United States Patent [19]

Leo

[11] **3,774,405**

[45] **Nov. 27, 1973**

[54] **MAGNETICALLY DRIVEN CRYOGEN VUILLEUMIER REFRIGERATOR**

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[73] Assignee: **The United States of America as represented by the Secretary of the Air Force**, Washington, D.C.

[22] Filed: **Sept. 9, 1971**

[21] Appl. No.: **178,866**

[52] **U.S. Cl.** **62/6**, 62/86, 62/88

[51] **Int. Cl.** **F25b 9/00**

[58] **Field of Search** 62/6, 86, 88

[56] **References Cited**

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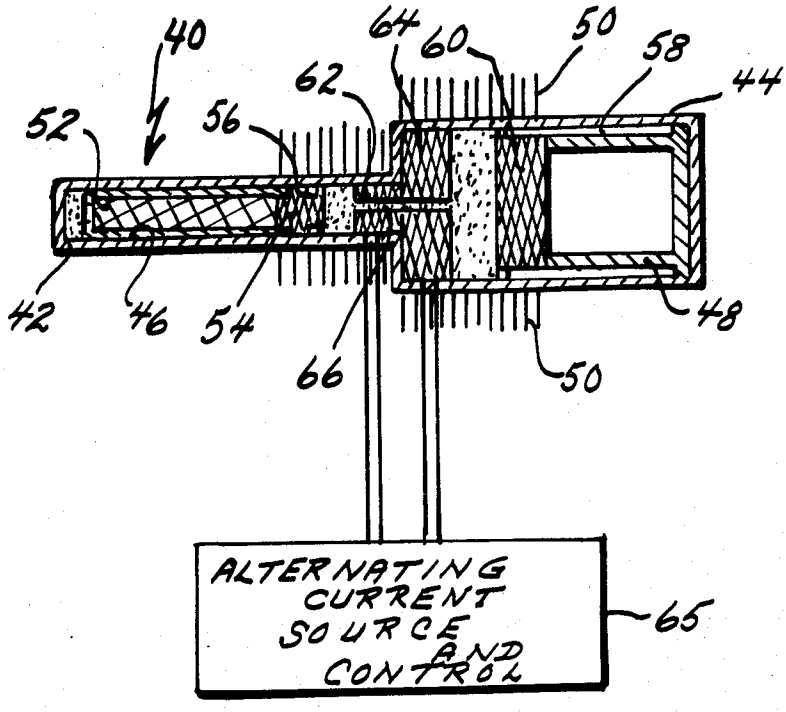
[57] **ABSTRACT**

A magnetically driven cryogenic refrigeration system using the Vuilleumier cycle having hot and cold gas displacer with incorporated regenerators, each displacer positioned in a cylinder and having a permanent magnet in its base, each cylinder having an electro magnet, powered by an alternating power source located at one end and a chamber connecting the hot and cold cylinders for allowing the gas to pass between them.

3 Claims, 3 Drawing Figures



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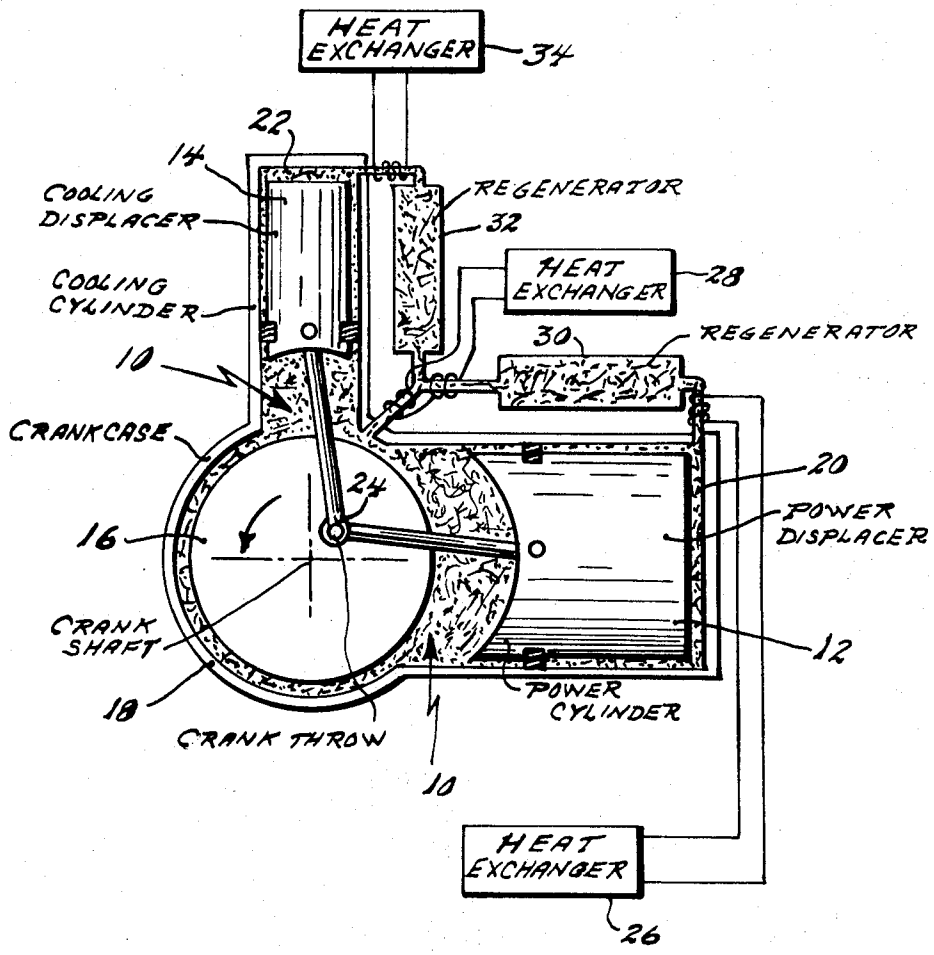

