

- [54] **PUMP FOR DELIVERING HEATED FLUIDS**
- [76] Inventors: **George M. Low**, Acting Administrator of the National Aeronautics and Space Administration with respect to an invention of; **Eric E. Sabelman**, Sierra Madre, Calif.
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- [58] Field of Search. 417/393, 52, 207, 417/208, 209, 379, 391; 60/25

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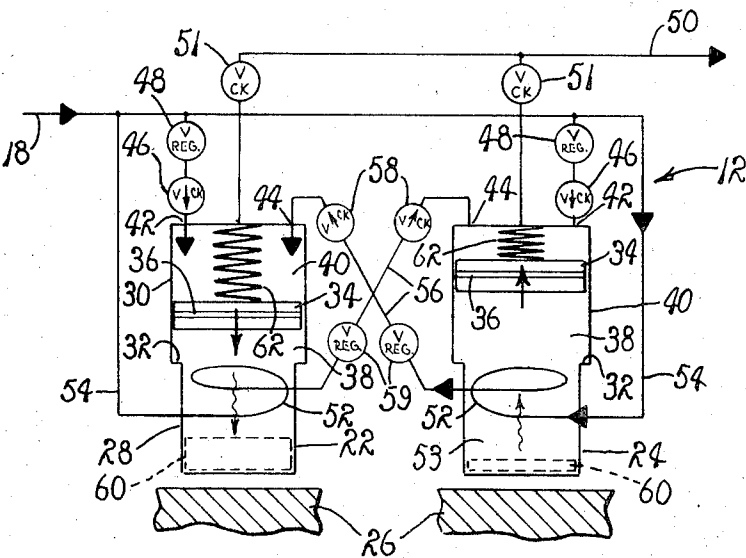
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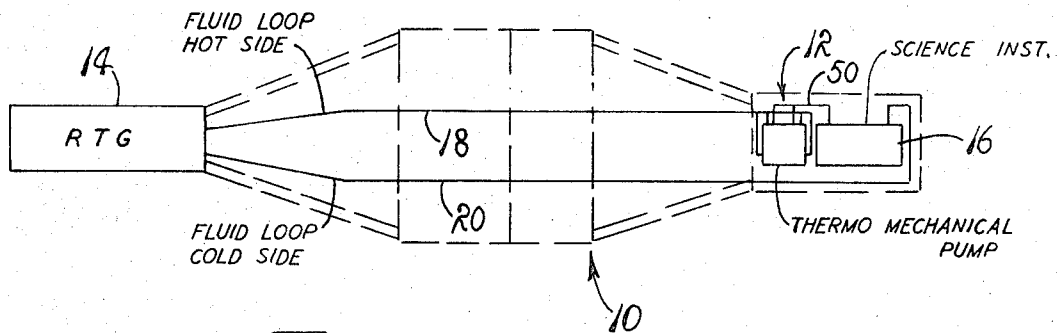
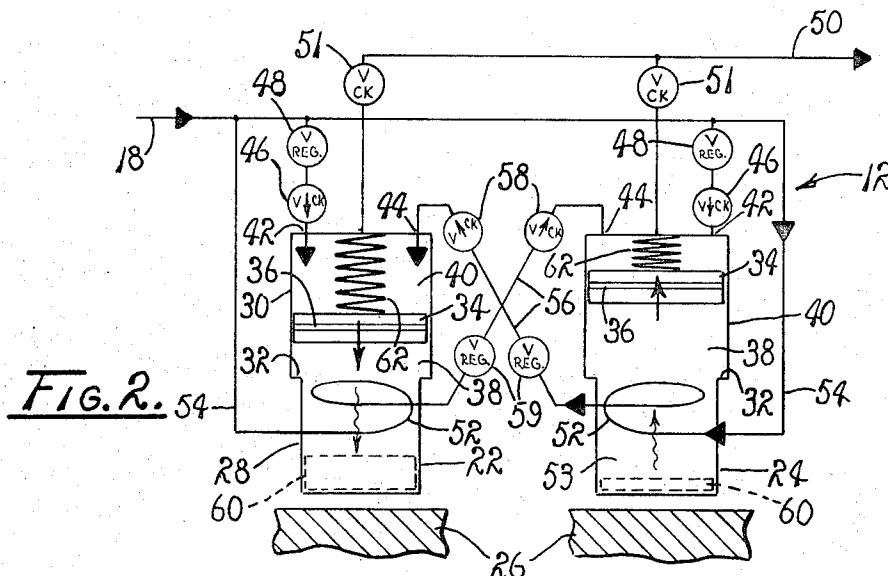
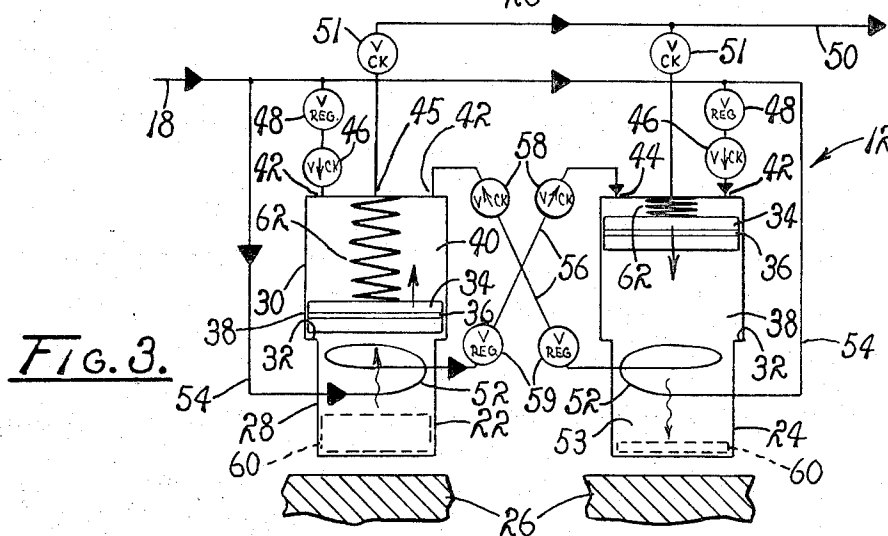
Primary Examiner—William L. Freeh
Assistant Examiner—G. P. LaPointe
Attorney—Monte F. Mott, Wilfred Grifka and John R. Manning

