Jan. 27, 1970 E. G. U. GRANRYD 3,491,554

HEAT-ACTUATED REGENERATIVE COMPRESSOR SYSTEM

Filed Dec. 11, 1968 3 Sheets-Sheet 1

FIG. 1

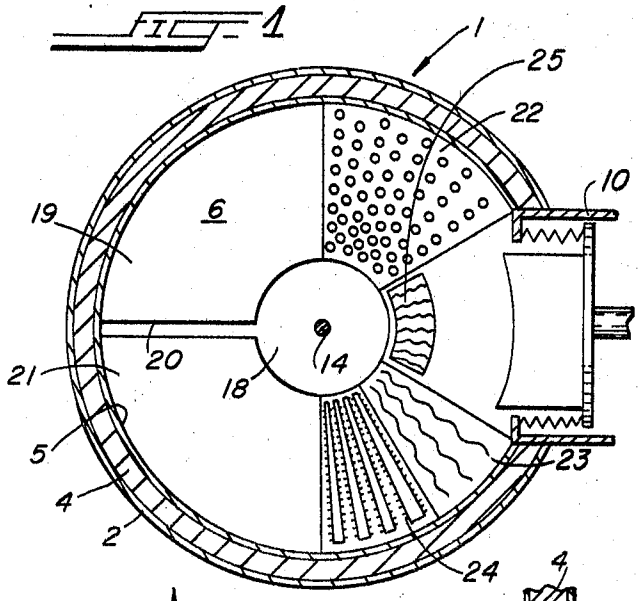


FIG. 2A

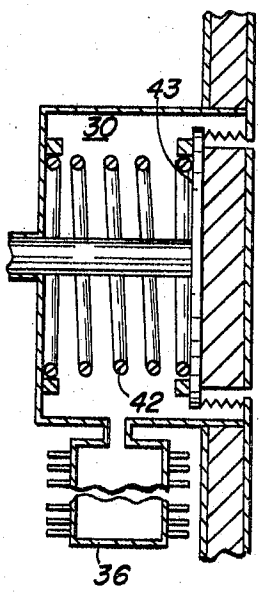


FIG. 2

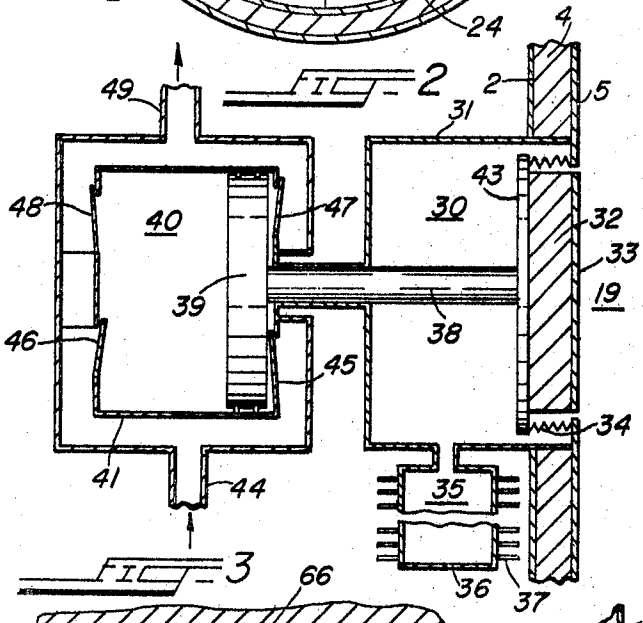


FIG. 2B

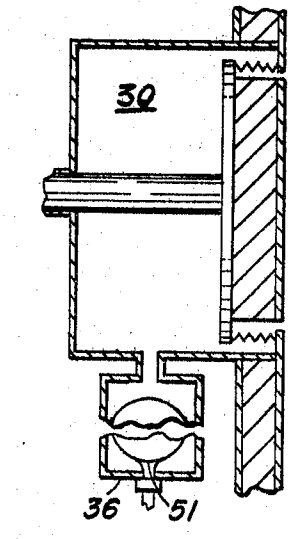
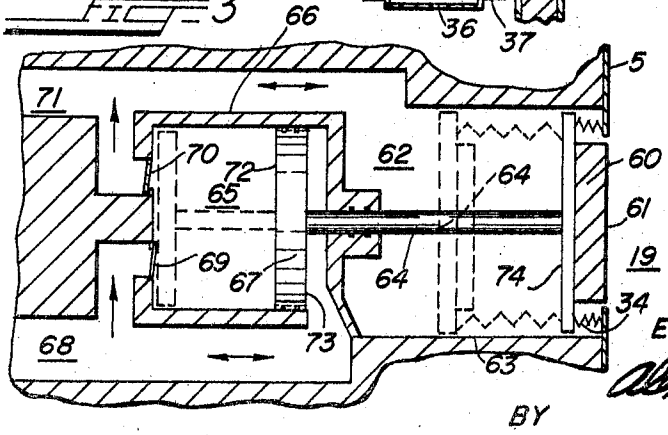