FIG. 1

PRIOR ART

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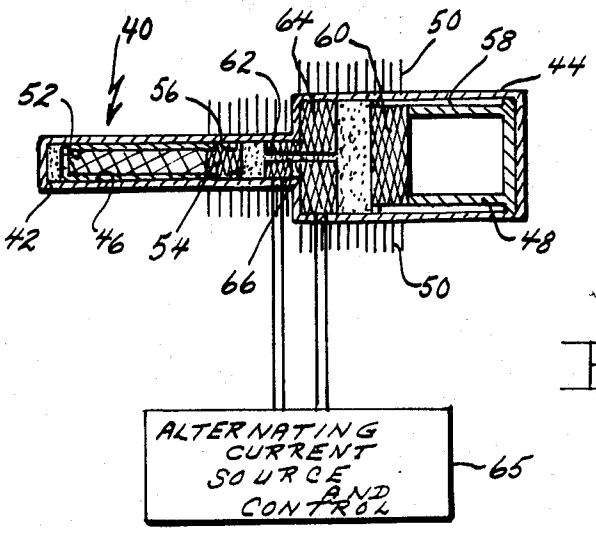

FIG. 2

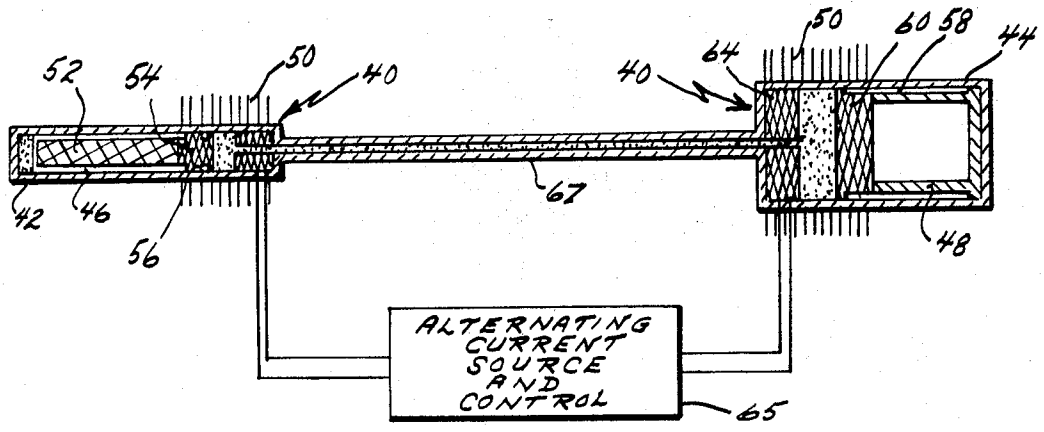

FIG. 3

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MAGNETICALLY DRIVEN CRYOGEN VUILLEUMIER REFRIGERATOR

BACKGROUND OF THE INVENTION

This invention relates generally to cryogenic refrigerators and more specifically to a magnetically driven Vuilleumier refrigerator.

