Dec. 31, 1968 H. K. BEUTEL ET AL 3,418,824

MANUALLY-OPERATED CLOSED-CYCLE REFRIGERATION SYSTEM

Filed June 16, 1967 Sheet 1 of 2

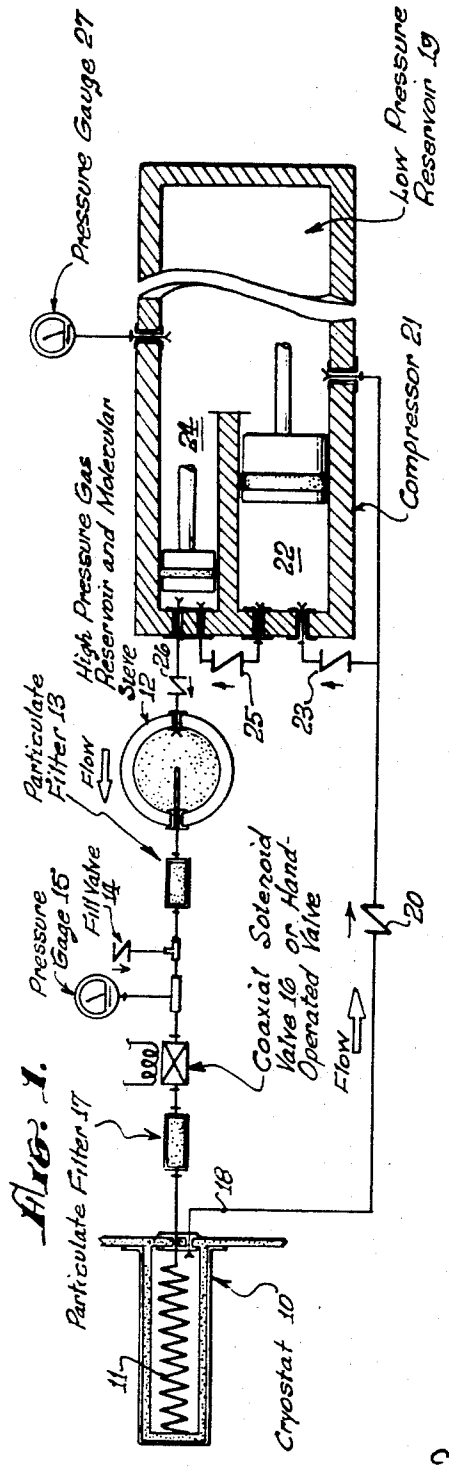


FIG. 1.

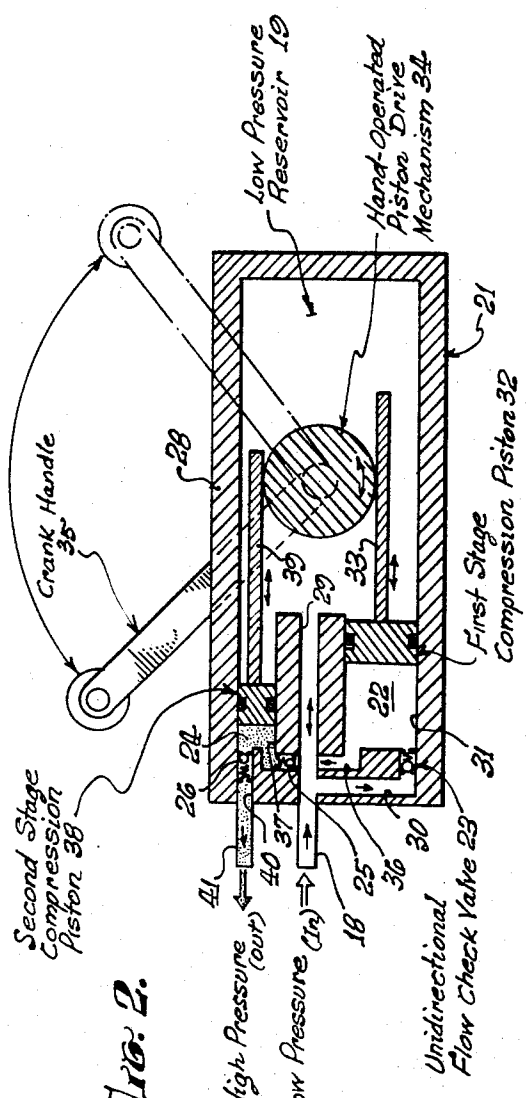


FIG. 2.

