

Jan. 31, 1961

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2,969,747

HEAT ACTUATED PUMPS

Filed March 28, 1957

2 Sheets-Sheet 1

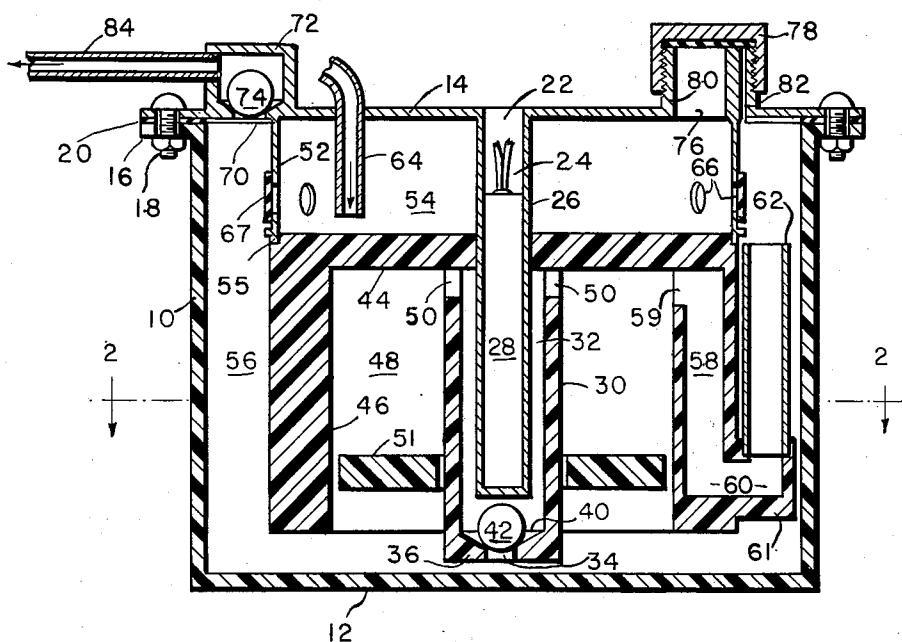


FIG. 1.

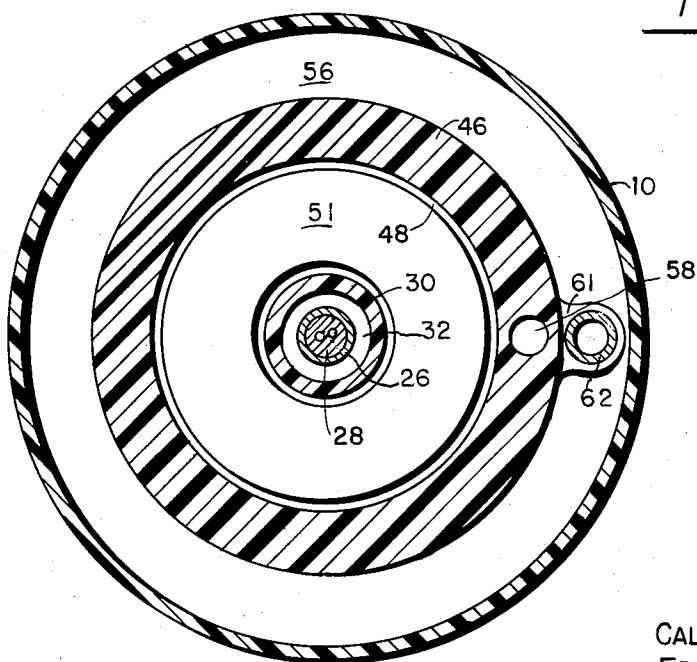


FIG. 2.

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2 Sheets-Sheet 2

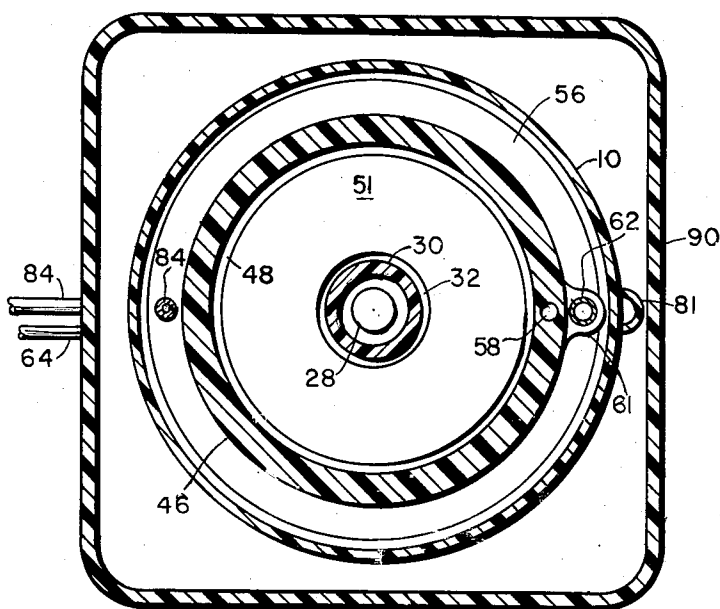


FIG. 4.

