NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

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REPLY TO ATTN OF: GP

TO: KSI/Scientific & Technical Information Division
Attn: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General Counsel for Patent Matters

SUBJECT: Announcement of NASA-Owned U.S. Patents in STAR

In accordance with the procedures agreed upon by Code GP and Code KSI, the attached NASA-owned U.S. Patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U.S. Patent No.	: 3,819,299
Government or Corporate Employee	: U.S. Government
Supplementary Corporate Source (if applicable)	: ~
NASA Patent Case No.	: LEW-11,672-1

NOTE - If this patent covers an invention made by a corporate employee of a NASA Contractor, the following is applicable:

YES /__/ NO /X/

Pursuant to Section 305(a) of the National Aeronautics and Space Act, the name of the Administrator of NASA appears on the first page of the patent; however, the name of the actual inventor (author) appears at the heading of column No. 1 of the Specification, following the words "...with respect to an invention of ..."

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Enclosure

United States Patent [19]
Brown

[11] 3,819,299
[45] June 25, 1974

[54] MAGNETOCALORIC PUMP

[75] Inventor: **Gerald V. Brown**, Lakewood, Ohio

[73] Assignee: **The United States of America as represented by the Administrator of the National Aeronautics and Space Administration**, Washington, D.C.

[22] Filed: **Nov. 10, 1972**

[21] Appl. No.: **305,639**

[52] **U.S. Cl.** **417/52**
[51] **Int. Cl.** **F04b 19/24**
[58] **Field of Search** 417/48, 207, 383, 52, 322

[56] **References Cited**

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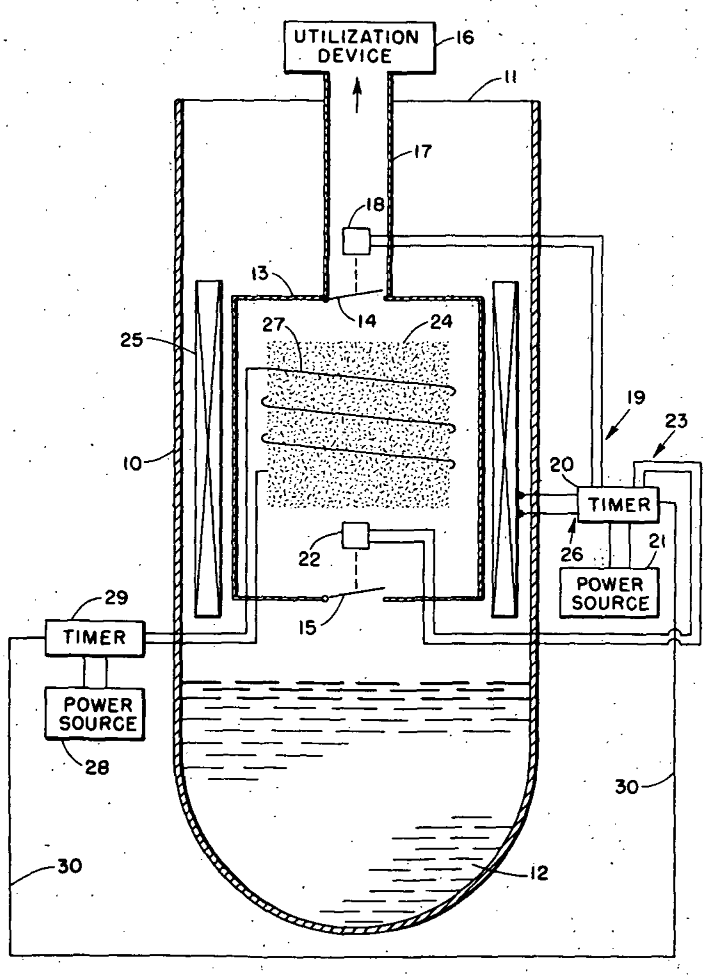
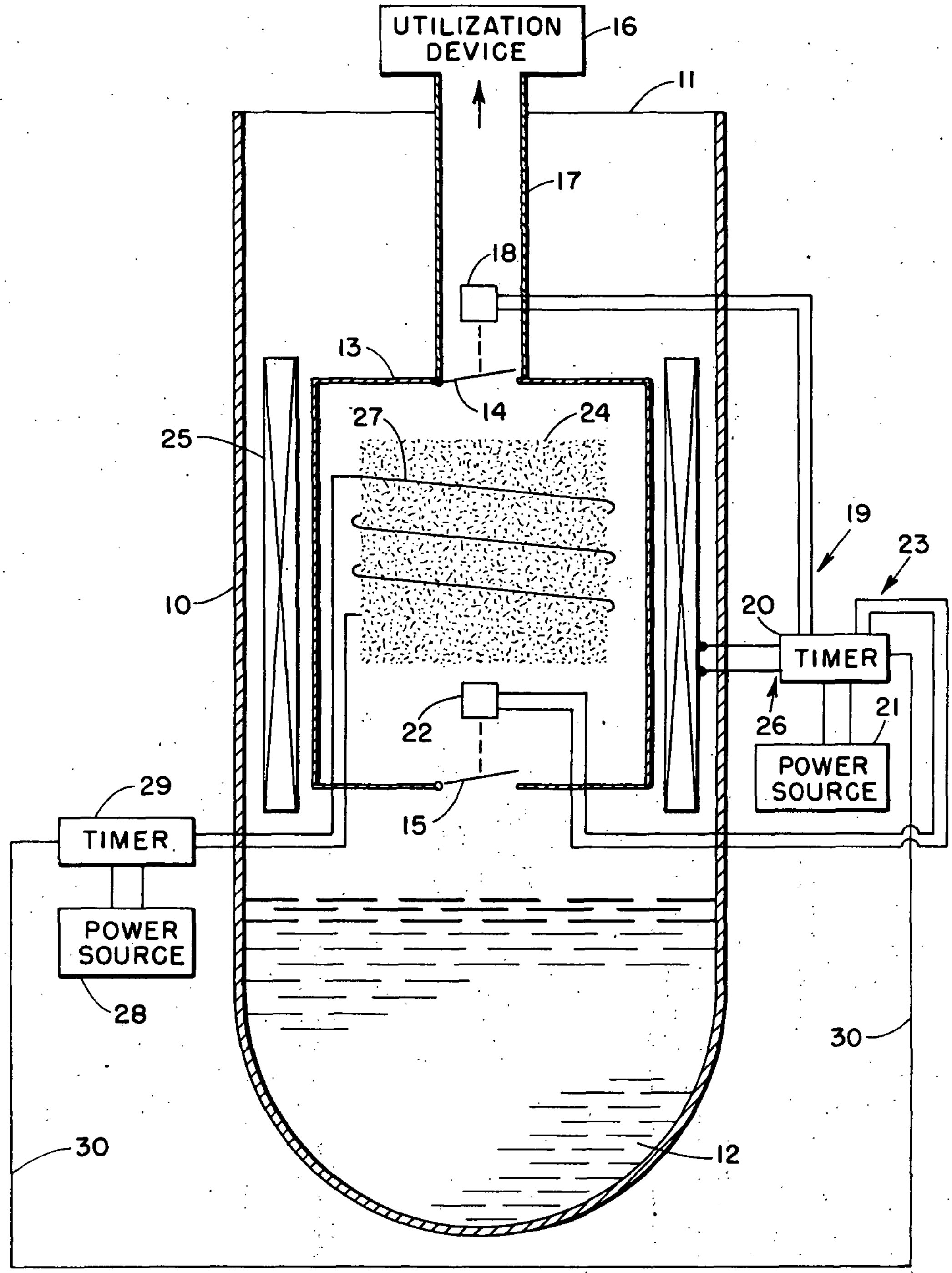
Attorney, Agent, or Firm—N. T. Musial; J. A. Mackin; J. R. Manning