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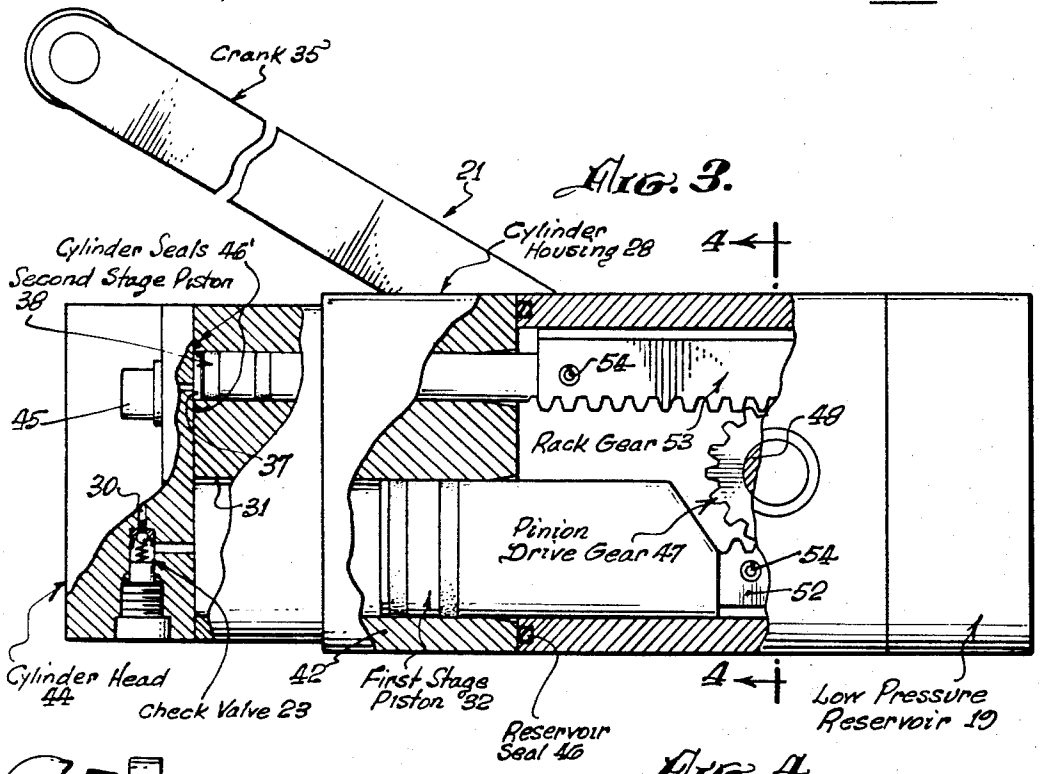


FIG. 3.