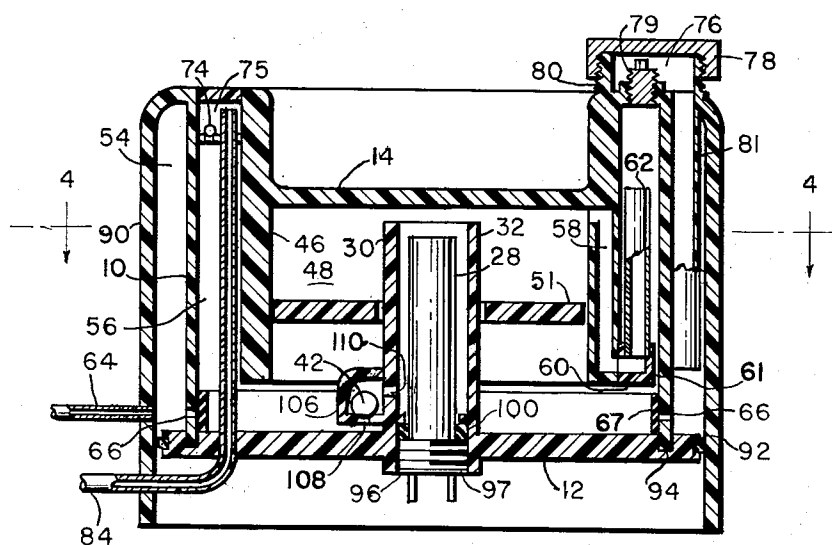


FIG. 3.

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2,969,747

HEAT ACTUATED PUMPS

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14 Claims. (Cl. 103—255)

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

It has previously been proposed to make a heat-actuated pump comprising a closed system of tubes and vessels wherein a liquid is alternately vaporized and condensed to produce volumetric changes within the pump. By connecting the system to a liquid supply source and a delivery point through a pair of check valves, these volumetric changes can be utilized to induce liquid flow from the source to the delivery point, as in U.S. patent to Kleen, 2,553,817.

The present invention has as a general object the provision of an improved thermopump characterized by simplicity and economy of manufacture as well as by efficient and trouble-free operation. More specifically, it is among the objects of the invention to provide a thermopump that lends itself to incorporation of inexpensive components that can be assembled by relatively unskilled personnel, and in which liquid leakage and heat loss problems are minimized.

In accordance with a preferred embodiment of the invention, the foregoing and other related objects and advantages are attained in a thermopump wherein the principal parts are enclosed within a liquid-tight shell, and the various chambers or compartments are defined by partitions dividing up the space inside the shell. In such an arrangement, the problem of leakage is not material because any leakage that may occur between the several compartments will not materially affect the operation and will not involve loss of liquid from the pump. Again, this configuration leads to saving of heat because those parts wherein heat is needed can be placed one within another. Moreover, such a configuration eliminates the need for certain connecting tubes and components required in systems wherein the principal parts are completely separate and self-contained, and makes possible considerable saving in fabrication cost, as well as eliminating potential leakage at tubing joints.

A more complete understanding of the invention, and of further objects and features thereof, can be obtained from the following description of illustrative embodiments thereof, when considered in connection with the accompanying drawing, wherein

Figure 1 is a sectional elevation of a thermopump embodying the present invention,

Figure 2 is a sectional plan view of the pump of Figure 1, taken on the line 2—2 of Figure 1,

Figure 3 is a sectional elevation of a modified form of thermopump embodying the present invention, and

Figure 4 is a sectional plan view of the pump shown in Figure 3.

Referring to Figure 1 of the drawing, a thermopump embodying the invention is shown to comprise an outer shell in the form of an upright cylinder 10 which encloses the various compartments of the pump described hereinafter.

The cylinder 10 includes an integral bottom plate 12

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and, preferably, a removable cover plate 14 which is clamped to a flange 16 by nuts and bolts 18 or the like to provide ready access to the internal parts described hereinafter. A gasket 20 between the cover plate 14 and the flange 16 provides a liquid tight seal between the parts 14, 16.

A central opening 22 in the cover plate 14 provides access to an elongated chamber 24 defined by a cylindrical wall member 26 which extends downwardly into the lower part of the shell 10 from the cover plate 14. This central cylinder 26 is closed at its lower end to form a liquid tight housing for an electrical heater cartridge 28 which can be inserted readily through the cover opening 22.

The space inside the shell 10 is divided into several compartments or chambers by partition means which include a first cylindrical partition 30. This partition 30 surrounds the lower portion of the central wall 26 to define therewith an annular chamber 32 within which to vaporize liquid by heat from the cartridge 28 passing through the inner chamber wall 26. A liquid inlet to the vaporizing chamber 32 is provided by an opening 34 in a bottom wall 36 of the partition 30. The inside surface of the bottom wall 36 is tapered to provide a seat 40 for a valve ball 42 which will permit liquid to flow into but not out of the chamber 32.