The Vuilleumier refrigeration cycle was initially discovered in the early twentieth century. Few practical applications have been made in the intervening years however, due to the fact that its efficiency is less than other known cryogenic refrigeration cycles at commercial load size applications.

Recent requirements for miniature flightweight cryogenic refrigerators to cool the low heat loads associated with infrared detectors and similar cryoelectronic devices coupled with some potentially inherent advantages of the cycle have precipitated renewed interest in its evaluation. The cycle can produce cryogenic refrigeration with a source of heat as the only input required. This concept of utilizing heat energy in lieu of more conventional mechanical energy for producing refrigeration may seem somewhat paradoxical; however, it is inherent in the Vuilleumier cycle and offers a number of advantages. For example, in space applications, the required heat source might be obtained via solar collector or through use of isotope capsule, thus obviating the requirement for large amounts of electrical power.

All cryogenic refrigerators employ three basic processes to obtain cooling. In general, all of these refrigerators compress a more or less ideal gas at ambient temperature and then expand this gas at a low temperature in a quasi-reversible manner; this method of expanding subtracts an amount of energy from the gas that can be then absorbed from the heat energy of a device thereby cooling or refrigerating it.

The first two processes (i.e., compression at ambient temperature and expansion at low temperature) are fundamentally simple in concept. A change of pressure is effected either by an addition of work (compression) or a subtraction of work (expansion). The last process is more complicated. To accomplish this in an efficient manner the heat that is removed from the gas in cooling it to low temperature must be added to the gas in heating it to ambient temperature. The process is accomplished either by countercurrent heat exchanger or thermal regenerators.

In the past cryogenic refrigerators using the Vuilleumier cycle have been constructed in a manner similar to that of the original conventional commercial refrigerators, that is, to use a piston and connecting rod attached to a rotating crank shaft. The crank shaft is turned with an associated motor and drive mechanism. Provided size, weight and maintenance were of little or no consideration, these refrigerators were adequate. However, in space applications these known refrigerators are limited by the aforementioned factors as well as the vibrations caused by the pistons recripicating in orthoginal planes.

SUMMARY OF THE INVENTION

The invention overcomes the disadvantages of the prior art by driving the gas displacers (pistons) magnetically thereby eliminating the drive and motor of the prior art devices. Further, the invention uses a linear motion in the gas displacers thereby eliminating one plane of vibration. The invention utilizes two displacers

which have no mechanical interconnection. At the base of each gas displacer is a permanent magnet, while in the base of each cylinder is mounted an electro magnet. As the polarity of the electro magnets is reversed the gas displacers are attracted or repelled and caused to move with a recipricating motion.

Since there is no connecting rod between the two displacers the hot and cold cylinders may be separated by a relatively large distance whereby the cold cylinder may be placed in the area to be cooled while the hot cylinder may be positioned at a more convenient location.

The invention further uses an internal regeneration system thereby eliminating external hardward and the use of valves to control the motion of the pistons.

It is thereofre an object of the invention to provide a new and improved cryogenic refrigerator.

It is another object of the invention to provide a new and improved magnetically driven cryogenic refrigerator.

It is a further object of the invention to provide a new and improved magnetically driven cryogenic refrigerator that uses the Vuilleumier cycle.

It is still another object of the invention to provide a new and improved Vuilleumier refrigerator that operates without motors or drive assemblies.

It is still a further object of the invention to provide a new and improved cryogenic refrigerator that provides motion in only one plane.

It is another object of the invention to provide a new and improved Vuilleumier refrigerator that controls the motion of gas displacers without the use of valves.

It is another object of the invention to provide a new and improved cryogenic Vuilleumier refrigerator that allows for physical displacement of the hot and cold cylinders.

It is another object of the invention to provide a new and improved cryogenic refrigerator that is lighter, smaller and more reliable than any hitherto known.

These and other advantages, features and objects of the invention will become more apparent from the following description taken in connection with the illustrative embodiments in the accompanying drawings.

DESCRIPTION OF DRAWINGS

FIG. 1 is a side elevational view of a typical prior art Vuilleumier cryogenic refrigerator.

FIG. 2 is a crossectional view of the invention in compact form.

FIG. 3 is a crossectional view of the invention in elongated form.