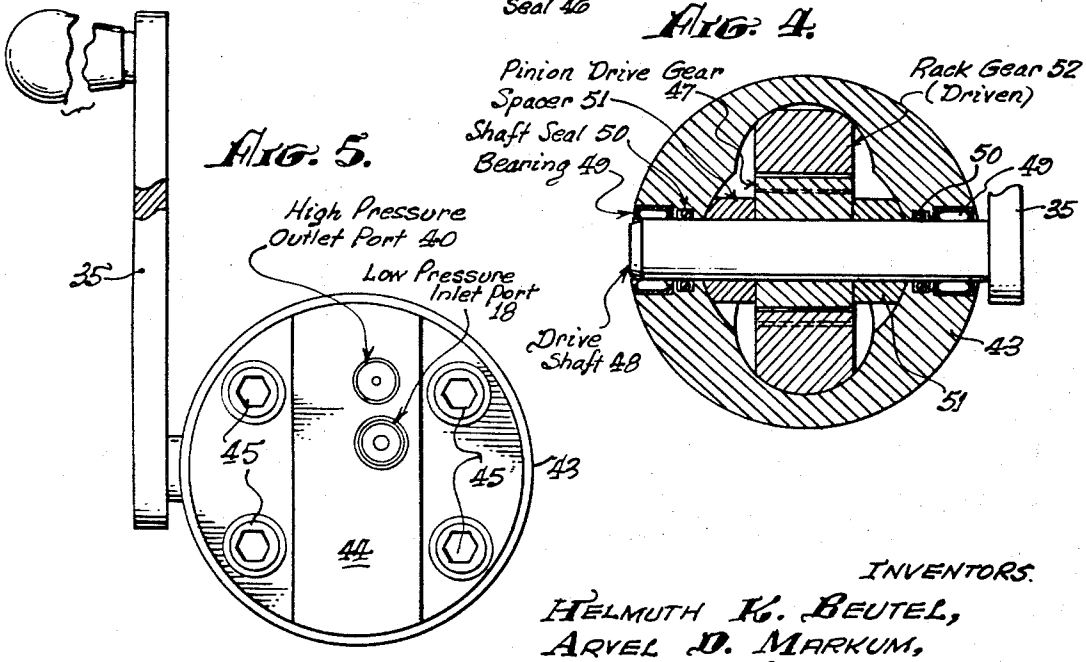


FIG. 4.

FIG. 5.

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3,418,824

MANUALLY OPERATED CLOSED-CYCLE REFRIGERATION SYSTEM

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6 Claims. (Cl. 62—474)

ABSTRACT OF THE DISCLOSURE

This disclosure is directed to a manually-operated closed-cycle refrigeration system. More particularly, the system includes three major sections: (1) a miniature Joule-Thomson heat exchanger (or cryostat), (2) a hand-operated compressor/low pressure reservoir section, and (3) a high pressure reservoir/control valve section. The hand-operated compressor comprises first and second compression stages each including a cylinder and piston, said second stage being operatively coupled in series with said first stage whereby gas is introduced into said first stage through an intake check valve from a low pressure reservoir connected with the system return line during the suction stroke of the first stage piston. During the compression stroke of the first stage piston the gas is forced through an interstage check valve into the second stage cylinder cavity and is then compressed to a higher pressure upon the compression stroke of the second stage piston. The two pistons are arranged so that when the first stage piston is in its compression stroke the second stage piston is in its suction stroke. The respective pistons are operatively coupled to a hand-operated reciprocating lever by way of a rack and pinion arrangement. Both of the compression stages are operatively associated with the low pressure reservoir such that leakage past the piston seals is collected by the reservoir thus preventing external leakage of the system.

Background of the invention

This invention relates to closed-cycle refrigeration systems, and more particularly to such a system which utilizes a hand-operated compressor. While closed-cycle cooling systems including a cryostat and a multistage compressor are known in the prior art as exemplified by U.S. Patent 3,204,422, such a system, as the present invention which utilizes a compressor which can be operated manually in an environment where electrical or mechanical power is not available is not previously known. Also, two-stage hand-operated pumps as exemplified by U.S. Patent 57,897 are known in the art. However, a two-stage hand-operated compressor utilizing the piston low pressure reservoir arrangement of the present invention is not previously known. Thus, this invention advances the stage of the art by providing a manually-operated closed-cycle refrigeration system which incorporates a novel two-stage hand-operated compressor.

Summary of the invention

Therefore, it is an object of this invention to provide a manually-operated closed-cycle refrigeration system.

A further object of the invention is to provide a manually-operated closed-cycle refrigeration system which utilizes a two-stage hand-operated compressor.

Another object of the invention is to provide a hand-operated two-stage pump assembly.

Another object of the invention is to provide a dual-stage hand-operated compressor wherein the piston units

thereof are positioned with respect to a low pressure reservoir such as to collect any fluid leaking past the pistons.