FIG. 3



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HEAT-ACTUATED REGENERATIVE COMPRESSOR SYSTEM

Filed Dec. 11, 1968 3 Sheets-Sheet 2

FIG. 4

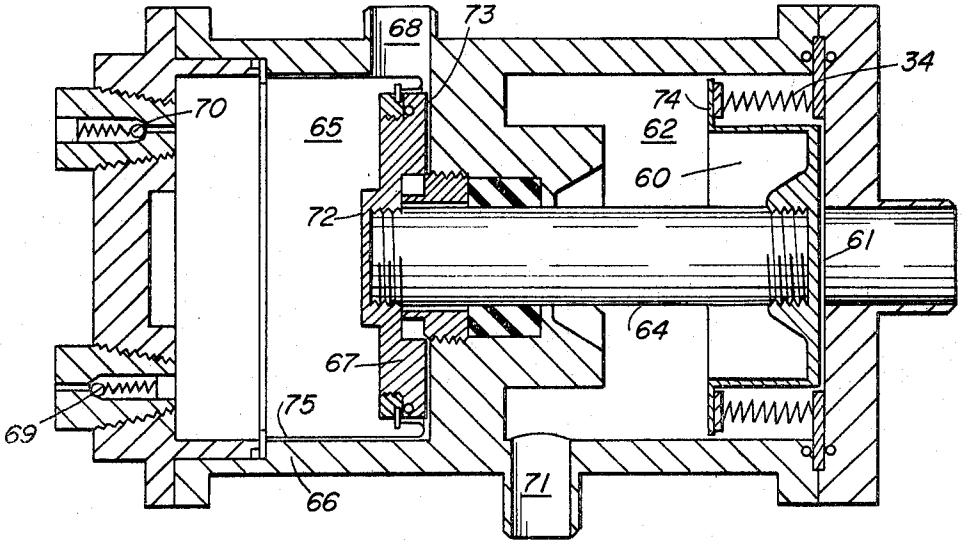
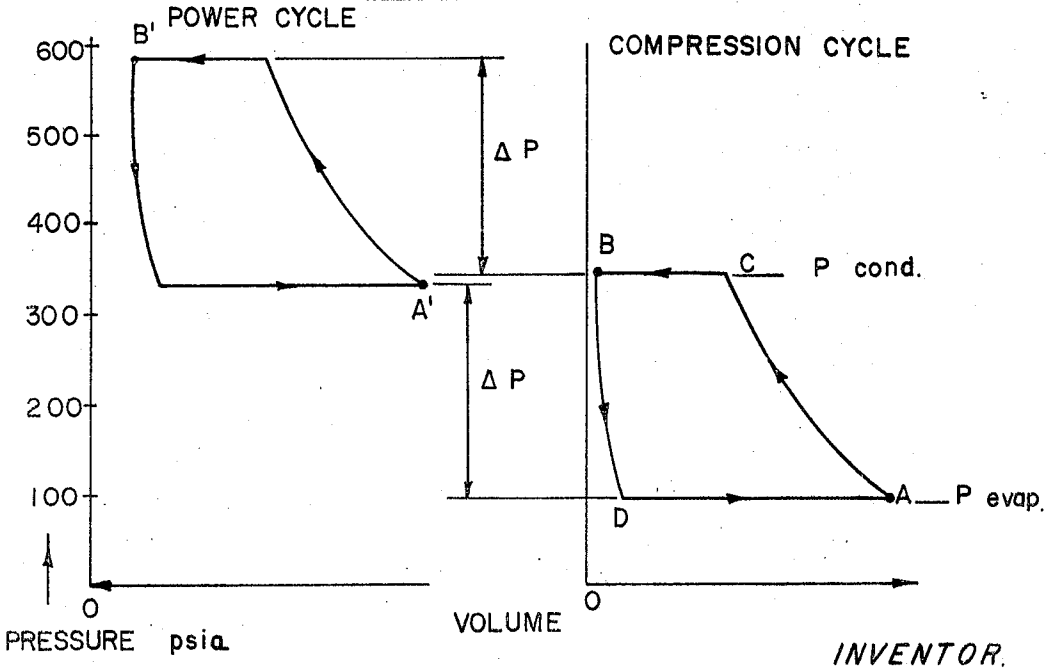


FIG. 5



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Jan. 27, 1970 E. G. U. GRANRYD 3,491,554

