United States Patent [19]

Edwards

[11] **3,886,764**

[45] **June 3, 1975**

[54] **COMPRESSOR-EXPANDER HAVING TILTING VANES FOR USE IN AIR CONDITIONING**

[75] Inventor: **Thomas C. Edwards,** Casselberry, Fla.

[73] Assignee: **The Rovac Corporation,** Maitland, Fla.

[22] Filed: **July 29, 1974**

[21] Appl. No.: **492,608**

[52] **U.S. Cl.** **62/402;** 62/401; 418/225

[51] **Int. Cl.** **F25d 9/00**

[58] **Field of Search** 62/402, 401; 418/225

[56] **References Cited**

UNITED STATES PATENTS

1,561,946	11/1925	Rasmussen	418/225
2,424,466	7/1947	Jessop	418/225
2,660,123	11/1953	Vlachos	418/225
3,136,304	6/1964	Tauscher	418/225
3,686,893	8/1972	Edwards	62/402

Primary Examiner—William J. Wye

Attorney, Agent, or Firm—Wolfe, Hubbard, Leydig, Voit & Osann, Ltd.

[57] **ABSTRACT**

A compressor-expander for use in air conditioning which includes a rotor rotating in a chamber of oval cross section having a compression side and an expansion side, each with inlet and outlet ports. Hinged to the periphery of the rotor are a plurality of axially extending vanes which are biased outwardly into engagement with the wall of the chamber to form compartments of varying volume. Each vane is equipped, along its outer edge, with a sealing member having rollers which support the member at a desired close running clearance with respect to the wall of the chamber. The sealing members have a curved profile which matches the curve of the supporting rollers so that the same running clearance is maintained in spite of the changes in the angling of the vane which occur during the rotative cycle. The rotor is formed with longitudinal grooves for receiving the sealing members and with adjacent recesses for receiving the rollers for minimizing the residual volume between adjacent vanes when the vanes are in their inwardly folded positions. The vanes are angled retreatingly with respect to the direction of rotation of the rotor so that the force resulting from inward acceleration of a vane when it is crowded inwardly due to the oval shape assists centrifugal force and the biasing force in maintaining the vane in engagement with the wall of the chamber, in spite of the tendency of the compressed air to unseat the vane from the wall.

In the preferred embodiment of the invention each vane is in the form of a thin laminated leaf spring, mounted cantilever-fashion on the rotor. In alternative forms of the invention the vanes are rigid having a rockable tongue and groove engagement with the rotor surface. In a final embodiment of the invention each vane has means at its outer edge positively for positioning the vane with respect to the wall of the chamber, holding it inwardly to establish running clearance and holding it outwardly so that it does not yield or retreat in the face of the reaction pressure of the compressed air.