[57] **ABSTRACT**

A thermomechanical pump particularly suited for use in pumping a warming fluid obtained from an RTG (Radioisotope Thermal Generator) through science and flight instrumentation aboard operative spacecraft. The invention is characterized by a pair of operatively related cylinders, each including a reciprocating piston head dividing the cylinder into a pressure chamber confining therein a vaporizable fluid, and a pumping chamber for propelling the warming fluid, and a fluid delivery circuit for alternately delivering the warming fluid from the RTG through the pressure chamber of one cylinder to the pumping chamber of the other cylinder, whereby the vaporizable fluid within the pair of pressure chambers alternately is vaporized and condensed for driving the associated pistons in pumping and intake strokes.

5 Claims, 4 Drawing Figures





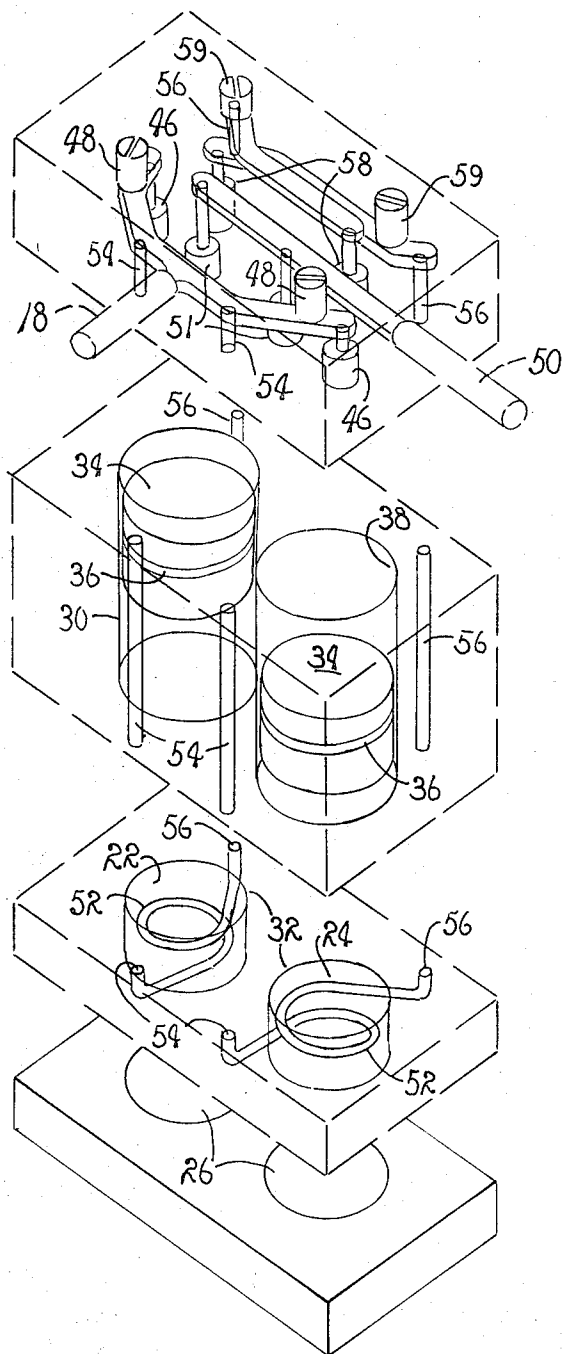
ERIC E. SABELMAN

INVENTOR

WILFRED L. GRIFFIN
INVENTOR
Mont. 11/6/09

ATTORNEYS:

FIG. 4.



ERIC E. SABELMAN
INVENTOR
Wilfred Grifka
Mont. F. Mott
ATTORNEYS

PUMP FOR DELIVERING HEATED FLUIDS

ORIGIN OF INVENTION

The invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of SECTIONS 305 of the National Aeronautics and Space Act of 1958, Public Law 85-568 (72 Stat. 435; 42 USC 2457).

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to a pump for delivering a heated fluid, and more particularly to a thermomechanical pump adapted to convert thermal energy given up by a heated fluid being pumped to mechanical energy for mechanical forcing the heated fluid through a delivery circuit.

2. Description of the Prior Art

The prior art includes numerous motors adapted to employ heated and expanding gases in converting stored energy to mechanical energy for thus providing a work product. Frequently, the work product is used in driving a pump suited for use in forcing a fluid through given circuitry for performing various functions. Normally, such motors are mechanically connected with fluid-pumping structure through a power train which delivers the work output of the motor at the input of the pump. Such structure tends to be inefficient, relatively massive, requires an external source of energy and has an operative life dictated, in part, by the quantity of available stored energy.

Currently various types of science and flight instrumentation is transported aboard operative spacecraft. This instrumentation often requires an input of heat in order to perform in an efficient manner. Normally, stored electrical energy is utilized in pumping heated fluids through circuits associated with the instrumentation in order that the instrumentation be maintained at a predetermined temperature. Electrical energy available aboard the spacecraft is of a limited quantity and therefore conservation of such energy is highly desirable, particularly where a spacecraft is employed over extended periods.

Accordingly, there currently exists a need for a practical, relatively lightweight, compact and economical pump for use in pumping heated warming fluids for controlling the temperature of instrumentation aboard spacecraft and the like.

OBJECTS AND SUMMARY OF THE INVENTION

It is therefore an object of the instant invention to provide an improved pump for delivering fluids through a fluid circuit.

It is another object to provide a reciprocating pump for delivering heated fluids aboard operative spacecraft.

It is another object to provide a cyclically operable pump capable of extracting heat energy from heated fluids employing a vapor-pressure expansion system and employing the extracted energy in pumping the heated fluid through a fluid receiver circuit.

It is another object to provide an improved, lightweight, efficient and economic pump for use in delivering heated fluids from an RTG unit through an instrumentation package operatively supported for operation aboard an operative spacecraft.