HEAT-ACTUATED REGENERATIVE COMPRESSOR SYSTEM

Filed Dec. 11, 1968 3 Sheets-Sheet 3

FIG. 6

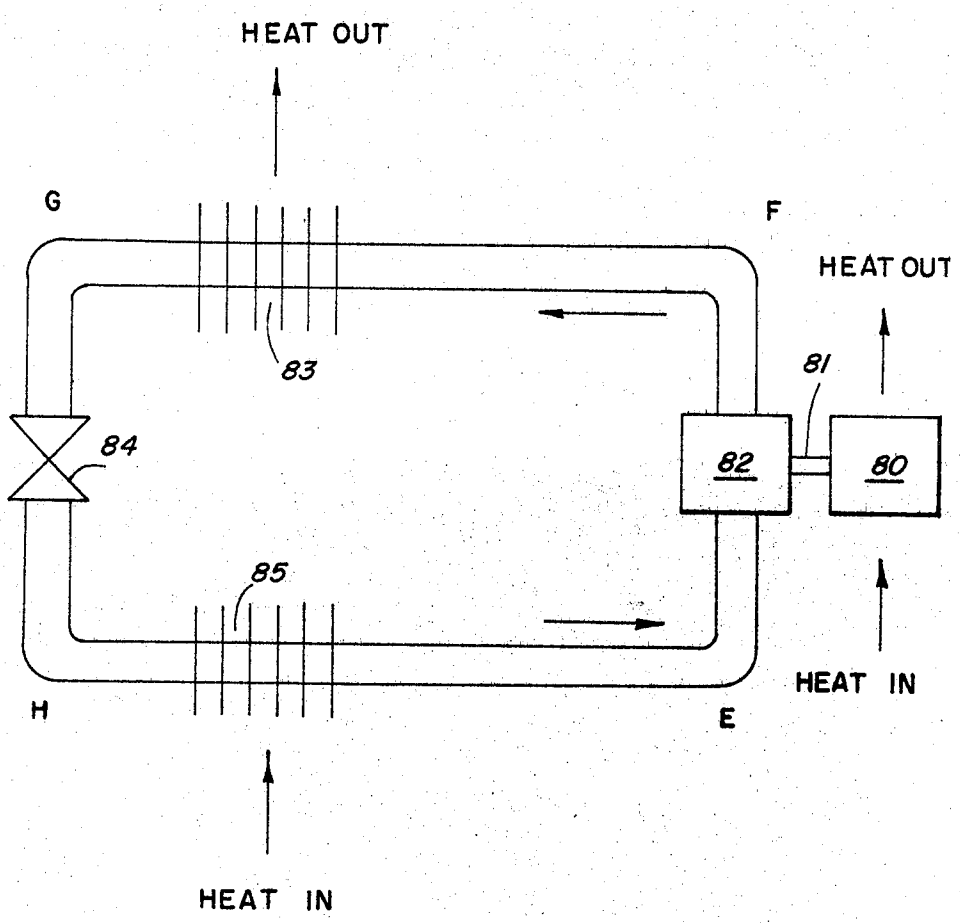
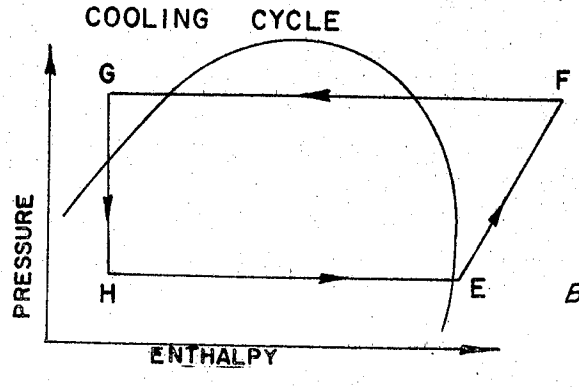


FIG. 7



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ATTYS

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3,491,554

HEAT-ACTUATED REGENERATIVE COMPRESSOR SYSTEM

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Continuation-in-part of application Ser. No. 698,857, Jan. 18, 1968. This application Dec. 11, 1968, Ser. No. 783,064

Int. Cl. F25b *1/00*; F03g *7/06*

U.S. Cl. 62—498 14 Claims

ABSTRACT OF THE DISCLOSURE

A heat-actuated regenerative compressor with a thin vane displacer for operation between fixed pressures at up to 500 cycles per minute. Such heat-actuated compressor in combination with pneumatic, hydraulic or mechanical assisted linkage to associated apparatus providing lower absolute pressures at the associated apparatus side of the linkage than at the heat-actuated regenerative compressor side of the linkage. A cooling system comprising a heat-actuated regenerative compressor containing a thermally efficient working gas operating a linkage for moving an efficient refrigerant through a condenser-expansion-evaporation - compression cooling cycle wherein the refrigerant acts upon the linkage providing a lower absolute pressure at the refrigerant side of the linkage than at the heat-actuated regenerative only be fitted into predetermined positions.

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of my copending application Ser. No. 698,857, filed Jan. 18, 1968.

BACKGROUND OF THE INVENTION

Heretofore, heat-actuated regenerative compressors have been used to compress gases for cooling systems. Heat-actuated regenerative compressor-cooling systems wherein the refrigerant is also a working fluid of such compressor using carbon dioxide and sulfur dioxide have been described in copending U.S. patent application Ser. No. 547,038, filed May 2, 1966, Patent No. 3,400,555 entitled Refrigeration System Employing Heat-Actuated Compressor. Further, such compressors for use in cooling systems have been described in copending U.S. patent application Ser. No. 547,040, filed May 2, 1966, Patent No. 3,413,815 entitled Heat-Actuated Regenerative Compressor for Refrigerating Systems. Methods for obtaining mechanical energy from heat-actuated regenerative compressors and dual gas cooling systems wherein the heat-actuated regenerative compressor contains a thermally efficient gas providing energy for moving a highly efficient refrigerant through a cooling cycle have been described in copending U.S. patent application Ser. No. 698,857. It has now been found desirable, especially in use of heat-actuated regenerative compressors in conjunction with cooling systems to provide a means for operation of such compressor at a different and higher absolute pressure than the pressure at which the associated cooling system is optimally operated.

DESCRIPTION OF THE INVENTION

My invention comprises a novel configuration of components providing operation of a heat-actuated regenerative compressor at higher cycle frequencies than previous compressors. My invention also provides for operation of a heat-actuated regenerative compressor at higher absolute pressures than the absolute operating pressures of external apparatus associated with such a compressor. The apparatus of my invention provides mechanical,

pneumatic or hydraulic pressures on linkages between such compressor and associated apparatus to provide a positive pressure in opposition to the pressure of the working gas of the heat-actuated regenerative compressor. The apparatus of my invention is particularly suitable for use in cooling systems wherein the heat-actuated regenerative compressor serves through a pressure translating means to pump an efficient refrigerant through a conventional cooling cycle.

