Jan. 28, 1969 K. W. COWANS 3,423,948

CRYOGENIC REFRIGERATOR ADAPTED TO MINIATURIZATION

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Fig. 1.

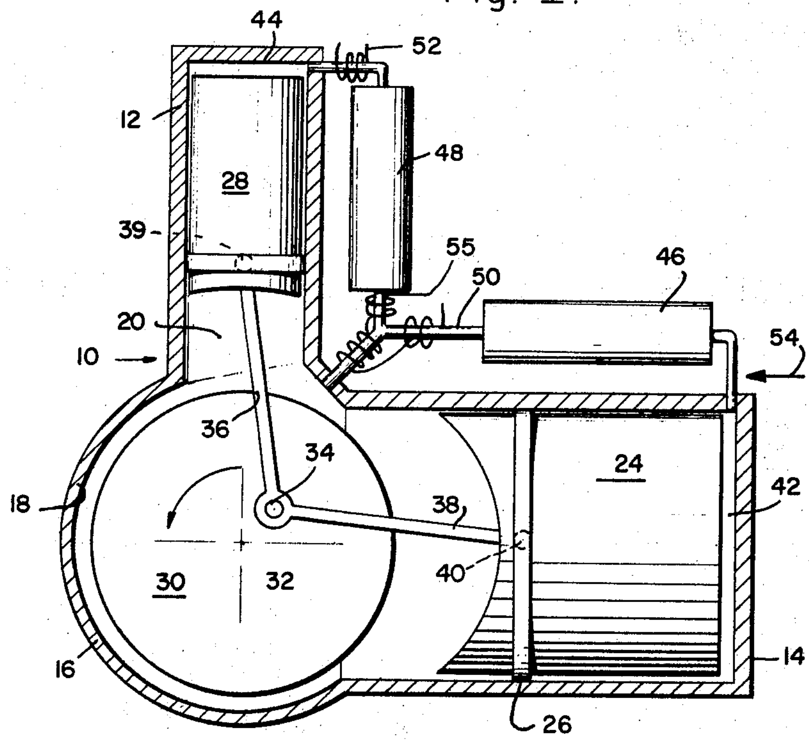
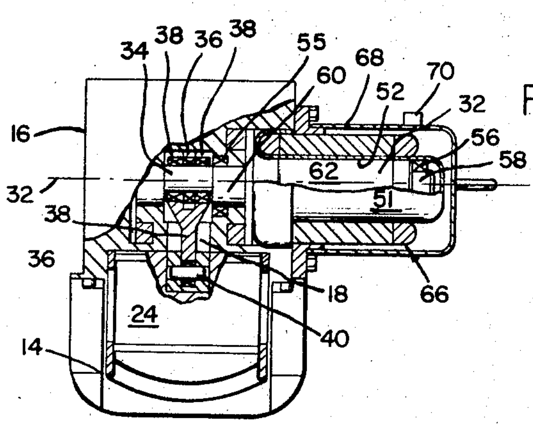


Fig. 2.



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CRYOGENIC REFRIGERATOR ADAPTED TO MINIATURIZATION

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ABSTRACT OF THE DISCLOSURE

The structure is a cryogenic refrigerator producing a low-level temperature by closed cycle circulation of a cryogenic fluid. A totally sealed housing is provided which defines a hot cylinder, cold cylinder, and crankcase chamber, the latter having a crankshaft rotatably mounted therein and directly connected to displacers in the cold and hot cylinders. The crankcase chamber which communicates directly with the cold and hot cylinders serves as a reservoir through which the cryogenic fluid is cycled during refrigerator operation. The direct rod connections, crankshaft to displacers, eliminate the need for cylinder-defining walls and the related seals and bearing guide arrangements. Motive power is provided by stator windings externally of the sealed housing which operatively cooperate with a rotor journalled internally of the housing and associated with the crankshaft.