Other objects of the invention, not specifically set forth above, will become readily apparent from the following written description and the accompanying drawings wherein:

Brief description of the drawings

FIG. 1 is a schematic view of an embodiment of the inventive closed-cycle manually-operated refrigeration system;

FIG. 2 is a schematic partial cross-sectional view of the novel hand-operated multistage compressor;

FIG. 3 is a side view partially in cross-section and with portions thereof cut away illustrating an embodiment of the inventive compressor of the type illustrated in FIG. 2;

FIG. 4 is a view taken along the lines **4**—**4** of FIG. 3; and

FIG. 5 is an end view of the FIG. 3 compressor with the cylinder head removed.

Description of the embodiment

The system is composed of three major sections; the miniature Joule-Thomson heat exchanger (or cryostat), the hand-operated compressor/low pressure reservoir section, and the high-pressure reservoir/control valve section. Referring now to FIG. 1, the illustrated embodiment of the inventive system comprises a Joule-Thomson heat exchanger or cryostat **10**, which is provided with the conventional cooling coiled tubing **11** connected with a high pressure gas reservoir and molecular sieve generally indicated at **12** via a particulate filter **13**, a fill valve assembly **14**, a pressure gage assembly **15**, a control valve assembly **16** which may be of the coaxial solenoid or hand-operated type, and a second particulate filter **17**. Cryostat **10** is also provided with discharge tubing indicated at **18** and connected to a low pressure reservoir **19** via a one-way valve assembly **20**. Low pressure reservoir **19** is defined by the housing of two-stage compressor generally indicated at **21**. The input of the first compressor stage indicated at **22** of compressor **21** is connected with the cryostat discharge line **18** and low pressure reservoir **19** via a one-way valve assembly **23**. The output of the first stage **22** is connected to the input of the second compressor stage indicated at **24** via a one-way valve assembly **25** and the output from the second stage **24** is connected with high pressure reservoir **12** via a one-way valve assembly **26**. A pressure gage **27** is operatively connected to the housing of compressor **21** for indicating the pressure within low pressure reservoir **19**. The compressor **21** and the associated valve assemblies **23**, **25** and **26** will be described in greater detail hereinafter.

The FIG. 1 system operation occurs in the following sequence, assuming that the high pressure reservoir **12** had been previously pressurized by compressor **21**:

(1) Upon activation of the control solenoid valve **16**, high pressure refrigerant gas flows as indicated by the flow arrow from the high pressure gas reservoir **12** to the miniature Joule-Thomson heat exchanger **10**.

(2) Upon existing the expansion nozzle portion of tubing coil **11**, the refrigerant gas cools (due to sudden release of pressure) to its desired temperature.

(3) The refrigerant gas then removes heat from the encasing sleeve or housing of cryostat **10**, and the incoming refrigerant gas is further cooled by the exhausting gas dischargnig between the cryostat coils **11** and the walls of the encasing sleeve of the cryostat, as known in the art.

(4) The exhausted gas is then accumulated in the low pressure reservoir **19** as indicated by the flow arrow.

(5) The exhausted low pressure refrigerant is then pumped from the low pressure reservoir **19** to the high pressure reservoir **12** by operating the two-stage compressor **21** as described hereinafter. Note that any leakage of the fluid about the pistons of compressor **21** will be received by the low pressure reservoir **19** thus preventing loss of the fluid.

(6) The molecular sieve portion of reservoir **12** removes contaminants from the refrigerant gas which may have been introduced during the cycle.

Tests conducted on the FIG. 1 system have demonstrated low leakage rates and the ability to recompress the refrigerant from a low reservoir pressure of 10 p.s.i.g. to a high output pressure of 1800 p.s.i.g. The closed cycle system makes it economically possible to use high priced exotic refrigerants to cool small components or miniature systems to cyrogenic temperatures. The system has applications in many areas requiring cyrogenic temperature environments, such as infrared detectors, superconductivity applications, materials' compatibility investigations, etc.