These and other objects and advantages are achieved through the use of an astable thermomechanical pump having a pair of operatively related cylinders, each including a reciprocating piston defining therewithin a pressure chamber and a pumping chamber, interconnected through a delivery circuit for alternately receiving a heated fluid from an associated RTG and forcing the fluid through an instrument package for controlling the temperature thereof in response to thermal energy extracted from the heated fluid being pumped.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic view, in block diagram form, depicting a typical system capable of employing the thermomechanical pump which embodies the principles of the instant invention.

FIG. 2 is a schematic view of the pump illustrated in FIG. 1, depicting the pump's components in a first astable condition.

FIG. 3 is a schematic view, similar to FIG. 2, illustrating a second astable condition for the pump.

FIG. 4 is a perspective, exploded view of the pump diagrammatically illustrated in FIGS. 2 and 3.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawing, wherein like reference characters designate like or corresponding parts throughout the several views, there is illustrated in FIG. 1 a system 10 of a type employable aboard an operative spacecraft.

A pump 12 of the type embodying the principles of the instant invention is illustrated in operative association with the system 10 and is employed in delivering a heated fluid acquired from an RTG 14 to a science and flight instrumentation package 16 for purposes of controlling its temperature. In practice, the pump 12 communicates with the output side of the RTG 14 through a suitable conduit 18 which serves as an input conduit for the pump. All of the fluid delivered from the RTG 14 through the conduit 18 to the pump 12 ultimately is discharged from the instrumentation package 16 and returned to the RTG 14 through a return conduit 20. Hence, the conduits 18 and 20 provide circuitry for circulating the heated fluid as it is received from and returned to the RTG 14.

Since the specific system 10, the RTG unit 14 and the instrumentation package 16 form no specific part of the instant invention, a detailed description thereof is omitted in the interest of brevity. Also, it should readily be appreciated that the pump 12 has utility separate and apart from the specific system 10 illustrated in FIG. 1, and may be employed in a terrestrial environment as well as in one found in celestial space.

The pump 12 includes a pair of related cylinders 22 and 24 having walls 25 fabricated of any suitable material, such as ceramics, laminated Micarta sheets and the like. Of course, the material employed must be capable of withstanding operative temperatures and pressures. Each of the cylinders 22 and 24 is associated with an adjacent heat sink 26, which, as a practical matter, can be utilized in transferring heat given up by the cylinders 22 and 24 to the instrumentation packages 16. If desired, however, the heat radiates directly into celestial space so that the enveloping environment functions as a heat sink.

The cylinders 22 and 24 are of a similar design and operate in a similar manner. In practice, each of the cylinders 22 and 24 is an hermetically sealed cylinder divided into a pair of coaxially related, adjacent cylinder segments 28 and 30. Each of these segments is provided with an internal diameter differing from the internal diameter of the adjacent segment of the cylinder.

As illustrated in FIGS. 2 and 3, the lower segment 28 is designated a base segment and is of a given diameter while the adjacent segment 30 is designated a distal segment and is of a diameter greater than the given diameter. An internal annular shoulder 32 is provided in each of the walls and separates the cylinder segments 28 and 30.

Within the distal segment 30 there is a reciprocable disk shaped piston 34. In practice, the piston 34 is formed of a suitable thermally non-conductive material, including various commercially available ceramic materials and the like. The piston 34 preferably is provided with an outside diameter approximating the internal diameter of the distal segment 30 and is supported for reciprocal displacement in an axial direction between the shoulder 32 and the distal end of the distal segment. Where desired, the piston 34 is provided with an annular wiper ring 36 seated in an appropriately formed groove for establishing a seal about its periphery. The material from which the ring 36 is fabricated is dictated by prevailing operative parameters and may be varied as required. Of course, rolling diaphragms, bellows and the like can be employed equally as well in establishing an hermetic seal between the walls of the cylinder segments 30 and the periphery of the pistons 34.