It is an object of my invention to provide heat-actuated regenerative compressors operable at cycle frequencies of up to 500 cycles per minute.

It is another object of my invention to provide a heat-actuated regenerative compressor system in which the heat-actuated compressor is operated at a higher pressure than fluid in associated apparatus.

It is still another object of my invention to provide an improved cooling system powered by a heat-actuated regenerative compressor wherein the absolute pressure of the working gas in the compressor is always higher than the absolute pressure of the refrigerant.

These and other important objects will become apparent from the drawings showing preferred embodiments wherein:

FIG. 1 is a plan view, in cross section, of a heat-actuated regenerative compressor of this invention.

FIG. 2 is a schematic cross section of a pneumatic linkage device according to this invention operating a double acting pump.

FIG. 2A shows the apparatus of FIG. 2 with additional mechanical assistance of a spring.

FIG. 2B shows the apparatus of FIG. 2 using hydraulic assistance.

FIG. 3 is a schematic drawing in cross section illustrating the linkage portion of a cooling apparatus according to this invention driven by a heat-actuated regenerative compressor wherein the operating pressure of the power compressor is higher than the operating pressure of the refrigerant.

FIG. 4 illustrates a linkage device according to a preferred embodiment of the apparatus shown in FIG. 3.

FIG. 5 is a graph illustrating the pressure-volume relationships in an apparatus according to an embodiment of this invention.

FIG. 6 is a schematic drawing showing a cooling system according to this invention.

FIG. 7 is a thermodynamic diagram of the cooling system of FIG. 6.

The apparatus of my invention may be used in association with conventional cooling systems. Refrigerants suitable for use in the cooling apparatus of my invention include those refrigerants suitable for compression-refrigeration cycles. Preferred refrigerants include halogenated hydrocarbons and SO_2. Particularly preferred refrigerants are those selected from the group consisting of Freon 12, Freon 22, Freon 502 and SO_2. Freon designates a group of halogenated hydrocarbons containing one or more fluorine atoms which are widely used as refrigerants. The operating conditions and particular refrigerant used determine the pressure and temperature relationships of the closed refrigerating cycle. Under most operating conditions the evaporating temperature is from about 35° to 50° F. and the condensing temperature from about 90° to 150° F., both under constant pressure. Particularly preferred condensing temperatures are from about 105° to 140° F. In conventional air-conditioning systems the pressure ratio, defined as the ratio of the absolute pressure in the condenser and the absolute pressure in the evaporator, is from about 3 to 4½.

Referring specifically to FIG. 1, the heat-actuated regenerative compressor **1** comprises outer shell casing **2**, insulation **4** and inner shell casing **5** defining gas chamber

6 which is generally cylindrical in shape. Shaft 14 is disposed through chamber 6, and retained in suitable rotatable relationship by bearing means. Shaft 14 penetrates casing 5 in fluid tight relationship and is connected through suitable linkage means to a power source (not shown) which causes shaft 14 to undergo an oscillating movement. Secured to shaft 14 is insulating hub 18 having vane 20 constructed of suitably supported thermal insulating material extending to and congruent with inner shell casing 5.

Vane 20 divides chamber 6 into a first "cold" section 19 and a second "hot" section 21. Positioned within chamber 6 from inner shell casing toward the center of chamber 6 to hub 18 extending substantially the entire length of chamber 6 separating cold section 19 from hot section 21 are cooling means 22, heat regenerative means 23, and heating means 24. The sizes of such components shown in FIG. 1 and described above are based upon current heat transfer materials, designs, and techniques, however, it would be apparent to one skilled in the art that if more efficient heat transfer units become available, the size proportions and shapes of the heat transfer units could readily be changed accordingly. The large hub 18 and insulator 25 provide a long travel distance insulating cold section 19 from hot section 21 at the heat exchangers.

Briefly, operation of the compressor is achieved by moving gas from cold section 19 in order through the cooler-regenerator-heater into hot section 21 at an average higher temperature-pressure relationship and then returning the gas from hot section 21 in order back through the heater-regenerator-cooler to cold section 19 at an average lower temperature-pressure relationship. Vane frequencies of from about 15 to 500 cycles per minute are suitable for the compressor of this invention. Preferred frequencies are from about 100 to 300 cycles per minute.

The heat actuated compressor is operated by use of gases having high thermal-conductivity and specific heat ratio. Preferred gases include hydrogen and monatomic inert gases such as helium. Either a single gas or mixtures of different gases may be used. Helium is especially preferred for use in the heat-actuated regenerative compressor according to this invention.

In FIG. 1 differential pressure means 10 comprises a pneumatic, hydraulic or mechanical assisted linkage to associated apparatus providing lower absolute pressures at the side of the linkage connected to such apparatus than at the side of the linkage in communication with the heat-actuated compressor. Combinations of such assistance may be used, for example, the assistance may be pneumatic and mechanical in combination. Specific embodiments illustrating such pressure responsive means are illustrated by further figures and description. The differential pressure means may be in communication with cold section 19 in the region of the cooler, or between the cooler and regenerator, but may be at either end or through the side of the heat-actuated regenerative compressor containment vessel.