[57] ABSTRACT

A pump for fluids is disclosed. A vessel having inlet and outlet valves is disposed in a container having disposed therein a fluid to be pumped and which fluid may be evolved from a liquid in the container below the vessel. A magnetocaloric substance is disposed in the vessel and causes fluid vapor in the vessel to expand and be expelled through the outlet valve when a magnetic field is impressed on a magnetocaloric substance of the type which increases in temperature when subjected to an increasing magnetic field. If the magnetocaloric substance is of a type which increases in temperature when subjected to a decreasing magnetic field, then fluid will be expelled from the vessel when the magnetic field is decreased or terminated. As the substance cools, vapor is drawn in through the inlet valve. The inlet valves may be one-way check valves or may be solenoid valves energized at appropriate times by timing circuits. A timer controlled heating element may also be disposed in the vessel to operate in conjunction with the magnetic field.

18 Claims, 1 Drawing Figure




UTILIZATION DEVICE
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POWER SOURCE
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MAGNETOCALORIC PUMP

ORIGIN OF THE INVENTION

This invention was made by an employee of the U.S. Government and may be manufactured or used by or for the Government of The U.S. of America without any payment of royalties thereon or therefor.

BACKGROUND OF THE INVENTION

This invention relates to pumps and is directed more particularly to a pump for cryogenic fluids.

In addition to transferring fluid from one location to another, pumps are used to cool fluids and particularly cryogenic fluids. An example of this occurs where liquid helium is disposed in a container and which, as a result of evaporation, also contains saturated helium vapor. By pumping saturated vapor out of the container to the atmosphere, cooling of the liquid is effected.