The pistons 34 thus serve to establish within each of the distal segments 30 of the cylinders 22 and 24 a pair of coaxially related, expansible chambers 38 and 40, employed as a pressure chamber and a pumping chamber, respectively. Each of the chambers thus established has a variable axial dimension which, in operation, is determined by the instantaneous position of the piston 34 as it is reciprocally advanced between the opposite ends of the cylinder segment.

Each of the cylinders 22 and 24 is provided with a pair of radially spaced fluid intake ports associated with its chambers 40, designated 42 and 44, and a concentrically related fluid discharge port, designated 45, through which the warming fluid is passed as the pump is operated.

Each of the intake ports 42 is connected with the conduit 18 through a one-way check valve 46 and a direct input flow-control valve 48 through which heated fluid is delivered from the RTG 14 to the associated chamber 40 as the piston 34 is driven in an intake stroke. Each of the discharge ports 45, in turn, communicates with the instrumentation package 16 through a common discharge conduit 50. As a practical matter, a one-way check valve 51 is interposed between each of the discharge ports 45 and the conduit 50 for precluding a back-flow of the fluid once it is expelled from the associated chambers 40.

It should be apparent that heated warming fluid derived from the RTG unit 14 is delivered through the flow-control valves 48 and the check valves 46 to the expansible chamber 40 as the chambers are charged

and the pistons 34 are advanced toward the base segments 28 of the cylinders 22 and 24 and that the fluid ultimately is discharged through the discharge ports 45 and the pistons 34 are advanced in an opposite direction. Hence, it can readily be appreciated that the pistons 34 operatively are advanced in intake strokes, as the chambers 40 are expanded and the chambers 38 are contracted, and advanced in pumping strokes as the chambers 38 are expanded and the chambers 40 are contracted. The flow-control valves 48 serve to dictate the flow-rate for the warming fluid as it is delivered through the check valves 46 to the chambers 40.

Within each of the base segments 28 there is mounted a heat exchanger 52 seated in a compression chamber 53 communicating with the chamber 38. While the heat exchanger 52 can be of any practical design, a heat exchanger conforming to a coil of thin-wall copper tubing functions quite satisfactorily for this purpose. Each of the coils 52 also is coupled with the conduit 18, preferably through a coil input line designated 54, and to one of the chambers 40, through a coil discharge line 56. Within each of the coil discharge lines 56 there is provided a one-way check valve 58 and a flow control valve 59. The valves 58 and 59 are similar to the valves 46 and 48 in design and function. Therefore, a detailed description thereof is not at this juncture believed required.

Within the chamber 53 of the cylinders 22 and 24 there is also deposited a predetermined quantity of fluid 60, FIGS. 2 and 3. The fluid is characterized by a capacity to undergo a phase change from its liquid phase to its vapor phase in the presence of heat, and to revert to a liquid phase once the heat is removed. As a practical matter, Freon is particularly suited for this purpose. Thus the fluid 60 serves to convert heat energy to mechanical energy as it is vaporized and expanded against the piston 34 for driving the piston in a pumping stroke. A subsequent intake stroke of the piston operatively is accommodated as the heated fluid is condensed and thus contracted.

Heating of the fluid 60 within the cylinders 22 and 24 is achieved in an alternating mode so that as one of the pistons 34 is advancing in its pumping stroke for expelling the warming fluid from the associated chamber 40, the other piston 34 is advancing in its intake stroke for thus charging the associated chamber 40. The mode of heating the fluid 60 is achieved in response to an intermittent and alternating flow of warming fluid through the heat exchanger 52.

Referring particularly to FIGS. 2 and 3, wherein darkened arrow heads are employed for purposes of illustrating instantaneous directions of flow, it should be apparent that as warming fluid is delivered to the chamber 40 of the cylinder 22, from the conduit 18 through the check valve 46 for charging the chamber, a flow of fluid also is established through the heat exchanger 52 located within the cylinder 24, while the flow through the heat exchanger 52 within the cylinder 22 is interrupted, due to the prevailing back-pressure established within the chamber 40 of the cylinder 24, as a consequence of the movement of the piston 34 in its pumping stroke. Thus the fluid 60 within the base segment 28 of the cylinder 24 is subjected to an input of heat delivered by the fluid, while the fluid 60 within the cylinder 22 is permitted to cool, due to the cooling ef-

fect of the heat sink 26 and the interruption of a delivery of warming fluid through the associated heat exchanger 52. Of course, once the piston 34 is bottomed against the shoulder 32, back-pressure is developed within the chamber 40 of the cylinder 22 and the flow of warming fluid through the exchanger 52 within the cylinder 24 is interrupted whereupon the direction of movement of the pistons 34 is reversed.