The invention relates to a cryogenic refrigerator adapted to produce extremely low temperatures required for efficient operation of certain electronic devices and amenable to miniaturization, simplified construction, and long service life.

A conventional type of closed-cycle cryogenic refrigerator employs a plurality of cylinders arranged generally in angular relation, the respective cylinders having a hot displacer, a cooling displacer reciprocable in the respective cylinders and defining, in the respective cylinders, a hot chamber and a cold chamber. Arrangements of this type characteristically incorporate a cool chamber at a temperature level between the temperature levels of hot and cold chambers. Passages interconnect the chambers and include regenerator means. The passages accommodate the transfer of refrigerating fluid between the chambers in response to displacer reciprocation. Characteristically, the regenerators are operative to absorb heat from excessively hot gases passing therethrough and return heat to relatively cool gases passing therethrough as the cyclic direction of gas flow is reversed.

As noted above, certain operating systems which require cryogenic cooling involve parameters wherein small size, efficient operation, low initial cost, and long service life are at a premium. Typical of such application is the cooling of electronic devices such as an infrared detector while the latter is being carried by a flying vehicle in, for example, orbital trajectory about the earth. Here the detecting device may be used to scan or otherwise "photograph" certain radiation patterns being emitted from the earth's surface or atmosphere and this contemplated use reasonably requires continued device operation over an extended period of time even, for example, for as long as one year or more.

Cryogenic refrigerators of prior art design characteristically employed rather complex connecting rod systems operatively associating the respective hot and cold displacers with a common crankshaft. Efficient operation requires a separate chamber, herein denominated a cool chamber, intermediate the hot and cold chambers and this structure coupled with connecting rod and sealing arrangements dictated complicated, well-sealed, expensive structure having excessive weight and bulkiness; clearly, a disadvantage when used in a flight mode. One reason for such complicated structure is the necessity for having a power source to drive a common crankshaft and effect the required out-of-phase displacer movement necessary for the cyclic flow of the refrigerating gas and thereby producing the refrigerating effect. Device operation requires a heat input source at the hot cylinder and cyclic action of the refrigerating fluid as the displacer elements are moved within their respective cylinders by the power source, i.e., electric motor provided. This connects the input heat energy at one cylinder to refrigerating energy at the cooling cylinder.

It is an object of the present invention to provide a sealed closed-cycle cryogenic refrigerator of the type described readily adaptable to miniaturization and thus provide the refrigerating effect desired in a small-sized, low-weight, compact package.

It is a further feature of the invention to utilize the crankcase space, that is, that volume wherein the connecting or common crankshaft is rotatably positioned, as a cool or intermediate temperature chamber during the cycling sequence necessary to achieve the refrigerating effect.

It is yet another object of the invention to provide a refrigerating device of the type described which eliminates the necessity for chamber-defining walls of prior art designs and the consequent necessity of connecting rod sealing and complicated connecting linkage.

It is still another object of the invention to provide a cryogenic refrigerator of the type described of such simplified construction that mechanical breakdown possibility is substantially reduced and long service life results.

It is yet a further object of the invention to provide a cryogenic refrigerator of the type described wherein certain components of the operative structure are enclosed in a sealed housing to thereby avoid the entrance of contaminants which experience has shown interferes with long service life.

Still another object of the invention is an arrangement described wherein the sealed housing contains all of the refrigerating gas, the major operating structural components of the refrigerator, while the motor windings, i.e., the stator which induces displacer motion are located externally of the housing and conventionally drive a related rotor through the housing wall to effect refrigerator operation.

These and other features and advantages of the invention will become apparent in the course of the following description and from an examination of the related drawings wherein:

FIGURE 1 is a schematic, vertical, sectional, elevational view of a typical embodiment of the invention herein disclosed; and

FIG. 2 is a partially fragmentary, elevational view of an embodiment of the refrigerator disclosed in FIG. 1 and illustrating the mode of motor construction in relation to the sealed housing.