In the prior art, the pumping of fluids has been accomplished by a variety of devices such as mechanical pumps, diffusion pumps, and various other types of cyclic and acyclic sorption pumps. Mechanical and diffusion pumps can cause contamination of the pumped fluid with oil or other substances which cannot be tolerated in many instances, as for example, where the pumped fluid must be of high purity. Furthermore, many of the prior art pumps can operate only above certain temperatures, as for example, normal room temperature, and would be inoperative at a temperature of, for example, 4.0° Kelvin.

Mechanical pumps in general involve moving parts which, of course, make the pump more subject to mechanical failure. The other types of pumps are generally more expensive and complex.

OBJECTS OF THE INVENTION

It is an object of the invention to provide a fluid pump having a minimum of moving parts.

It is another object of the invention to provide a pump which does not contaminate the fluid being pumped.

Still another object of the invention is to provide a pump which is particularly suitable for pumping extremely cold vapors, for example, as low as 4.0° Kelvin.

Yet another object of the invention is to provide a pump which is specially effective in pumping saturated vapors at a high rate of delivery.

Another object of the invention is to provide a pump for fluids which either expand or contract when heated.

It is a further object of the invention to provide a pump suitable for cooling liquid in a closed container.

BRIEF DESCRIPTION OF THE DRAWING

The single FIGURE is a schematic drawing of a magnetocaloric pump embodying the invention.

DESCRIPTION OF A PREFERRED EMBODIMENT

Referring to the single FIGURE, there is shown a suitable container **10** having a closed top **11**. Container **10** may be partially filled with a liquid **12** such as helium, nitrogen, hydrogen, or neon, although operation is not restricted to these particular liquids. For example, the pump will also operate when the liquid is water. Disposed inside container **10** above the liquid **12** is a pump embodying the invention and comprising a suitable vessel **13** having an outlet valve **14** and an inlet valve **15**. The outlet valve **14** communicates with a utilization device **16** or with the atmosphere through a conduit **17** which extends through a port in the top **11** of the container **10**. Thus, the interior of the vessel **13** is periodically and alternately in communication with the interior or the container **10** and with the utilization device **16** or atmosphere. The valve **14** communicates with the atmosphere when the pump is being used to cool a liquid by expelling saturated vapor, as discussed previously.

Although the valves **14** and **15** are disposed in the top and bottom, respectively, of the vessel **13**, it will be understood that the valves may be located at any point in the walls of the vessel **14** provided the communication paths are maintained, that is, the outlet valve **14** is maintained in communication with a utilization device **16** or atmosphere while the inlet valve **15** is maintained in communication with the interior of the chamber **10**. Inlet valves **14** and **15** may be simple one-way check valves. However, outlet valve **14** may be of the type having a solenoid **18** energized from a first output **19** of a timer **20** which received electrical power from a power source **21**. Likewise, inlet valve **15** may be provided with a solenoid **22** energized from a second output **23** of the timer **20**. The timer is preferably programmed to alternately open the valves **14** and **15**.

Pumping action is provided by a body of magnetocaloric material **24** disposed in the vessel **13**. A magnetocaloric material is one which is either increased or decreased in temperature when subjected to the magnetic field. Examples of such materials are the rare earth elements such as Gd, Dy and Ce, the transition series elements such as Fe, Cr, Ni and Co, and the salts of these two groups. For maximum heat exchange whereby the fluid being pumped is heated and cooled by the magnetocaloric body **24**, the body is porous and may be made by sintering, granulating or otherwise providing openings in such magnetocaloric body. To the end that a magnetic field will be applied to the magnetocaloric material **24**, a solenoid winding **25** is disposed around the vessel **13**. Solenoid **25** is energized from a third output **26** of timer **20**. Preferably the magnetic field is supplied by a super-conducting magnet for maximum effectiveness.

To increase the pumping rate and efficiency of the pump a heating element **27** may be disposed around or in the magnetocaloric material. The heating element **27** is energized from a power source **28** by means of a timer **29**, the operation of which will be described presently. In order that the heating element **27** will be energized during the time when pumping action is occurring, that is when fluid is being expelled from the vessel **13** by way of the outlet valve **14**, a synchronizing lead **30** is connected between timer **29** and timer **20**. It will be understood by those skilled in the art, that dependent upon the electrical requirements of solenoid **25**, solenoids **18** and **22** and the heater element **27**, timers **20** and **29** could be combined in one unit as is also possible with the power sources **21** and **28**.

Operation of the magnetocaloric pump will now be described. It will be assumed that the magnetocaloric body **24** has a positive effect, that is, it increases in temperature when subjected to a magnetic field. It will be understood that there are magnetocaloric materials which have a negative effect and would require the valves **14** and **15** to be opened for conditions under which they would be closed for a material having a positive effect.