23 Claims, 15 Drawing Figures

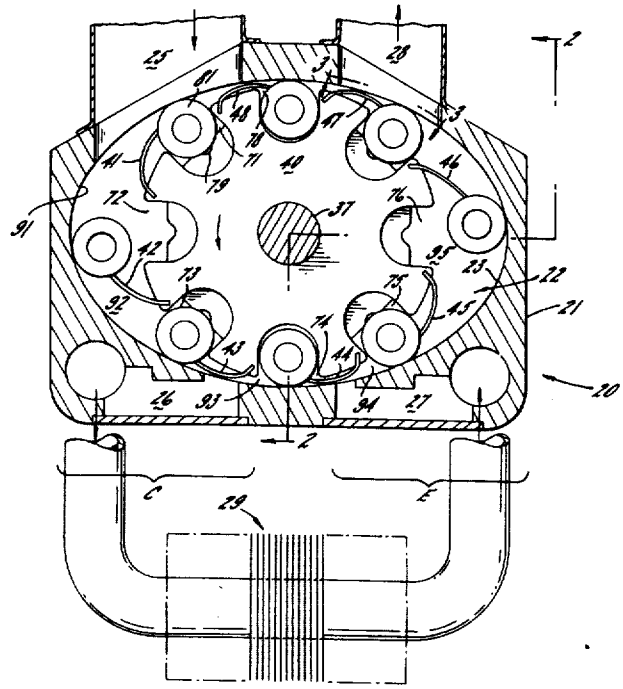


Fig. 1

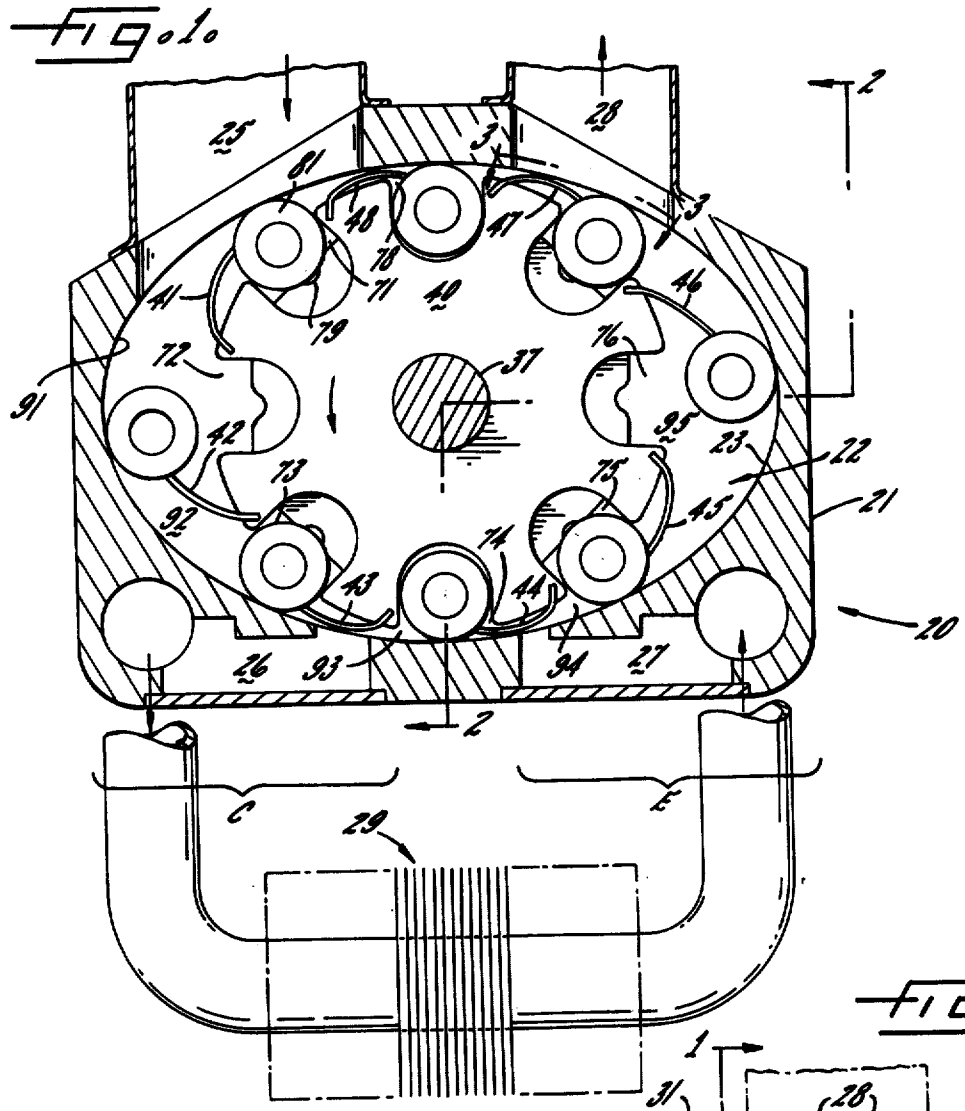


Fig. 2

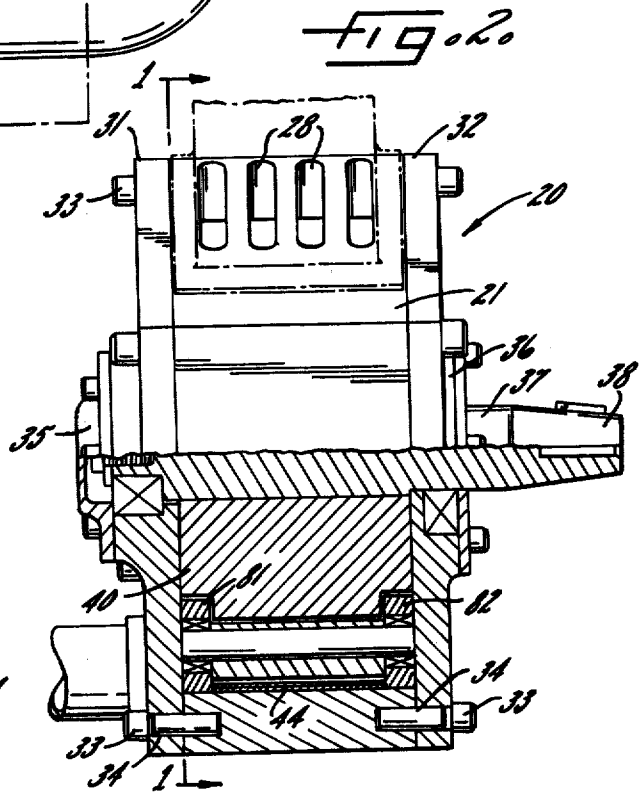