The partition 30 extends downwardly from and may be formed integrally with a lateral partition 44 which extends from the central wall 26 and terminates short of the wall of the shell 10. Depending from the periphery of this lateral partition 44 and, preferably, formed integral therewith, is a second cylindrical partitioning member 46 which extends downwardly within the shell 10, terminating just above the bottom plate 12.

This partition 46 cooperates with the partition 30 to define an annular chamber 48 within which to collect vapor formed in the vaporizing chamber 32. Vapor transfer passages between the vaporizing chamber 32 and the vapor collecting chamber 48 are provided by a plurality of openings 50 in the upper part of the intermediate partition 30. The vaporizing chamber preferably contains an annular float 51 for separating the liquid and vapor in the collector 48.

In some instances, as explained hereinafter, the lateral partition 44 may be coincident with the cover plate 14, but in the embodiment of the invention presently being described, the partition 44 is spaced from the cover plate 14 by an auxiliary cylindrical partitioning member 52 which encloses a pressure accumulator chamber 54, considered in detail hereinafter.

The remaining annular space 56 within the shell 10 and outside of the cylindrical partitions 46, 52 constitutes a chamber within which to condense vapor collected in the collector compartment 48. Since the wall 46 of the collector chamber 48 terminates above the bottom plate 12 of the shell 10, free communication is provided between the lowermost part of the vapor collecting chamber 48 and the condenser chamber 56, under the lower end of the wall 46.

Additional communication between the vapor collecting chamber 48 and the condenser chamber 56 is provided by a passageway comprising a duct 58 formed in the partition 46 and opening into the upper portion of the collector compartment 48 through a port 59. Near the lower end of the partition 46, the duct 58 opens laterally through a connecting elbow 60 into a tube 62 which extends upwardly into the condenser compartment 56. Advantageously, the elbow 60 may be formed in an appendage 61 which extends into the chamber 56 and carries the tube 62 as a press-fitted insert.

The inlet to the pump structure shown in Figures 1 and 2 comprises a tube 64 which extends through the

cover plate 14 into the accumulator chamber 54. The partition 52 around the accumulator has a plurality of holes 66 therein affording communication between the accumulator compartment 54 and the condenser compartment 56. These holes 66 are covered by a loose-fitting, resilient band 67 of rubber or the like which extends around the outside of the partition 52. This band 67 cooperates with the holes 66 to provide low-pressure-drop one-way flow passages or check valves between the accumulator chamber 54 and the condenser chamber 56, for a purpose to be explained presently.

The liquid outlet from the pump structure is taken from the condenser chamber 56, and comprises an opening 70 in the cover plate 14. Advantageously, this outlet opening 70 may be incorporated in a check valve assembly comprising a housing 72 mounted on the cover plate 14 over the opening 70. The check valve closure member comprises a ball 74 which rests on the periphery of the hole 70.

The pump is filled initially through a cover plate opening 76 which communicates with the accumulator chamber 54. The fill opening 76 is closed by a threaded cap 78 which screws onto a collar 80 extending upwardly from the plate 14 around the opening 76. The collar 80 also has a vent passage 82 therein which opens into the condenser chamber 56, being closed off by the cap 78 when the latter is in place.

With the fill cap 78 removed, a priming charge of the liquid to be pumped can be poured in through the opening 76. The weight of this liquid will readily displace the check valve band 67, permitting the liquid to flow from the accumulator chamber 54 into the condenser chamber 56. This incoming liquid will expel air from the chamber 56 through the vent 82. As the liquid starts to rise in the collector chamber 48, it will force air ahead of it through the duct 58 and the tube 62 to the same exit opening 82. Similarly, the rising liquid level will force liquid into the vapor generating chamber 32 through the inlet opening 34 by displacing the ball 42.

When the electric heater cartridge 28 is connected to a suitable power source, heat from the cartridge will vaporize liquid in the annular chamber 32. As vapor forms in the chamber 32, it will flow through the outlet holes 50 into the collecting chamber 48. The vapor being collected will force liquid to flow downwardly out of the chamber 48 beneath the lower rim of the partition 46, upwardly through the outlet hole 70 and out the pipe 84 leading from the valve housing 72. A small amount of liquid will also be displaced from the duct 58 through the tube 62 as vapor collects in the duct 58.

The collection of vapor will continue, with the liquid levels in the chamber 48 and duct 58 continuing to fall, until the vapor reaches the lower end of the duct 58. Once the vapor level reaches the elbow 60, the hydrostatic balance between liquid and vapor pressures in the chamber 48 will be lost, and liquid will start to flow upwardly into the chamber 48, forcing vapor ahead of it through the duct 58 and tube 62 into the condenser chamber 56. As the vapor contacts the relatively cool liquid in the condenser chamber 56, rapid condensation will occur. This will immediately result in an inrush of liquid through the holes 66 to fill the space formerly occupied by the condensed vapor. The pressure drop accompanying condensation in the chamber 56 will draw in liquid readily against the negligible restraining force of the elastic band 67. As soon as the pump completely refills, the foregoing cycle will repeat.