Describing the invention in detail and directing attention to FIG. 1, the numeral **10** generally illustrates a sealed housing containing the refrigerator. The housing **10** is provided with a cold cylinder **12** at one aspect and a hot cylinder **14** at another aspect, said cylinders preferably being in 90° relation to each other as seen in FIG. 1. Interconnecting the cold cylinder **12** and hot cylinder **14** is a main housing **16**, the latter defining a working volume or chamber **18** internally thereof. As will be seen, the working volume **18** is in direct communication with the inner portion **20** of the cold cylinder **12** and the inner portion **22** of the hot cylinder **14**.

With this construction in mind, it will be apparent that a hot displacer **24** may be positioned in chamber **22** of cylinder **14** for reciprocal motion therein. An appropriate annular seal **26** may be provided.

Directing attention to cold cylinder **12**, it will be seen that a cold displacer **28** is positioned within the chamber **20** defined by cylinder **12** and is also sealed as at **30** whereby the displacer may effect reciprocating motion within the cylinder **12**.

Within working volume or chamber **18** a crankshaft **30** is positioned for rotatable motion about a central axis **32**, the latter being perpendicular to the plane of FIG. 1. A crank pin or throw **34** is positioned eccentrically with reference to the axis of rotation **32** and serves as a journal for mountnig the connecting rods **36** and **38**, said rods pivotally interconnecting the throw **34** and the cooling displacer **28**, and the throw **34** and the hot displacer **24**, as is shown at **39** and **40**, respectively.

The hot displacer **24** defines with cylinder **14** a hot chamber **42**. Similarly, the cooling displacer **28** defines with cylinder **12** a cold chamber **44**. Intermediate the chambers **42** and **44**, the main housing **16** and the chamber **18** defines a cool chamber surrounding the crankshaft **30** and extending partially into the respective cylinders **12** and **14**.

It will also be noted that all of the chamber volumes of the miniaturized cryogenic refrigerator **10** are in communication via first regenerator **46**, second regenerator **48**, and connecting central piping **50**, the latter establishing communication between the regenerators and the cool chamber **18**. A heat load **52** is provided adjacent the cold cylinder **12**. That heat load may be an electronic detector or the like which must be cooled to a cryogenic temperature as a result of refrigeration developed at the cylinder **12**. To provide heat input to the device **10**, a heat source **54**, which may be an open flame but is here shown by an arrow, is in heat exchange relation with the hot chamber **42** of cylinder **14**. The heat source **54** may be at any relatively high temperature as, for example, 1000° F. and may continuously supply heat to the chamber **42** during operation. A heat exchanger **55** may be provided in association with the piping **50** to reject heat to ambient from the passing refrigerating fluid.

Considering briefly the operation of the structure, the crank throw **34** may be assumed to be in the upwardly directed position (FIG. 1) indicating the displacer **28** is at top-dead-center in cylinder **12** while the displacer **24** is in an intermediate position in cylinder **14**. When the crank throw moves 90° to the leftwardly-directed position of FIG. 1, the cold displacer **28** moves to central position and the hot displacer **24** moves to bottom-dead-center. Refrigerating fluid moves from chamber **18** to chambers **42** and **44** and the expansion phase of the cycle is being achieved. Refrigeration is produced at cylinder **44**. Refrigerating fluid moving to chamber **44** is, of course, cooled by passage through regenerator **48** and fluid then heated by passage through regenerator **46**. At exchanger **55** heat is discharged to ambient. Continued movement of throw **34** to downwardly directed position of FIG. 1 brings displacer **28** to bottom-dead-center and displacer **24** to intermediate position. The expansion or refrigerating phase of the cycle is thus completed and pressure in the arrangement minimized.

As the crank throw **34** moves to the rightwardly-directed position, the hot displacer **24** is brought to top-dead-center while the cold displacer **28** moves to an intermediate position. Both displacers are compressing the refrigerating fluid and pressure in the system is increased.