FIGS. 2–5 illustrate in greater detail the manually-operated two-stage compressor **21** of the FIG. 1 system. Referring first to FIG. 2, the flow diagram and mechanical operational sequence is illustrated. Compressor **21** comprises a housing **28**, a portion of which defines low pressure reservoir **19** which is connected with cryostat discharge conduit **18** and the first compressor stage **22** via passageways **29** and **30**, respectively. First compressor stage **22** comprises a chamber or cylinder **31**, defined by housing **28**, within which a first stage compression piston **32** reciprocates, piston **32** being connected via a piston rod or rack **33** to a hand-operated piston drive mechanism indicated at **34** and actuated by a crank handle **35**. Unidirectional flow check valve **23** of the ball and spring type functions as the inlet or intake valve for the first stage **22** while the similarly constructed unidirectional flow check valve **25** positioned in a passageway **36** in housing **28** interconnecting the compressor stages functions as the output or exhaust valve therefor. The second compressor stage **24** comprises a chamber or cylinder **37**, defined by housing **28**, within which a second stage compression piston **38** reciprocates, piston **38** being connected via a piston rod or rack **39** to piston drive mechanism **34**. The pistons **32** and **38** are connected to drive mechanism **34** in such a manner that when piston **32** is on its intake stroke (movement to the right as shown) piston **38** is on its compression stroke, and vice versa, as illustrated in FIG. 2 and indicated by the double arrows on the piston rods **33** and **39**. Movement of crank handle **35** from the solid line position to the right so as to be in the phantom position causes pistons **32** and **38** to reverse the position shown, thus placing the first stage **22** on compression and the second stage **24** on intake. Unidirectional flow check valve **25** in passageway **36** functions as the input or intake valve for the second stage **24** while the similarly constructed unidirectional flow check valve **26** positioned in a passageway **40** of housing **28**, interconnecting the second stage with a conduit **41** connected to high pressure reservoir **12** for example, functions as the output or exhaust valve therefor.

It is seen from FIG. 2 that low pressure fluid in tubing or conduit **18** flows into low pressure reservoir **19** via passageway **29** and upon movement of the first stage piston **32** on the suction stroke, to the right, the fluid is drawn into chamber or cylinder **31** from conduit **18** and/or low pressure reservoir via passageway **30** and valve assembly **23** as shown by the flow arrows. Simultaneously, upon movement of piston **32** to the right, second stage piston **38** moves to the left as shown on the compression stroke and forces fluid under high pressure via valve assembly **26** and passageway **40** to a point of use. Due to the fluid pressure in cylinder **37** being greater than the fluid pressure in cylinder **31**, the valve assembly **25** is positioned as shown thus preventing communication between the cylinders during compression of the second stage **24**. Movement of the crank handle to the position shown in phantom places the first stage **22** on compression and the second stage **24** on intake or suction thus forcing fluid from cylinder **31** through passageway **36** and valve assembly **25** into cylinder **37** as indicated by the flow arrow in passageway **36**. It is thus seen that continuous oscillation of the crank handle causes continuous two stage compressor operation.

Pumping efficiency is maintained by minimizing the volumes of the unidirectional flow check valves and by reducing the dead-end volume to a minimum. Additional efficiency is obtained by properly balancing the compression ratios between stages. The ratios are determined by the expected operating parameters of the compressor.

Referring now to the specific embodiment of the inventive two-stage compressor as illustrated in FIGS. 3–5, like reference numerals are utilized for the components above described with respect to FIGS. 1 and 2. Compressor housing **28**, as shown in FIG. 3, comprises a section **42** defining the cylinders, a section **43** defining the low pressure reservoir, and a cylinder head **44** containing certain of the passageways and the check valves, secured to housing portion **42** via bolts **45**, sections **42** and **43** having a reservoir seal **46** disposed therebetween, while a pair of cylinder seals **46'** are disposed between section **42** and cylinder head **44**. The hand-operated piston drive mechanism **34** illustrated in detail in FIGS. 3 and 4 comprises a pinion drive gear **47** drivingly connected to crank **35** via a drive shaft **48** mounted on bearings **49** in housing section **43**. A pair of shaft seals **50** are positioned around drive shaft **48**, while a pair of spacers **51** are positioned within housing section **43** intermediate the pinion drive gear **47** and the internal surface of the housing section. A pair of driven rack gears **52** and **53** are operatively mounted with respect to drive gear **47** and may be integral with piston rods **33** and **39**, respectively, or connected by means such as pins **54** with said piston rods for driving same.