The specific construction shown in Figures 1 and 2 has particular application in closed systems, wherein liquid is continuously recirculated through a closed circuit connected to the inlet and outlet pipes 64, 84. In such a system, an expansion space or accumulator is required at some point in the system to absorb the displacement which occurs in the pump. When not available

elsewhere in the system, such a space is conveniently provided by the chamber 54, by having the inlet tube 65 extend somewhat below the cover plate 14 as shown. This arrangement will maintain a volume of air trapped above the liquid in the chamber 54 to absorb displaced liquid as stated above. Where an accumulator is not required in the pump, the upper partition 44 can be coincident with the cover plate 14.

In certain systems, it is also feasible to eliminate the outlet check valve 74. Where the pressure drop in the system through which the pump is working is more than the drop through the inlet valve 66, 67, the outlet valve 74 can be eliminated.

For example, when the pump is connected to a load having restricted flow passages, the back flow through such passages will be substantially smaller than the flow through the low pressure drop inlet check valve 66, 67. Thus, on the suction stroke of the pump, much more liquid will flow through the valve 66, 67 than will flow backward through the outlet line 84. This mode of operation is particularly feasible where an accumulator is built into the pump on the inlet side thereof as in the foregoing embodiment of the invention.

The purpose of the valve ball 42 in the chamber 32 is to prevent displacement of liquid from the chamber 32 as vapor forms. This is a desirable feature for two reasons. First, it insures an adequate supply of liquid in the chamber 32 for continued vapor generation throughout the expulsion part of the cycle. Also, by preventing hot liquid from flowing out of the vapor generating chamber 32, the amount of liquid that has to be reheated each cycle is substantially decreased. The small quantity of make-up liquid required to replace vaporized liquid will flow into the chamber 32 through the opening 34 when the liquid level in the collector chamber 48 rises above the level in the chamber 32.

It can also be seen that there is a marked advantage in having the generating chamber 32 centrally disposed in the pump, because the same partition 30 which surrounds the chamber 32 also serves as one wall of the collecting chamber 48. Since this chamber wall must be hot enough to maintain a body of vapor in the collector 48 during vapor collection, there will not be any heat lost from the wall surface 30 as would be the case with a separate vapor generator structure.

In order to maintain sufficient temperature differential between the collecting and condensing chambers to ensure condensation, the partition 46 should not transfer heat readily. Also, it is advantageous to minimize loss of heat from the vapor being collected in the chamber 48. Therefore, an insulating material such as glass, Bakelite, hard rubber or the like is preferred for the partition 46, and the partition 44 preferably comprises a similar insulating material. These considerations advantageously lend themselves to forming the partition elements 30, 44, 46 integrally, as by molding or the like. The walls 10 and bottom 12 of the outer shell may be made in the same way and of similar material. The top plate 14 and central well 26 may be made of metal having good heat conductivity and welded or similarly attached to each other.

The auxiliary partition 52 may also be made of metal, welded or otherwise suitably secured to the cover plate, and fitting a suitable annular groove 55 on the rim of the partition 44. Regardless of the manner in which these several parts are formed and assembled, it can be seen that the fabrication and assembly procedures are greatly simplified by the fact that it is not essential to have an absolutely leak-tight joint between the parts which are connected together inside of the shell 10. By contrast, if the generator chamber 32, the collector chamber 48 and the condenser chamber 56 were defined by completely separate vessels attached together by connecting tubes, it would be essential to have a leak-tight joint where each of the tubes is connected to its associated vessels. In

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the present construction, on the other hand, any slight leakage that may occur between the various chambers due to imperfect joints will not have a material effect on the operation of the system, nor will there be any liquid loss from the system as a whole.

It will be understood that the principles of the invention can be applied to advantage in modified structural forms without sacrificing the advantages to be derived therefrom. For example, as shown in Figures 3 and 4, it is entirely feasible to have the heating element 28 inserted from the bottom of the assembly, rather than from above as in the construction of Figures 1 and 2.

In the pump of Figures 3 and 4, the accumulator chamber 54 is annular, being defined by an additional outer wall 90 which surrounds and is spaced from a principal or inner shell wall 10. This outer wall may have any desired shape, such as rectangular as shown in Figure 4, if preferred for appearance or other reasons.

In this embodiment of the invention, the top or cover portion 14 is formed integral with the outer and inner walls, 90 and 10, respectively, and with the intermediate partition 46. The bottom 12 is formed as a removable plate which has a press fit within the outer wall 90 and is made liquid-tight by means of a resilient O-ring 92 of rubber or the like. A similar sealing ring 94 also may be used between the bottom plate 12 and the lower end of the main or inner shell wall 10 to seal the accumulator 54 from the condenser 56.