On a return of the crank throw **34** to the upwardly-directed position, the cold displacer **28** is moved to top-dead-center and the hot displacer **24** is moved to an intermediate position to thus arrive at the initiation point of the refrigerating phase of the cycle.

The net effect of a complete cycle of operation is that heat energy is supplied from source **54** to chamber **42** and the work equivalent thereof is delivered as refrigeration at the cold cylinder **12**.

In this somewhat schematic view of FIG. 1, it will be particularly noted that the working volume or cool chamber **18** is the volume wherein the crankshaft **34** journally moves. There are no walls separating the working volume **18** from the displacers **24** and **28** and direct connecting rods **36** and **38** may couple the crank throw **34** and the respective displacers **24** and **28**. Complicated sealing is not required. This structure complements miniaturization (low weight), efficient operation, and long service life due to elimination of many sources of possible structural failure.

FIG. 2 is an illustrative view of another feature of the invention which contributes importantly to miniaturization and light weight, complements the sealed closed-cycle system, and thereby conrtibutes to long service life of the refrigerator. Certain aspects of FIG. 2 are identical with FIG. 1 and where identity exists identical numerals will be used.

The hot cylinder of FIG. 2 is shown at **14** in partially broken fragmentary view having the hot displacer **24** disposed therein. The crankshaft or main housing is indicated at **16**, as in FIG. 1, and defines internally thereof the cool chamber **18**. Structure defining the cold cylinder **12** and related parts is not shown in this figure because in normal construction it would be perpendicular and behind the plane of the page illustrating the structure. The center of rotation of the crankshaft is shown at **32**, as in FIG. 1, and the center line of the eccentric crank throw is shown at **34**. Rod **38** is journalled to crank throw **34** and is pin-connected as at **40** to the displacer **24**. The crank-connecting rod **36**, normally attached to the cool displacer **28**, is illustrated but its connection to that displacer is not shown.

It will be recalled that the refrigerator here under discussion is a closed and sealed arrangement, the integrity of that sealing being intended to be preserved during the entire operating life of the refrigerator. This avoids the introduction of contaminants into the refrigerating fluid which could have deleterious effect on machine service life as well as machine efficiency during operation. Accordingly, the housing **16** is provided with a connected wall which projects to the right of said housing as seen in FIG. 2. This wall is indicated by the numeral **50**. The wall defines internally thereof the cavity **52** which communicates with the internal aspects of the refrigerator and partially seals said internal aspects from communication with ambient. The wall **50** is cylindrical. A pair of spaced bearings **55** and **56** are mounted in the cavity **51** and chamber **18** respectively and journally support bosses **58** and **60** which are integrally formed with a rotor **62** of a conventional electric motor. Note particularly the bosses **58** and **60** are journalled for rotation about axis **32**. Projecting from the boss **60** is an eccentric crank throw **63** which, upon rotation of the rotor **62**, provides the driving mode for the connecting rods **36** and **38** and the connected displacers **24** and **28**. The throw **63** is identical in function with the throw **34** of FIG. 1. In order to drive the rotor **36**, the motor-stator, here shown generally at **66**, is positioned peripherally around the wall **50**, the latter being interposed between the stator **66** and rotor **62**. A covering housing **68** may be conventionally bolted to housing **16** and may be provided with an electrical connection **70** to provide appropriate electrical power to the stator **66**. Upon appropriate connection, the electrical fields generated in the stator **66** induce rotation of the rotor **62** and provide the rotative power to induce the displacer motion earlier described which completes the refrigerating cycle. It is noted that a particular advantage of this structure is that contaminants normally associated with insulation and sealing of stator windings are shielded from the sealed internal portions of the refrigerator, thus avoiding contamination thereof and contributing to service life. Further, motor-stator service is readily accomplished by removal of housing **68** without the necessity of machine disassembly.