FIG. 1 shows specific embodiments of the heat-actuated regenerative compressor which result in surprising improvements in its operation, as compared with the prior devices. Thin vane 20, constructed of materials affording thermal insulating properties, is especially effective in the rapid movement of the working gas of the compressor from cold section 19 through the three heat transfer units to hot section 21. Operation of vane 20 at frequencies in the order of 200 cycles per minute affords especially efficient transfer of thermal energy in the heater, regenerator and cooler thermal transfer units in the oscillating manner utilized in this apparatus. Due to the physical configuration of the components in the active chamber of the heat-actuated regenerative compressor, the sweep of the oscillating vane may vary from about 180 to 250 degrees depending upon the efficiency of the thermal transfer units, gas utilized, and frequency of operation desired.

The pressure ratio of the heat-actuated regenerative compressor, defined as the ratio of the maximum absolute pressure in the compressor to the minimum absolute pressure in the compressor, is determined by the mass means temperature ranges operable using desired gases in the heat-actuated regenerative compressor. Pressure ratios in heat-actuated regenerative compressors range from about 1.0 to 1.8.

Required pressure ratios for operating various desired apparatus are frequently different from the pressure ratio of the direct output of the heat-actuated regenerative compressor. One such application is in the powering of cooling systems with a heat-actuated regenerative compressor. As pointed out above, the pressure ratio in conventional cooling systems is between 3 and 4½ while the pressure ratio in the heat-actuated regenerative compressors is from about 1.3 to about 1.8. One feature of the present invention is to provide differential pressure linkage means between the heat-actuated regenerative compressor and associated apparatus, such as cooling systems thereby making possible the use of one-stage heat-actuated compressor systems. The linkage pressure differential is preferably constant throughout one cycle of the heat-actuated regenerative compressor, but may be variable within the period of one cycle of the heat-actuated regenerative compressor.

Referring specifically to FIG. 2, the cross-section of a pneumatic linkage device according to this invention is shown as exemplary of a specific embodiment of the differential pressure means 10 shown in FIG. 1. The pneumatic linkage shown in FIG. 2 operates a double action pump to drive any fluid or gas system and may be used to drive a highly efficient refrigerant through a condensation-expansion-evaporation-compression cooling cycle. The differential pressure means comprises a first cylinder 31 defining cylinder chamber 30, piston 32 adapted for reciprocating motion within cylinder 31 and having face 33 in communication with cold section 19 of said heat-actuated regenerative compressor and face 43 in communication with chamber 30. Piston 32 reciprocates with substantially gas tight relationship between cylinder chamber 30 and cold section 19 by bellows 34, attached at one end to inner shell casing 5, and at the other end to piston 32.

Bellows 34 must be constructed of suitable material and of suitable design to permit the required flexing and expansion while at the same time maintaining gas-tight relationship between cold section 19 and cylinder chamber 30. Metal bellows are most satisfactory using copper, nickel and various stainless steel alloys or mixtures of copper and nickel. It is also apparent that other flexible materials such as certain rubber or synthetic materials may be used if they do not permit diffusion of gases between cold section 19 and cylinder chamber 30. Suitable bellows are available commercially.

Cylinder chamber 30 is in communication with reservoir 35 defined by reservoir casing 36. Reservoir casing 36 may be of any suitable shape and of suitable volume in proportion to the volume of cylinder chamber 30. Cylinder chamber 30 and reservoir 35 are filled with a gas or mixture of gases of appropriate compressibility characteristics. Nitrogen is a suitable gas.

Heat transfer fins 37 may be attached to reservoir 35 to provide surface area for temperature control by external means to permit use of a condensing-boiling refrigerant within cylinder chamber 30 and reservoir 35. It is apparent that the temperature may also be controlled by internal heat exchangers or fins. Boiling refrigerants which change state from liquid to gas over only a few degrees change in temperature are suitable. Boiling refrigerants suitable for use in cylinder chamber 30 and reservoir 35 include halogenated hydrocarbons, namely

Freons, such as 12, 22 and 502, SO_2, CO_2, and lower aliphatic alcohols such as methanol and ethanol. The choice of the boiling fluid is governed by the desired pressure-temperature relationship.

When using the boiling refrigerant, the reservoir should be equipped with thermal exchanger means which are alternately heated and cooled by the condensation and vaporization of the boiling refrigerant at different points in the cycle. As piston **32** reduces the volume in cylinder chamber **30** and reservoir **35**, the boiling refrigerant tends to rise in pressure and the thermal exchangers are used to condense the refrigerant to the desired extent to achieve a desired, almost constant, pressure on piston face **43**. Conversely, as piston **32** moves to permit expansion of gases in communicating chambers **30** and **35**, the increased volume reduces the pressure of the enclosed refrigerant causing the refrigerant liquid to evaporate. The heat that was released during condensation, and stored in the thermal exchanger is then used to evaporate the refrigerant.

Piston **32** is attached to one end of connecting rod **38** and compression piston **39** is connected to the other end of connecting rod **38**, the central portion of connecting rod **38** passing through gas-tight seals separating cylinder chamber **30** from compression chamber **40** defined by compression chamber walls **41**.

The difference in pressure between chamber **19** and cylinder **40** effected by the pneumatic linkage is determined by the pressure which is maintained in cylinder chamber **30**.