The intermediate partition 30 is formed integral with the bottom plate 12. An internally threaded opening 96 is provided to receive the heating element 28, which has a threaded shank 97 at its lower end. In this embodiment of the invention, the heater 28 is of so-called immersion type, cooperating directly with the partition 30 to define therebetween the annular generator chamber 32. In order to seal the heater element 28 to the bottom plate 12, a rubber O-ring 100 is compressed between the upper face of the heater shank 97 and a flange 102 formed on the inner surface of the wall 30.

The inlet check valve to the generator chamber 32 comprises a valve ball 42 in a housing 106 appended to one side of the vapor chamber partition 30. The housing 106 has a bottom inlet opening 108 (normally closed by the ball 42) and an outlet opening 110 communicating with the vapor generating chamber 32.

To provide an inlet check valve from the accumulator chamber 54 to the condenser chamber 56, the main shell wall 10 has openings 66 therein near the lower end thereof. These openings 66 are covered by an internal resilient ring 67 which will deflect inwardly to permit liquid to flow in through the openings 66.

The pump inlet comprises a tube 64 which extends into the accumulator chamber 54 through the outer wall 90. The outlet comprises a tube 84 sealed into the bottom plate 12 and extending into the condenser chamber 56. If an outlet check valve is required, it can take the form of a ball 74 located in a valve chamber 75 at the upper end of the outlet line 84. In certain applications, as previously mentioned, such valve is not required because of the characteristics of the load to which the pump is connected.

The pump in Figures 3 and 4 also is provided with a vapor tube 58, 60, 62 of the same configuration and arrangement as the vapor tube in the pump of Figures 1 and 2. Provision for filling the pump shown in Figures 3 and 4 is also similar to that previously described, and includes a fill opening 76 communicating with the condenser chamber 56 and the accumulator chamber 54. In this case, a separate plug 79 is provided for closing the condenser fill opening, and a dip-tube 81 leads from the fill opening into the accumulator chamber to establish an air pocket above the level of the liquid in the accumulator chamber.

The pump shown in Figures 3 and 4 operates in substantially the same manner as already described in con-

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nection with Figures 1 and 2. When the pump has been filled and heat is supplied by connecting the heater 28 to a suitable source of electric power, vapor formed in the generator chamber 32 will be collected therein and in the collector chamber 48. When the level in the collector chamber reaches the lowermost point in the vapor duct, vapor will flow into the condenser chamber and the pump will recycle.

The assembly of the pump in Figures 3 and 4 is extremely simple. The heater element 28 first is threaded into place in the base 12, and the check valve ring 67 is positioned adjacent the partition 10. The base 12 then is forced into place inside the outer housing 90, and the pump is ready for operation.

From the foregoing, it can be seen that the present invention provides an improved heat-actuated pump which is simple and inexpensive to fabricate and assemble, and which has many important features from the standpoint of improved operation.

What is claimed is:

1. In a thermally actuated pump of the type in which alternating volumetric changes are produced by alternately collecting vaporized liquid in a first portion of said pump and condensing the vaporized liquid in a second portion of said pump, in combination, a closed outer shell, a first cylindrical partition in said shell encompassing a first central compartment inside said shell in which to vaporize liquid by heating, a second cylindrical partition surrounding said first partition and defining therewith an annular second compartment adjacent to said first compartment in which to collect vapor formed in said first compartment and defining with said shell an annular third compartment in which to condense vapor, said first partition having opening portions affording communication for liquid flow from the lower part of said second compartment to the lower part of said first compartment and affording communication for vapor flow from the upper part of said first compartment to the upper part of said second compartment, said second partition having an open portion providing a liquid conductive passageway between said third compartment and the lower part of said second compartment, means defining a U-shaped vapor conduit connecting the upper portions of said second and third compartments and extending downwardly through said second partition from the upper part of said second compartment and then upwardly outside said second partition and within said third compartment, and inlet and outlet means for said shell for transferring volumetric changes from inside to outside said shell.

2. In a thermally actuated pump of the type in which alternating volumetric changes are produced by alternately collecting vaporized liquid in a first portion of said pump and condensing the vaporized liquid in a second portion of said pump, in combination, a closed outer shell, a plurality of concentric cylindrical partitions within said shell dividing the space inside said shell into a plurality of concentric compartments including a first compartment within which to vaporize liquid by heating, a third compartment within which to condense vaporized liquid and a second compartment disposed between said first and third compartments and within which to collect vapor formed in said first compartment, said partitions having open portions affording communication for liquid flow between the lower parts of all said compartments and for vapor flow from the upper part of said first compartment to the upper part of said second compartment, means defining a U-shaped vapor conduit connecting the upper portions of said second and third compartments and extending downwardly from the upper part of said second compartment and then upwardly into the upper part of said third compartment, and volumetric change transferring means for said shell effectively providing an inlet and outlet for the pump.