Loss of gas due to leakage is minimized by making all internal seals either static or low-pressure reciprocating seals. Leakage past the piston seals, while decreasing pumping efficiency, is not a serious factor since it is collected in the low pressure reservoir. The only dynamic seals from internal to external are the reciprocating seals that seal the drive shaft in the low-pressure reservoir. By the use of fine finishes on the rack gears, gear ways, shaft and compression cylinders, lubrication requirements are minimal, for example, lubrication could consist of using high vacuum grease on the piston seals, rackways and shaft seals.

It has thus been shown that the present invention provides a closed-cycle refrigeration system which includes a two-stage manually-operated compressor which incorporates a low pressure reservoir around the compression pistons to collect leakage past the piston seals. Also, if desired, the compressor can be operated by any type power plant capable of providing the necessary reciprocating motion for the pistons.

Although a particular embodiment of the invention has been illustrated and described, modifications will become apparent to those skilled in the art, and it is intended to cover in the appended claims all such modifications as come within the true spirit and scope of the invention.

What we claim is:

1. A two stage compressor comprising: a housing, a first piston cylinder positioned within said housing at one end thereof, a second piston cylinder positioned within said housing at the same end thereof as said first cylinder and parallelly disposed substantially adjacent to said first cylinder, said first and second piston cylinders each having an open end and a substantially closed end, a reservoir within said housing at the opposite end of said housing from said first and second cylinders said reservoir

in communication with the open ends of said first and second piston cylinders, a first piston head operable within said first piston cylinder, a first piston rod connected to said first piston head and extending into said reservoir, a second piston rod connected to said second piston head and extending into said reservoir, said first piston rod including a rack gear portion and said second piston rod including a rack gear portion parallelly disposed to said rack gear portion of said first piston rod, a drive shaft rotatably mounted in said housing and extending outward therefrom, a drive gear mounted upon said drive shaft for rotation therewith, said drive gear operably associated with said rack gear portions of said first and said second piston rods, a crank assembly secured to the external portion of said drive shaft to rotate said drive shaft and thereby reciprocate the piston rods, a first fluid passageway within said housing extending from the substantially closed end of said first cylinder to the exterior of said housing, a second fluid passageway within said housing interconnecting the substantially closed end of said first cylinder with the substantially closed end of said second cylinder, a third fluid passageway within said housing extending from the substantially closed end of said second cylinder to the exterior of said housing, a fourth fluid passageway within said housing interconnecting said reservoir with said first fluid passageway, a first unidirectional valve means operably positioned within said first passageway to pass fluid into the first cylinder, a second unidirectional valve means operably positioned within said second passageway to pass fluid from said first cylinder to said second cylinder, and a third unidirectional valve means operably positioned within said third passageway to pass fluid under pressure from said second cylinder to the exterior of said housing.

2. The two-stage compressor defined in claim **1**, additionally including bearing means for said drive shaft operatively mounted in said housing.

3. The two-stage compressor defined in claim **2**, additionally including seal means operatively positioned about said drive shaft.

4. The two-stage compressor defined in claim **1**, additionally including spacer means positioned within said housing on each side of said drive gear means.

5. The two-stage compressor defined in claim **1**, in combination with a closed refrigeration system including a high pressure reservoir, a control valve assembly and a heat exchanger assembly, said third passageway being operatively connected to said high pressure reservoir, and said first passageway being operatively connected to said heat exchanger.

6. The combination defined in claim **5**, additionally including a molecular sieve positioned between said compressor and said control valve assembly, a pressure gage positioned between said high pressure reservoir and said control valve, and at least one particulate filter means positioned between said high pressure reservoir and said heat exchanger means.

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U.S. Cl. X.R.

62—467, 510, 514; 230—183