The embodiment shown in FIG. 2 may be used to drive refrigerant through a cooling cycle by inlet **44** permitting ingress of gases through inlet valves **45** and **46** from the evaporator of an air conditioning apparatus, followed by egress from compression chamber **40** through outlet valves **47** and **48** to outlet **49** connected to the condenser of an air conditioning apparatus. Such a differential pressure linkage provides for operation of cooling systems under optimum refrigerant conditions and pressures while at the same time obtaining optimum operation of a heat-actuated regenerative compressor in one stage which is achieved by using substantially higher absolute pressures than in the cooling system.

FIG. 2A shows the cylinder chamber portion of the apparatus shown in FIG. 2 with the addition of mechanically assisted linkage by use of spring **42** positioned within chamber **30** to operate between piston face **43** and the opposite end of said cylinder chamber. The apparatus shown in FIG. 2A employs the mechanical assistance of the spring in addition to the pneumatically assisted linkage such as described in connection with FIG. 2. It is apparent that a suitable solely mechanically assisted linkage system may be designed by omission of reservoir **36**. Such mechanical linkage would generally be in the form of the spring, but any suitable mechanical assistance may be utilized. The spring mechanism may be used alone or in conjunction with the pneumatic or hydraulic assistance mechanisms of this invention.

FIG. 2B shows the cylinder chamber portion of the apparatus shown in FIG. 2 utilizing a hydraulic assisted linkage by placement of a flexible gas filled accumulator shown as **51** within reservoir chamber **35**. Of course, for use as a hydraulic assisted mechanism the external heat exchange fins shown in FIG. 2 as **37** may be omitted from reservoir **36**. In chamber **30** any suitable incompressible fluid may be used such as hydraulic oils and water. Such hydraulic assisted linkage may be used alone or in conjunction with the above-described mechanically assisted mechanisms, such as the spring shown in FIG. 2A.

FIG. 3 shows the pneumatic linkage portion of a cooling apparatus of this invention wherein the linkage between the piston for compression of the refrigerant and the output of the heat-actuated regenerative compressor driving the cooling unit is assisted by the pressure of the refrigerant to enable operation of the heat-actuated regenerative compressor at higher absolute pressures than the refrigerant. Piston **60** having face **61** in communication with cold section **19** is mounted for reciprocating action in cylinder chamber **62** defined by cylinder wall **63**. Cylinder chamber **62** is maintained in gas-tight relationship with cold section **19** by bellows **34**. Face **74** of piston **60** is in communication with cylinder chamber **62**, which in turn is in communication with conduit **71**. Piston **60** is rigidly attached to connecting rod **64** which passes in gas-tight relationship to compression chamber **65** defined by compression chamber walls **66**. Compression piston **67** is rigidly connected to the opposite end of connecting rod **64** from piston **60**, and moves in reciprocating action in generally gas-tight relationship within compression chamber **65**. Conduit **68** is in communication with the evaporator of the cooling cycle and splits the flow of refrigerant gas between inlet valve **69** opening to compression chamber **65** and thereby in communication with face **72** of piston **67** and the opposite face **73** of piston **67** providing the refrigerant evaporation pressure to face **73**. Communication of both sides of piston **67** with refrigerant gas in conduit **68** minimizes the requirement for high quality seals between piston **67** and compression chamber walls **66**. The configuration also eliminates having connections to the atmosphere or to a vacuum chamber. Such an ararngement of components permits a completely hermetically sealed compressor unit for use in air conditioning systems.

The refrigerant is compressed by action of piston **67** in compression chamber **65** and the compressed refrigerant exits through outlet valve **70** to conduit **71**. Conduit **71** is in communication with the condenser of the cooling cycle and with face **74** of piston **60**. A constant resistant force corresponding to the refrigerant condenser pressure acts on face **74** of piston **60**. Such resistant force permits operation of the heat-actuated regenerative compressor in communication with face **61** of piston **60** at higher absolute pressures than the refrigerant pressure in the cooling apparatus. The force on piston **60** may be reduced by the relative size of connecting rod **64** and piston face **74**.

By the configuration of components shown in FIG. 3, the condenser pressure of the regrigerant is utilized to furnish pneumatic assistance to the linkage between a heat-actuated regenerative compressor and associated cooling apparatus, permitting operation of the driving compressor at higher absolute pressures than the pressures of the refrigerant.

FIG. 3 shows pistons **60** and **67** in full line position A at the end of the full refrigerant compressor suction stroke and by dotted line at the opposite extreme position at the end of the refrigerant compression stroke, position B.

FIG. 4 shows a cross-section of a preferred embodiment of the pneumatic linkage shown schematically in FIG. 3. The same numerals used for components shown in FIG. 3 are applied to corresponding components in FIG. 4. FIG. 4 additionally shows seal **75** in compression chamber **65** providing a gas-tight seal between piston **67** and cylinder walls **66**. Seal **75** comprises a reinforced rubber diaphram providing a gas-tight and pressure-tight seal with minimum friction. One suitable seal commercially available is known as Bellofram seal. Due to operation of such diaphram seals, it is preferred that connecting rod **64** be in a vetrical position.

It should be apparent that the term "piston" as used in the description and claims includes various shapes and mechanisms providing for reciprocating motion within a confined chamber and is meant as used herein to include diaphrams, bellows, and the like.