3. In a thermally actuated pump of the type wherein alternating volumetric changes are produced by vaporizing a liquid in one compartment and subsequently condensing said liquid in another compartment, in combination, a liquid tight shell, a wall of heat conductive material defining a cylindrical cavity extending into and separated by said wall from the central portion of the space inside said shell, partition means inside said shell cooperating with said shell and with said heat conductive wall to define three concentric annular compartments surrounding said heat conductive wall and including a first compartment within which to vaporize liquid, a second compartment surrounding said first compartment and within which to collect vapor generated in said first compartment and a third compartment in which to condense vapor, said partition means having open portions affording communication for liquid flow from the lower part of said second compartment to the lower part of said first compartment and affording communication for vapor flow from the upper part of said first compartment to the upper part of said second compartment and affording communication for liquid flow between said third compartment and the lower part of said second compartment, means defining a U-shaped vapor conduit connecting the upper portions of said second and third compartments and extending downwardly through said second partition from the upper part of said second compartment and then upwardly outside said second partition and within said third compartment, and inlet and outlet means for said pump providing for the transfer of volumetric changes from inside to outside said shell.

4. In a thermally actuated pump of the type in which alternating volumetric changes are produced by alternately collecting vaporized liquid in a first portion of said pump and condensing said vaporized liquid in a separate second portion of said pump, in combination, a closed outer shell having a cylindrical cavity extending into the central portion of said shell, a first cylindrical partition in the central portion of said shell cooperating with said shell to define a first annular compartment surrounding said cylindrical cavity and in which to vaporize liquid by heating, a second cylindrical partition cooperating with said first partition to define a second annular compartment surrounding said first compartment in which to collect vapor formed in said first compartment, said second partition further cooperating with said shell to define a third annular compartment within which to condense vapor collected in said second compartment, said first cylindrical partition having open portions affording communication for liquid flow from the lower part of said second compartment to the lower part of said first compartment and affording communication for vapor flow from the upper part of said first compartment to the upper part of said second compartment, means defining a liquid conductive passageway between said third compartment and the lower part of said second compartment, means defining a U-shaped vapor conduit extending downwardly from the upper part of said second compartment and then upwardly above said second compartment and to said third compartment, and inlet and outlet means for said shell for providing an effective pumping action.

5. In a thermally actuated pump of the type in which liquid is alternately displaced by vapor and drawn in by condensation of said vapor, in combination, a substantially vertical outer cylinder which is closed at both ends, a cylindrical first shell of insulating material mounted vertically within said outer cylinder with radial spacing therebetween, thereby providing an annular third compartment between said cylinder and said shell within which to condense vapor, said shell being closed at its upper end and open at its lower end, said shell encompassing a second compartment within which to collect vapor, means extending into said second compartment

for delivering vaporized liquid into said second compartment, and means defining a U-shaped vapor conduit communicating between said third and second compartments and extending downwardly from the upper part of said third compartment to a point just above the lower end of said shell, and thence upwardly to the upper part of said second compartment.

6. In a thermally actuated pump of the type in which liquid is alternately displaced by vapor and drawn in by condensation of said vapor, in combination, a substantially vertical outer cylinder which is closed at both ends, a cylindrical shell of insulating material mounted vertically within said outer cylinder with radial spacing therebetween, thereby providing an annular third compartment between said cylinder and said shell within which to condense vapor, an end wall closing said shell at its upper end and said shell being open at its lower end, said shell encompassing a second compartment within which to collect vapor, an inner cylinder within said cylindrical shell defining a first compartment within which to form vapor by heating liquid inside said inner cylinder, said inner cylinder having outlet and inlet openings at its upper and lower ends, respectively, and means extending into said inner cylinder through which to supply heat to liquid contained in said first compartment.

7. In a thermally actuated pump of the type in which alternating volumetric changes are produced by alternately vaporizing liquid in a first portion of said pump and condensing said vaporized liquid in a separate second portion of said pump, in combination, a closed outer shell, partition means in said shell defining three substantially concentric annular compartments in said shell, the innermost one of said compartments constituting a first compartment in which to vaporize liquid by heating, the intermediate one of said compartments comprising a second compartment in which to collect vapor formed in said first compartment and the outermost one of said compartments comprising a third compartment in which to condense vapor collected in said second compartment, said partition means having openings therein affording communication for liquid flow between the lower parts of said compartments and affording communication for vapor flow from the upper part of said first compartment to the upper part of said second compartment, and means defining a U-shaped vapor conduit extending downwardly from the upper part of said second compartment and then upwardly above said second compartment and to said third compartment, and inlet and outlet means in said shell.

