaching such a temperature that its vapor pressure is above that of inlet pressure—a condition which must result in failure of pumping action—and the greater the range between the maximum and minimum pressures at which the pump can function.

In cases where the pump operates with liquids having gases absorbed therein, e. g. ammonia-water solutions, the reduction of pressure producing the ultimate opening of the inlet valve at each stroke may be produced by reabsorption of the gas.

In carrying the invention into effect according to a modified construction illustrated in Figure 2 applicable in particular to pumps intended to supply a considerable quantity of liquid per stroke or for delivery against considerable pressure, we provide a similar form of U-shaped tube *a b* with downward extension *d* and small bore connecting pipe *e* from the lower end of *d* to the limb *a* together with a receptacle *f* forming a generator proper connected to the limb *b* but provide the lower connection *j* between the generator *f* and the limb *b* with an upturned end, the arrangement being such that when liquid moves upwards past this upturned end (within the limb *b* of the U-shaped tube) an ejector action is produced which prevents liquid from entering the lower end of the generator proper *f* as long as the liquid is in motion.

The operation of this arrangement is similar to that described above up to the point when the hydraulic instability begins to develop.

Instead of the receptacle and end *b* of the U-shaped tube being both rapidly flooded with liquid from the longer limb, however, inflow of liquid to the lower end of the generator *f* is prevented by the ejector action (whilst the transfer of vapor from the limb *b* to the limb *a* is not interfered with) and consequently the action of the generator proper *f* is delayed until the hydraulic turnover is completed and until the intake stroke (i. e. refilling of the pump) is well advanced.

According to a further modification illustrated in Figure 3 in which a delay action is provided in the action of the generator proper, this modification being especially applicable to pumps intended for the delivery of a considerable quantity of liquid or for delivery against a considerable pressure, we connect the lower end of the generator proper *f* by a pipe *k* to the lower end of the downward extension *d* instead of connecting it to the limb *b*.

The operation of this device is similar to that described above in that access of liquid to the generator proper *f* is delayed pending a reduction in pressure to a sufficient extent to initiate the intake stroke following thereon owing to there being nothing but vapor in this lower connection *k* until all vapor has been transferred from the limb *b* to the condenser section at *a*, i. e. *b* can fill completely before any liquid can reach *f*.

According to a further modification as illustrated in Figure 4 the inlet connection *m* to the device instead of being made to the U-shaped tube itself is made to an auxiliary receptacle *n* connected at its upper and lower ends with the longer limb *a* of the U-shaped tube in the region of the outlet valve *c*, this auxiliary receptacle containing at its upper end the depending and preferably enlarged end *o* of the tube *e* leading from the lower end of the downwardly projecting extension from the limb *b* of the U-shaped tube.

With this arrangement the depending tube *o* within the auxiliary receptable *n* constitutes a comparatively inefficient condenser and consequently vapor or gas tends to remain momentarily uncondensed therein, thus permitting of a more violent hydraulic swing in the first instance and subsequently tending to prevent any liquid from finding its way down the tube *e* (and thus feeding the generator) until the whole system is completely filled with liquid.

With this arrangement, moreover, liquid expelled on the outstroke carries away sensible heat without the same appreciably raising the temperature of the condenser *n*, *o*.

In applying the invention to pumps for pumping oil, such, for example, as paraffin, it is preferred that in no circumstances the heated receptacle shall boil completely dry since such action tends to produce the formation of solid deposits within the heated receptacle.

According to a further modification as illustrated in Figure 5 the results obtained in the preceding example (i. e. a quick hydraulic swing and the prevention of liquid returning prematurely down the pipe *e* connecting the two limbs *a b* of the U tube) are obtained in a more simple manner by omitting the auxiliary receptacle *n* of Figure 4 and connecting the small bore connecting pipe *e* with the limb *a* at its highest point. The upper end of this limb *a* constitutes a relatively inefficient condenser but the limb is enlarged in section at *p* at a point somewhat below its upper end to give efficient condensing action at this point. The liquid inlet connection is made in injector form at *q* so as to tend to promote circulation in the U tube in a direction down the limb *a* thus to counteract any tendency for liquid to be drawn down the tube *e* (and thus to cause premature regeneration of vapor).

Having now described our invention, what we claim as new and desire to secure by Letters Patent is:—

1. A thermally actuated pump of the kind indicated including a generator comprising a heated portion having a considerable heating surface but small volumetric capacity and an unheated portion, unrestricted conduits between said portions, a cool-inlet duct, an outlet duct for pumped liquid, a connection from one end of the unheated portion to said duct, a vapor outlet duct and a connection therefrom to the other end of said cool-inlet duct whereby a progressive though intermittent forward movement of liquid is produced in said unheated portion.

2. A thermally actuated pump as claimed in claim 1 including also means controlled by a hydraulic swing effecting delay in access of liquid to the said heated portion of the generator thereby enabling the internal pressure in the boiler to drop below that of the liquid supply source.

3. A thermally actuated pump as claimed in claim 1 including means controlled by a hydraulic swing comprising an injector through which the liquid is caused to pass upon occurrence of the hydraulic swing thereby effecting delay in access of liquid to the generator thereby enabling the internal pressure in the generator to drop below that of the liquid supply source.

4. A thermally actuated pump as claimed in claim 1 including also means controlled by a hydraulic swing comprising a connection from the heated portion to the vapor outlet duct at the region of the junction between the latter and the unheated portion.

5. A thermally actuated pump as claimed in claim 1 including also means controlled by a hydraulic swing comprising a connection from the heated portion to the vapor outlet duct at the region of the junction between the latter and the unheated portion together with means comprising a downward extension of the upper end of the said vapor outlet tube serving as an inefficient condenser.

6. A thermally actuated pump as claimed in claim 1 including also means controlled by a hydraulic swing comprising an injector disposed in the cool liquid inlet duct.

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