Pumping action is initiated by filling the vessel **13** with a fluid to be pumped thus ensuring that the magnetocaloric material **24** is at the same temperature as the fluid. This may be done with the magnetic field either off or on. If the pump is primed with the magnetic field on, a reduction or termination of the magnetic field will cause the magnetic material **24** to cool and the fluid in the vessel **13** will contract drawing in more fluid through the valve **15**. If the valve **15** is of the solenoid type the timer **20** will cause the solenoid to be energized to open the valve during the time the fluid is contracting.

To expel the fluid from the vessel **13** the magnetic field is again impressed on the material **24** by supplying or increasing the current to the solenoid winding **25** to cause heating of the material **24**. This expands the fluid in the vessel **13** causing it to be expelled through the outlet valve **14** and through the conduit **17** through the utilization device **16**. The outlet valve may be of the solenoid type in which case the solenoid **18** is energized by the timer **20** during the period of time that the fluid in the vessel **13** is expanding. The magnetic field is again either terminated or reduced and the cycle is repeated.

As explained previously, the heating element **27** may be energized simultaneously with the solenoid **25** to iincrease the pumping action by providing additional heat to expand the fluid in the vessel **13** where the fluid is one which expands when heated. There are certain fluids, which contract when heated within certain temperature ranges. An example is water between 0° and 4°C. With such fluids it will be understood that, if the valves **14** and **15** are solenoid types rather than one-way valves, they must be actuated in reversed order to their normal sequence.

The magnetocaloric pump embodying the invention is most effective for pumping saturated vapors. Such vapors have a temperature equal to the boiling point of the liquid **12**. If the liquid is helium, for example, the boiling point is −269°C or 4.2°K.

The liquid **12** need not be in the container **10**. The requirement for the pump to work is that the inlet valve **15** be in communcation with a fluid to be pumped. Thus, a fluid could be supplied to container **10** from a supply of the fluid being pumped. For example, the magnetocaloric pump embodying the invention may be used to pump natural gas. In such an arrangement, the pipe carrying the natural gas and the source of the gas would be the equivalent of the container **11**.

It will be understood that changes and modifications may be made to the above-described magnetocaloric pump without departing from the spirit and scope of the invention as set forth in the claims appended hereto.

What is claimed is:

1. A fluid pump comprising

a container filled with a substantially nonmagnetic, nonelectro fluid to be pumped;

a vessel disposed in said container;

an inlet valve disposed in a wall of said vessel;

an outlet valve disposed in a wall of said vessel, said second valve communicating with a port in the wall of said container;

a body of magnetocaloric material disposed in said vessel; and

means for subjecting said body of magnetocaloric material to a time-wise varying magnetic field to cause alternate expansion and contraction of the fluid.

2. The apparatus of claim **1** and including means for alternately opening said outlet valve and said inlet valve.

3. The apparatus of claim **1** wherein said inlet and outlet valves are one-way check valves.

4. The apparatus of claim **1** wherein said last named means comprises a magnetic winding disposed around said vessel and means for supplying an alternately increasing and decreasing electrical current to said winding.

5. The apparatus of claim **1** wherein said last named means includes a superconducting magnet.

6. The apparatus of claim **1** and including a heating element disposed in said vessel and means for energizing said heating element simultaneously with the expansion of the fluid in said vessel.

7. The apparatus of claim **1** wherein the magnetic field is of such intensity that the temperature of said magnetocaloric material does not rise above the boiling point of said liquid, when said liquid is water.

8. The apparatus of claim **1** wherein said inlet and outlet valves are solenoid type and including a power supply for said solenoid valves and timing means for opening said outlet valve when fluid in said vessel is expanding and for opening said inlet valve when fluid in said vessel is contracting.

9. The apparatus of claim **1** wherein said inlet valve is disposed in a bottom wall of said chamber and said inlet valve is disposed in a top wall.

10. The apparatus of claim **1** wherein said magnetocaloric material is porous.

11. The apparatus of claim **1** wherein said magnetocaloric material is a rare earth.

12. The apparatus of claim **1** wherein said magnetocaloric material is the salt of a rare earth.

13. The apparatus of claim **1** wherein said magnetocaloric material is a transition of element.

14. The apparatus of claim **1** wherein said magnetocaloric material is the salt of a transition element.

15. The apparatus of claim **1** wherein said container is partially filled with a liquid.

16. The apparatus of claim **11** and including means to heat said liquid to a temperature greater than its boiling point temperature.

17. The apparatus of claim **15** wherein said liquid is selected from the group consisting of helium, hydrogen, nitrogen and neon.

18. The apparatus of claim **1** and including receiving means communicating with said port in said container wall to receive fluid expelled from said pump.

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