8. In a thermally actuated pump of the type wherein alternating volumetric changes are produced by vaporizing a liquid in a first portion of said pump and subsequently condensing said liquid in a second portion of said pump, in combination, a liquid-tight, upright, cylindrical outer shell, a wall of heat conductive material defining a cylindrical cavity extending downwardly into the central portion of said shell, a first cylindrical partition surrounding the lower portion of said wall and defining therewith an annular first compartment within which to vaporize liquid, a second cylindrical partition extending downwardly from the upper end of said shell and surrounding said first partition to provide between said partitions a second annular compartment within which to collect vapor and further defining between said second partition and said shell a third annular compartment within which to condense vapor, a lateral partition at the upper end of said first partition extending from said heat conductive wall to said second partition and closing off the upper ends of said first and second compartments, thereby providing between said wall, said lateral partition, said second partition and the upper end of said shell a fourth annular compartment, an inlet tube extending from outside said shell into said fourth compartment, said second partition having openings

therein above said lateral partition providing communication between said third and fourth compartments, a resilient band extending around said second partition and covering said openings to provide check valves between said third and fourth compartments, said shell having an outlet opening therein communicating with said second compartment, said first partition having openings in the upper portion thereof to provide passages for vapor flow out of said first compartment, said first partition having an inlet opening in the lower portion thereof for admitting liquid to said first compartment, a ball valve cooperative with said inlet opening to admit liquid to said first compartment, said second partition having a vapor transfer passage therein extending from the upper portion of said second compartment to a point just above the lower end of said second compartment, and a vapor delivery tube in said third compartment extending upwardly from the lower end of said vapor transfer passage to a point above the upper end of said second compartment.

9. In a thermally actuated pump of the type wherein alternating volumetric changes are produced by vaporizing a liquid in a first portion of said pump and subsequently condensing said liquid in a second portion of said pump, in combination, a liquid-tight outer shell, an upright, cylindrical, inner shell within said outer shell and defining therewith a closed annular chamber, said shells having a common bottom wall and a common top wall, a cylindrical first partition extending upwardly from said bottom wall and encompassing a first compartment within which to vaporize liquid, a heating element extending into said first compartment, a cylindrical second partition extending downwardly from said top wall and surrounding said first partition to provide between said partitions an annular second compartment within which to collect vapor and further defining between said second partition and said inner shell an annular third compartment within which to condense vapor, an inlet tube extending through said outer shell into said chamber, said inner shell having openings therein providing communication between said chamber and said third compartment, a resilient band extending around the inside surface of said inner shell and covering said openings to provide check valves between said third compartment and said chamber, an outlet tube extending through said bottom wall into said second compartment, said first partition being open at the top to provide a passage for vapor flow out of said first compartment, said first partition having an inlet opening in the lower portion thereof for admitting liquid to said first compartment, a ball valve for said inlet opening to said first compartment, said second partition having a vapor transfer passage therein extending from the upper portion of said second compartment to a point just above the lower end of said second compartment, and a tube in said third compartment extending upwardly from the lower end of said vapor transfer passage to a point above the upper end of said second compartment.

10. In a thermally actuated pump of the type wherein alternating volumetric changes are produced by vaporizing and condensing liquid in separate portions of said pump, in combination, a liquid tight outer shell, a cylindrical inner shell within said outer shell and defining therewith an annular chamber, a cylindrical first partition extending upwardly from the bottom wall of said outer shell and concentric with said inner shell, means extending through said bottom wall into the space encompassed by said first cylindrical partition for vaporizing liquid within said encompassed space, a cylindrical second partition extending downwardly from the top wall of said outer shell between said inner shell and said first partition and separating the space therebetween into annular second and third compartments within which to collect and condense vapor, respectively, said first parti-

tion having openings at the upper and lower ends thereof of providing communication between said encompassed space and said second annular compartment, said second partition having an opening at the lower end thereof of providing communication between said second and third compartments, said inner shell having an opening in the lower portion thereof providing communication between said chamber and said third compartment, a resilient band disposed on the inner surface of said inner shell and overlying said opening therein, said second partition having a vapor transfer passage therein extending from the upper portion of said second annular compartment to a point just above the lower end of said second compartment, a tube in said third compartment extending upwardly from the lower end of said vapor transfer passage to a point above the upper end of said second compartment, an outlet tube extending from outside said outer shell into said third compartment, and an inlet tube extending from outside said outer shell into said chamber.

11. In a thermally actuated pump of the type wherein alternating volumetric changes are produced by vaporizing a liquid in a first portion of said pump and subsequently condensing said liquid in a second portion of said pump, in combination, a liquid-tight cylindrical shell, a wall of heat conductive material defining a cylindrical cavity extending into the central portion of said shell, a cylindrical first partition surrounding the lower portion of said wall and defining therewith an annular first compartment within which to vaporize liquid, a cylindrical second partition surrounding said first partition to provide between said partitions an annular second compartment within which to collect vapor and further defining between said second partition and said shell an annular third compartment within which to condense vapor, a lateral partition at the upper end of said first partition extending from said heat conductive wall to said second partition and closing off the upper ends of said first and second compartments, thereby providing between said wall, said lateral partition, said second partition and the upper end of said shell a fourth annular compartment, an inlet opening extending from outside said shell into said fourth compartment, check valve means providing communication for liquid flow from said fourth to said third compartment, said shell having an outlet opening therein communicating with said second compartment, said first partition having openings in the upper portion thereof to provide passages for vapor flow out of said first compartment, said first partition having an inlet opening in the lower portion thereof for admitting liquid to said first compartment, said second partition having a vapor transfer passage therein extending from the upper portion of said second compartment to a point just above the lower end of said second compartment, and a tube in said third compartment extending upwardly from the lower end of said vapor transfer passage to a point above the upper end of said second compartment.