DESCRIPTION OF PREFERRED EMBODIMENTS

Referring now to FIG. 1, the known prior art type of Vuilleumier refrigerator is a constant volume system wherein the geometrical working volume shown generally at **10** cannot vary because of any motion of the displacers **12** and **14.** Because of changes in the average temperature of the gas that fills the working volume of the refrigerator, the pressure can and does vary as the displacer moves. Motion of the power displacer **12** toward the center of the crankshaft **16** forces gas to move from the crankcase **18,** the temperature of which is approximately that of the radiator, to the hot end **20** of the power cylinder. This movement increases the average temperature of the gas in the working volume and hence the pressure in the fixed volume increases.

Similarly, motion of the cool displacer **14** forces some gas to leave the crankcase and flow to the cold ends **22** of the cooling cylinder. In this way the working gas is cooled and its pressure decreases.

When the crankshaft is in the position shown at **24** the pressure in the working volume assumes a high value. As the crank shaft moves in the counterclockwise direction the power displacer **12** compresses the gas since most of it is flowing into the hot cylinder volume **20** and is absorbing heat. The cold cylinder volume is expanding and producing refrigeration because the rest of the gas is pushing the cooling displacer **14** and performing work. The result is that an amount of the working gas is transferred to the cold end of the cooling cylinder with little change in pressure.

As the crank shaft continues to rotate and the point **24** reaches the lowest point of its travel, both of the displacers allow the gas to expand and the pressure falls to a low value. With further motion the cooling displacer **14** compresses the gas and the power displacer allows it to expand with little change in pressure. As the motion continues to point **24** and beyond, the displacers compress the gas,heat is rejected to the ambient and the pressure returns to the high value since heat is being absorbed in the hot cylinder volume **20.**

The system is completed by providing a heat source **26** to heat the gas in the system. A heat exchanger **28** is connected between the hot regenerator **30** and the cold regenerator **32.** The heat exchanger removes excess heat from the system to the ambient. The heat exchanger is used to remove heat from the refrigerator and heat enters the system through this exchanger.

Using the same concept of refrigeration discussed with regard to FIG. **1,** the invention is shown in FIG. **2.** The system consists of housing shown generally at **40,** having two cylindrically shaped, opposed ends **42** and **44.** Within the cylinders are gas displacers **46** and **48.** The smaller displacer (**46**) and cylinder form the cold end of the system. Heat taken from the load on the cold end of the device is given off to the ambient through the fins **50.** The cold displacer **46** is provided with a lattice like portion **52** which constitutes the cold regenerator. At the base of the cold displacer is a permanent magnet **54** in which is mounted a seal **56.** The hot displacer **48** is provided with a recessed area **58** around the displacer mid-section which acts as a hot regenerator. This displacer is fitted with a permanent magnet **60.**

The invention has, mesially located, a pair of electro magnets **62** and **64** that are controlled by the alternating current source **65.**

In operation the gas displacers are moved in a linear motion by the reversing fields of the electromagnets. The gas, moved by the motion of the displacers **46** and **48** passes through the chamber **66** thereby creating the proper expansion and contraction of the gas needed for refrigeration.

FIG. **3** concerns an alternative embodiment of the invention. The numerals of FIG. **3** are the same as those of FIG. **2.** The invention provides an additional degree of flexibility over currently existing devices in that the hot and cold cylinders (**44** and **42**) may be separated by the addition of an elongated chamber **67.** With this embodiment it is possible to place the cold cylinder in an area where refrigeration is required while the hot cylinder remains separated from the area thereby lowering refrigeration requirements as well as providing alternative solutions to the packaging problems inherent in space vehicles.

Having thus described my invention in detail, I present the following claims to that which I consider my invention:

1. The refrigeration apparatus comprising: a housing, including a first, hot cylinder, and a second, cold cylinder, said cylinders being interconnected to allow the passage of a fluid therebetween; means affixed to said first cylinder for dissipating heat away from the housing; first and second fluid displacers movably positioned in said first and second cylinders and having recessed areas so shaped as to form regenerative means between said displacers and said cylinders; magnet means positioned at one end of each of the said displacers; magnet means positioned at one end at each of said cylinders; means connected to the housing for causing a magnetic interaction between said cylinders magnet means and said displacers magnet means to cause reciprocating movement of said displacers and thereby causing movement of a fluid from one cylinder to the other cylinder.

2. A system according to claim **1** wherein said magnetic means for causing motion includes a permanent magnet positioned in the base of each of the first and second gas displacers and a pair of electro magnets mounted in the housing.

3. A system according to claim **2** wherein the means for controlling the motion of the gas displacers is a source of alternating current coupled to the electro magnets.

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