Referring to FIG. 5, the pressure-volume relationships of the apparatus of FIGS. 3 and 4 are shown using helium as the working gas in the power unit (heat-actuated regenerative compressor as shown in FIG. 1) and Freon 22 as the refrigerant in the cooling unit. This is one preferred combination of gases suitable for use in the apparatus shown in FIGS. 3 and 4. The point A for the

refrigerant compressor cycle and A' for the power cycle correspond to position shown by the full-line representation in FIG. 3. This shows the position of the pistons at the end of the full refrigerant compressor suction stroke and corresponding pressure-volume relationships. The point B for the refrigerant compressor cycle and B' for the power cycle on the graphs correspond to the position shown by the dotted line representation in FIG. 3. This shows the position of the pistons at the end of the full refrigerant compression stroke and corresponding pressure-volume relationships.

It is readily observed from FIG. 5 that the pressure ratio of the working gas in the power cycle is nearly 1.8 and the pressure ratio of the refrigerant in the cooling cycle is 3.8. It is also apparent that the pressure ratio of the power cycle can be chosen to other levels, if desired, by appropriate sizing of relative areas of pistons **60** and **67**. The pressure ratio of the cooling cycle is dependent upon the refrigerant, and, for example, using Freon 22 as refrigerant, the refrigerant pressure ratio of about 3.8 can be achieved by a single stage heat-actuated regenerative compressor unit. Prior methods not using the assisted linkage of this invention required multiple stages of heat-actuated regenerative compressor outputs to achieve the required pressure ratio for the most desirable refrigerants. FIG. 5 further illustrates that it is desirable to operate the pneumatic linkage in a fashion so that it continuously maintains a constant pressure differential between the working gas of the heat-actuated regenerative compressor and the working refrigerant. This is evident from the notations of ΔP as shown in FIG. 5. The economic savings and space savings resulting from the cooling apparatus of this invention are readily apparent. Air-conditioning units according to this invention suitable for residential use are also obtained.

FIG. 6 shows a complete cooling system according to my invention wherein **80** represents a heat-actuated regenerative compressor power unit as shown in one embodiment in FIG. 1, the "heat-in" represents thermal energy added to the active gas of the power unit compressor by the internal heater, and the "heat-out" represents thermal energy removed from the active gas of such compressor by the internal cooler. Heat-actuated regenerative compressor **80** is in communication with refrigerant compressor **82** through a pneumatic, hydraulic and/or mechanically assisted linkage **81** providing lower absolute pressures at the refrigerant compressor **82** side of the linkage than at the power unit **80** side of the linkage. The heat-actuated regenerative compressor **80** through linkage **81**, such as shown in specific embodiments FIGS. 2, 3, and 4 powers refrigerant compressor **82** driving refrigerant through a condensation-expansion-evaporation-compression cooling cycle.

The states of the refrigerant shown in FIG. 6 as letters correspond to the letters on the thermodynamic diagram shown in FIG. 7. Refrigerant gas flows from refrigerant compressor **82** at state F through condenser **83** removing heat from the refrigerant to the ambient atmosphere, flowing from condenser **83** at state G as a liquid, through expansion throttle **84** reducing the pressure to state H, and through evaporator **85** wherein heat is taken up from the exterior cooled atmosphere and re-entering the heat-actuated regenerative compressor at state E for compression. Evaporator **85** represents the cooling of confined room air in the case of a room air conditioning unit.

Referring particularly to FIG. 3, one important embodiment of my invention is the provision of an improved cooling system powered by a heat-actuated regenerative compressor wherein the absolute pressure of the working gas in the compressor is always higher than the absolute pressure of the refrigerant. My invention includes a process for cooling contained exterior atmosphere by a compression-condenser-expansion-evaporation cooling cycle comprising the steps of compressing contained gaseous refrigerant by a second piston driven by a first piston, one side of the first piston being in communication with the active volume of a heat-actuated regenerative compressor and the other side of the first piston in communication with the contained gaseous refrigerant at condenser pressure of the cooling cycle. The process of my invention renders compact heat-actuated regenerative compressor driven cooling systems practical from the standpoint of economics, space requirements and overall efficiency. Cooling systems, according to my process, are readily obtained when the pressure ratio of the heat-actuated regenerative compressor is from about 1.3 to 1.8 and the pressure ratio of the cooling cycle is from 3.0 to 4.5. Cooling apparatus suitable for residential uses are obtained by the process of my invention.

While in the foregoing specification this invention has been described in relation to certain preferred embodiments thereof, and many details have been set forth for purpose of illustration, it will be apparent to those skilled in the art that the invention is susceptible to additional embodiments and that certain of the details described herein can be varied considerably without departing from the basic principles of the invention.

I claim:

1. In a heat-actuated regenerative compressor of the type comprising a casing defining a generally cylindrical chamber for confining gas, heating means, cooling means, and heat regenerating means positioned within said chamber extending from said casing toward the center of said chamber and extending substantially the length of said chamber, an oscillating displacer dividing said chamber into a first volume and a second volume and by oscillatory movement displacing said gas from said first volume through said heating, regenerating and cooling means into said second volume at a higher average temperature-pressure relationship, and returning said gas from said second volume through said heating, regenerating and cooling means into said first volume at a lower average temperature-pressure relationship, and a pressure responsive means in said casing in communication with said first volume providing for expansion and contraction of said gas for operation of said compressor between fixed pressures, the improvement comprising; said displacer having a central hub and a thin vane extending to and congruent with said shell casing, said vane oscillating at from about 100 to 300 cycles per minute.