12. In a thermally actuated pump of the type wherein alternating volumetric changes are produced by vaporizing a liquid in a first portion of said pump and subsequently condensing said liquid in a second portion of said pump, in combination, a cylindrical outer shell, first and second concentric cylindrical partitions in the lower portion of said shell defining therebetween an annular compartment within which to collect vapor and further defining between said second partition and said shell a second annular compartment within which to condense vapor, means communicating with the space encompassed by said first partition for delivering vapor therefrom, a lateral partition at the upper end of said cylindrical partitions closing off the upper end of said encompassed space and providing between said lateral partition, said second partition and the upper end of said

shell a third compartment, an inlet tube extending from outside said shell into said third compartment, said second partition having openings therein above said lateral partition providing communication between said second and third compartments, a resilient band extending around said second partition and covering said openings to provide check valves between said second and third compartments, said shell having an outlet opening therein communicating with said second compartment, said second partition having a vapor transfer passage therein extending from the upper portion of said second compartment to a point just above the lower end of said second compartment, and a tube in said third compartment extending upwardly from the lower end of said vapor transfer passage to a point above the upper end of said second compartment.

13. A thermally actuated pump of the type in which volumetric changes are produced in repetitive cycles by alternately vaporizing liquid in one region of the pump and condensing the vaporized liquid in another region of the pump comprising a shell enclosing said pump and providing an inlet and an outlet for liquid flow into and out of said shell, said pump having an inner compartment within said shell in which to vaporize liquid by heating, said pump including a second compartment within said shell near said first compartment for collecting vapor formed in said first compartment, said shell including a vapor transfer passage from said first compartment to said second compartment for transferring vapor to said second compartment, said pump including a third compartment within said shell for condensing vapor transferred from said second compartment, said shell including a second vapor transfer passage extending from said second compartment to said third compartment, said second vapor transfer passage beginning at a point near the top of said second compartment and progressing downwardly to a level substantially below said point and then turning and progressing upwardly and communicating with said third compartment at a point substantially above said level, said shell including liquid transfer passageways extending between said third compartment and the lower portions of said first and second compartments, said shell including a fourth compartment for accommodating the displacement which occurs in said pump, said inlet communicating with said fourth compartment, and said shell including an opening between said third and fourth compartments, and

one-way flow valve means preventing flow of liquid from said third to said fourth compartment through said opening.

14. A thermally actuated pump of the type in which volumetric changes are produced in repetitive cycles by alternately vaporizing liquid in one region of the pump and condensing the vaporized liquid in another region of the pump comprising a shell enclosing said pump and providing an inlet and an outlet for liquid flow into and out of said shell, said pump having an inner compartment within said shell in which to vaporize liquid by heating, said pump including a second compartment within said shell near said first compartment for collecting vapor formed in said first compartment, said shell including a vapor transfer passage from said first compartment to said second compartment for transferring vapor to said second compartment, said pump including a third compartment within said shell for condensing vapor transferred from said second compartment, said shell including a second vapor transfer passage extending from said second compartment to said third compartment, said second vapor transfer passage beginning at a point near the top of said second compartment and progressing downwardly to a level substantially below said point and then turning and progressing upwardly and communicating with said third compartment at a point substantially above said level, said shell including liquid transfer passageways extending between said third compartment and the lower portions of said first and second compartments, said shell including a fourth compartment for accommodating the displacement which occurs in said pump, said inlet communicating with said fourth compartment, heat insulation partition means within said shell for insulating said first and second compartments from said third and fourth compartments, and said shell including an opening between said third and fourth compartments, and one-way flow valve means preventing flow of liquid from said third to said fourth compartment through said opening.

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UNITED STATES PATENT OFFICE
CERTIFICATION OF CORRECTION

Patent No. 2,969,747

January 31, 1961

Calvin D. MacCracken et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 4, line 3, for "65" read -- 64 --; column 7, line 27, for "compartmrnt" read -- compartment --; column 8, lines 58 and 59, 67 and 68, and column 9, line 34, for "partion", each occurrence, read -- partition --.

Signed and sealed this 13th day of June 1961.

(SEAL)

Attest:

ERNEST W. SWIDER

Attesting Officer

DAVID L. LADD

Commissioner of Patents