In practice, it has been found that a rapid response to a heating of the fluid 60 is achievable for rapidly driving the pistons 34 in pumping strokes, while the responsive intake strokes tend to be retarded for various reasons, including the rates at which the fluid 60 is converted to its liquid phase. As a consequence, a compression spring 62 is seated within each of the chambers 40 and acts against the associated piston 34 for reducing the rate of displacement of the pistons 34, during their pumping strokes while increasing the rate of displacement during their intake strokes. The compression springs 62 thus function as rate regulators for controlling the pumping rates for the pump 12.

Of course, the operation of the pump 12 can be initiated in any practical manner which permits the fluid 60 within one of the cylinders to be heated while the other is maintained in a cooled condition. A resistance heating coil, not shown, has been employed quite satisfactorily for this purpose.

OPERATION

It is believed that in view of the foregoing description, the operation of the device will be readily understood and it will be briefly reviewed at this point.

As illustrated in FIG. 1 heated warming fluid is derived from the RTG 14 and delivered by the conduit 18 to the pump 12 and then returned to the RTG via the conduit 20, after being circulated through the instrumentation package 16.

For purposes of illustration, it is assumed that heated fluid from the conduit 18 within the cylinder 22, FIG. 2, is interrupted and that the fluid 60 within the cylinder 22 is cooling and reverting to its liquid phase. As the body of fluid 60 is cooled, the piston 34 is advanced in an intake stroke for permitting heated fluid to be drawn from the conduit 18 through the intake line 54 and the coil 52 within the cylinder 24, for purposes of delivering to the associated fluid 60 within the base segment 28 of the cylinder 24 thermal energy acquired as the fluid is circulated through the RTG 14. Hence, it will be appreciated that as the piston 34 within the cylinder 22 is advanced in an intake stroke heated fluid is drawn through the coil 52 of the cylinder 24 and introduced, in a slightly cooled condition, through the port 44 into the pumping chamber 40 of the cylinder 22. Simultaneously, the piston 34 within the cylinder 24 is advancing to expel the warming fluid from the chamber 40 of that cylinder due to a heat initiated expansion of the fluid 60. Once the piston 34 within the cylinder 22 is seated or bottomed on the shoulder 32 charging of the chamber 40 is completed within the cylinder 22 and the flow of the heated liquid through the coil 52 of the cylinder 24 is arrested.

Due to the fact that the heat sink 26 associated with the cylinder 24 continuously extracts heat from the fluid 60 within the compression chamber 53, the vaporized fluid 60 is reverted to its liquid phase thus

permitting the spring 62 within the cylinder 24, as well as the pressure of the fluid acting through the input port 42 to drive the piston 34 in an intake stroke, whereupon a circulation of heated fluid through the compression chamber 53 of the cylinder 22 is re-established. As the circulation through the chamber 53 is re-established, a reheating of the fluid 60 is achieved in order to again drive the piston 34 within the cylinder 22 in a pumping stroke as the piston 34 within the cylinder 24 is thus driven in an intake stroke. The check valve 51, of course, regulates the direction of flow from the discharge port 45 of the pumping chambers 40.

In view of the foregoing, it should readily be apparent that each cycle of operation for the pump repetitively is initiated as the piston 34 comes to rest on the shoulder 32, within one of the cylinders 22 and 24, for thus arresting the flow of heated warming fluid through the compression chamber 53 of the other cylinder, whereupon a cooling of the fluid 60 within that cylinder is initiated for thus affording the associated piston 34 an opportunity to advance in a fluid intake stroke.