2. The apparatus of claim **1** wherein said pressure responsive means is a differential pressure means comprising pneumatic assisted linkage to associated apparatus providing lower absolute pressures at the side of said linkage connected to said associated apparatus than at the side of said linkage in communication with said first volume.

3. The apparatus of claim **2** wherein said differential pressure means comprises a closed pnemuatic assisted linkage comprising a cylinder defining a cylinder chamber; a piston adapted for reciprocating motion within said cylinder chamber and having one face in communication with said cylinder chamber and the opposite face in communication with said first volume, said piston reciprocating with substantially gas-tight relationship between said cylinder chamber and said first volume; a connecting rod rigidly attached to said one face and extending in substantially gas-tight relationship exterior to said cylinder chamber to power said associated apparatus; a reservoir in communication with said cylinder chamber; and gas contained within said cylinder chamber and reservoir which exerts pressure on said one face whereby said associated apparatus may be operated at lower absolute pressures than said heat-actuated regenerative compressor.

4. The apparatus of claim **3** wherein said gas is nitrogen.

5. The apparatus of claim **3** wherein said associated apparatus operates a condenser-expansion-evaporation-compression cooling cycle.

6. The apparatus of claim 3 wherein said reservoir has a thermal exchanger and said gas is a boiling refrigerant selected from the group consisting of halogenated hydrocarbons, SO_2, and CO_2.

7. The apparatus of claim 1 wherein said pressure responsive means is a differential pressure means comprising hydraulic assisted linkage to associated apparatus providing lower absolute pressures at the side of said linkage connected to said associated apparatus than at the side of said linkage in communication with said first volume.

8. The apparatus of claim 7 wherein said differential pressure means comprises a closed hydraulic assisted linkage comprising a cylinder defining a cylinder chamber; a piston adapted for reciprocating motion within said cylinder chamber and having one face in communication with said cylinder chamber and the opposite face in communication with said first volume, said piston reciprocating with substantially gas-tight relationship between said cylinder chamber and said first volume; a connecting rod rigidly attached to said one face and extending in substantially gas-tight relationship exterior to said cylinder chamber to power said associated apparatus; a flexible fluid accumulator in communication with said cylinder chamber; and an incompressible fluid contained within said cylinder chamber and accumulator which exerts pressure on said one face whereby said associated apparatus may be operated at lower absolute pressures than said heat-actuated regenerative compressor.

9. The apparatus of claim 1 wherein said pressure responsive means is a differential pressure means comprising mechanical assisted linkage to associated apparatus providing lower absolute pressures at the side of said linkage connected to said associated apparatus than at the side of said linkage in communication with said first volume.

10. A cooling apparatus comprising a heat-actuated regenerative compressor containing a working gas; a cooling mechanism comprising a condenser means, expansion means, evaporation means, compression means and contained refrigerant; and a differential pressure means connecting said heat-actuated compressor to said cooling mechanism including said compression means comprising a first cylinder defining a cylinder chamber, a first piston adapted for reciprocating motion within said cylinder chamber and having one face in communication with said cylinder chamber and the oppoiste face in communication with said heat-actuated regenerative compressor, said piston reciprocating in substantially gas-tight relationship between said cylinder chamber and said compressor, said cylinder chamber in communication with said condenser means; a second cylinder defining a compression chamber, said second cylinder having an inlet valve to said compression chamber in communication with said evaporation means permitting flow of refrigerant from said evaporation means into said compression chamber and an outlet valve from said compression chamber in communication with said condenser means; a connecting rod having a first and second end, said first end rigidly attached to said one face and said second end extending in substantially gas-tight relationship into said compression chamber; a second piston rigidly attached to said second end of said connecting rod and adapted for reciprocating motion within said compression chamber and having a first face in communication with said compression chamber and an opposite second face in communication with said evaporation means; whereby said cooling mechanism is operated at lower absolute pressures than said heat-actuated regenerative compressor.

11. The apparatus of claim 10 wherein said working gas is helium and said refrigerant is a halogenated hydrocarbon.

12. The apparatus of claim 11 wherein said halogenated hydrocarbon is selected from the group consisting of Freon 12, Freon 22 and Freon 502.

13. The apparatus of claim 10 having bellows attached at one end to said first piston and at the other end to said heat-actuated compressor to maintain substantially gas-tight relationship between said cylinder chamber and said compressor.

14. In a heat-actuated regenerative compressor of the type comprising a casing defining a generally cylindrical chamber for confining gas, heating means, cooling means, and heat regenerating means positioned within said chamber extending from said casing toward the center of said chamber and extending substantially the length of said chamber, an oscillating displacer dividing said chamber into a first volume and a second volume and by oscillatory movement displacing said gas from said first volume through said heating, regenerating and cooling means into said second volume at a higher average temperature-pressure relationship, and returning said gas from said second volume through said heating, regenerating and cooling means into said first volume at a lower average temperature-pressure relationship, and a pressure responsive means in said casing in communication with said first volume providing for expansion and contraction of said gas for operation of said compressor between fixed pressures, the improvement comprising; said displacer having a central hub and a vane extending to and congruent with said shell casing, said vane oscillating at from about 100 to 500 cycles per minute.

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