From the succinct description given above, it will be apparent to those familiar with the cryogenic refrigeration field that an appropriate refrigerating structure is provided readily adapted to miniaturization and having physical features which eliminate structure characteristic of added weight and mechanical failure in prior art devices. Modern service requirements which demand minimal weight, efficient operation, and long service life without maintenance are thus met.

The invention is disclosed by way of illustration and not limitation and may be modified in many particulars all within the scope and spirit thereof.

What is claimed is:

1. In a cryogenic refrigerator to produce refrigeration by closed cycle circulation of a cryogenic fluid, the combination of:

a sealed housing;

said housing having a hot cylinder, a cold cylinder, and a work chamber therein;

a hot displacer in the hot cylinder having a first surface defining with the cylinder a hot chamber;

a cold displacer in the cold cylinder having a first surface defining with the cylinder a cold chamber;

other surfaces on the respective displacers in direct facing communication with the working chamber;

rotatable means in the work chamber having rod means pivotally connecting the rotatable means with the respective displacers whereby upon rotation of the rotatable means the displacers reciprocate in their respective cylinders in out-of-phase relationship;

and circulation means comprising passage means having regenerator means therein interconnecting a hot chamber, the working chamber and the cold chamber whereby reciprocation of the displacers induces circulation of the fluid between said chambers.

2. A cryogenic refrigerator according to claim **1**, and including means to dissipate heat to atmosphere at the approximate point of communication of the passage-means with the working chamber.

3. A cryogenic refrigerator according to claim **2**, wherein said rotatable means comprises a rotor, said rotor being disposed within the sealed housing, and stator means to create electrical field means to induce motor rotation,

said stator means being operationally associated with the rotor and positioned externally of the housing.

4. In a cryogenic refrigerator to produce refrigeration by closed cycle circulation of a cryogenic fluid, the combination of:

a sealed housing defining a hot chamber, a cold chamber, and an intermediate working chamber;

all of said chambers being in direct communication with each other;

a hot displacer in the hot chamber for reciprocating movement therein and providing the sole means of demarcation between a hot volume in the hot chamber and a cool volume in the working chamber;

a cold displacer in the cold chamber for reciprocation

therein and providing the sole means of demarcation between a cold volume in the cold chamber and the cool volume of the working chamber;

first passage means establishing communication between the hot volume in the hot chamber and the cool volume in the working chamber;

other passage means establishing communication between the cold volume of the cold chamber and the cool volume of the working chamber;

independent regenerator means in the respective passage means;

the respective passage means being in joined communication adjacent the point of entry of the passage means to the cool volume of the working chamber,

crank means located in the working chamber and having connection means to the respective displacers whereupon rotation of the crank means induces reciprocation of the respective displacers in out-of-phase relationship,

and means to controllably induce rotation of the crank means.

5. A cryogenic refrigerator according to claim **4**, wherein said last-mentioned means comprises electric motor means,

said motor means having stator windings externally of the sealed housing,

said crank means including electric rotor means operatively associated with the stator means and disposed within the sealed housing,

said sealed housing being physically interposed between the stator means and the rotor means.

6. In a cryogenic refrigerator to produce refrigeration by closed-cycle circulation of a cryogenic fluid,

the combination of a sealed housing defining a hot cylinder and a cold cylinder,

said housing further defining a working chamber operatively intermediate the cylinders,

displacer elements within the respective cylinders defining, respectively, a hot chamber in one cylinder and a cold chamber in the other cylinder,

crank means operatively connected to the respective displacers to produce out-of-phase reciprocation thereof upon rotation of the crank means,

said crank means comprising the rotor of an electric motor journalled for rotation within the sealed housing,

and a stator for the electric motor positioned externally of the housing and operatively associated with the rotor to controllably induce rotation thereof.

References Cited

UNITED STATES PATENTS

3,074,244	1/1963	Malaker	62—6
3,128,605	4/1964	Malaker	62—6
3,145,527	8/1964	Morgenroth	62—6
3,147,600	9/1964	Malaker	62—6
3,355,882	12/1967	Kohler	62—6

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