In view of the foregoing, it is to be understood that the pump 12 embodying the principles of the instant invention is a practical, economic and efficient pump which utilizes energy readily available aboard spacecraft of a given variety for pumping heated fluids to fluid receivers, such as temperature control circuits associated with instrumentation packages.

Although the invention has been herein shown and described in what is conceived to be the most practical and preferred embodiment, it is recognized that departures may be made therefrom within the scope of the invention, which is not to be limited to the illustrative details disclosed.

What is claimed is:

1. A reciprocating pump for delivering heated fluids comprising:
 - A. a pair of operatively associated cylinders;
 - B. a pair of reciprocating pistons seated within said pair of cylinders dividing each of the cylinders into a pair of expansible, adjacent chambers, each pair of adjacent chambers including a pressure chamber and a coaxially related pumping chamber;
 - C. a compression chamber operatively associated within said pressure chamber;
 - D. delivery means for alternately delivering a heated fluid through the compression chamber of one cylinder to the pumping chamber of the other cylinder of said pair of cylinders; and
 - E. means for alternately driving each piston of said pair of pistons in pumping strokes for alternately expelling fluid from said pumping chambers in response to a delivery of heated fluid through said compression chamber.
2. The pump of claim 1 wherein:
 - A. said delivery means includes a heat exchanger; and
 - B. said means for driving said piston is a vaporizable fluid operatively associated with the heat exchanger.
3. The pump of claim 2 wherein:

- A. the delivery means further includes a valved conduit operatively associated with a source of heated fluid; and
- B. the pumping chamber of each cylinder is associated with a fluid receiver.
- 4. A reciprocating pump operatively associated with a source of heated fluid adapted to utilize thermal energy given up by the heated fluid for pumping the fluid to a fluid receiver comprising:
 - A. a pair of operatively related cylinders, each including a reciprocable piston dividing the cylinder into a coaxially related pressure chamber and pumping chamber;
 - B. means defining within each pumping chamber a fluid intake port and a fluid discharge port;
 - C. a compression chamber operatively associated with each of said pressure chambers;
 - D. a vaporizable fluid within each of said compression chambers adapted to undergo a phase change in response to changes in temperature;
 - E. a compression spring operatively seated in each of said pumping chambers for continuously urging said pistons toward said pressure chambers;
 - F. a fluid circuit including a first leg having therein a first coil operatively related to the compression chamber of one of said cylinders and terminating at the intake port of the pumping chamber of the other cylinder of said pair, and a second leg including therewithin a second coil operatively associated with the compression chamber of the second cylinder of said pair of cylinders and terminating at the intake port of the pumping chamber of the other cylinder of said pair of cylinders, and a one-way check valve interposed in each of said legs for precluding the counterflow of fluid therein;
 - G. a fluid receiver conduit operatively associated with each discharge port, including therein a one-

- way check valve for precluding a counterflow of fluid through the discharge ports of said pumping chambers; and
- H. a heat sink operatively coupled with the compression chamber of each of the cylinders, whereby an established flow of heated fluid through said first leg is interrupted and said vaporizable fluid is condensed within the related compression chamber for effecting an intake stroke of the associated piston as a flow of heated fluid is established through the second leg of the circuit for vaporizing the vaporizable fluid confined within the pressure chamber associated with the other cylinder to thus achieve an expansion thereof, so that a pumping stroke is imparted to the piston associated with said other cylinder.
- 5. A reciprocating pump for delivering heated fluids including:
 - A. a multiplicity of adjacent cylinders;
 - B. a multiplicity of reciprocable pistons seated within said multiplicity of cylinders defining within each of said cylinders a pressure chamber and a coaxially related pumping chamber;
 - C. means defining within each of said cylinders a compression chamber communicating with the pressure chamber defined within the cylinder;
 - D. a heat exchanger including means comprising a tubular conduit seated in the compression chamber defined within each of the cylinders and terminating in a pumping chamber defined within another cylinder for serially delivering heated fluid through the within another chambers to the pumping chambers, and
 - E. means including a vaporizable fluid disposed within each of said compression chambers responsive to a delivery of heated fluid therethrough for expelling from the pumping chambers heated fluid delivered thereto.

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