Fig. 3

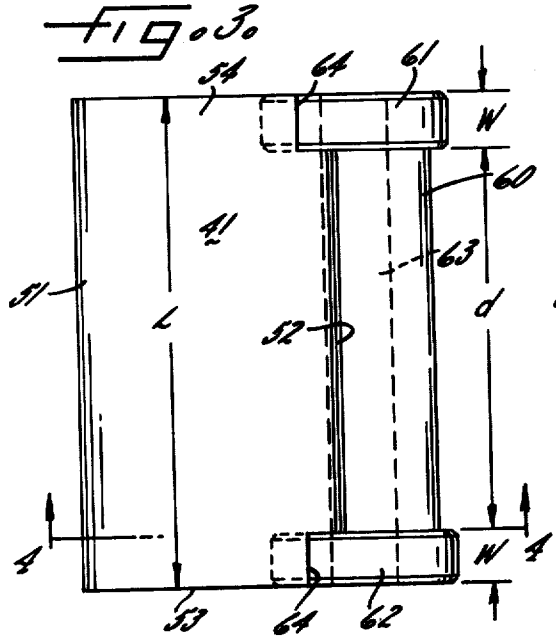


Fig. 4.

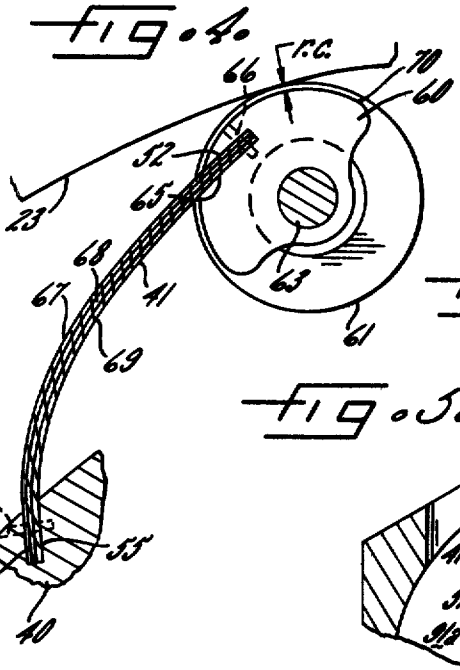


Fig. 4a.

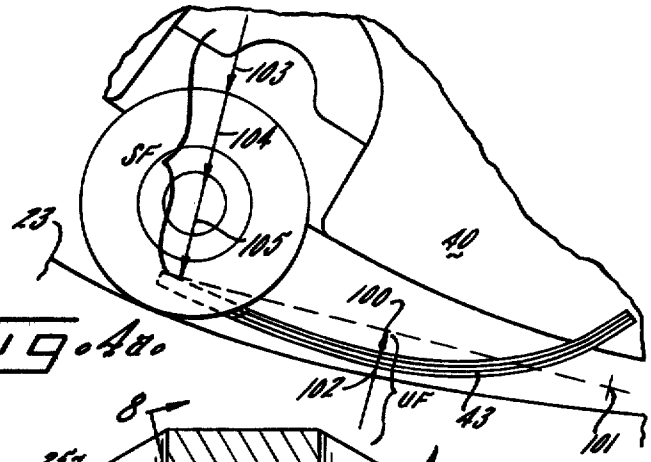


Fig. 5.

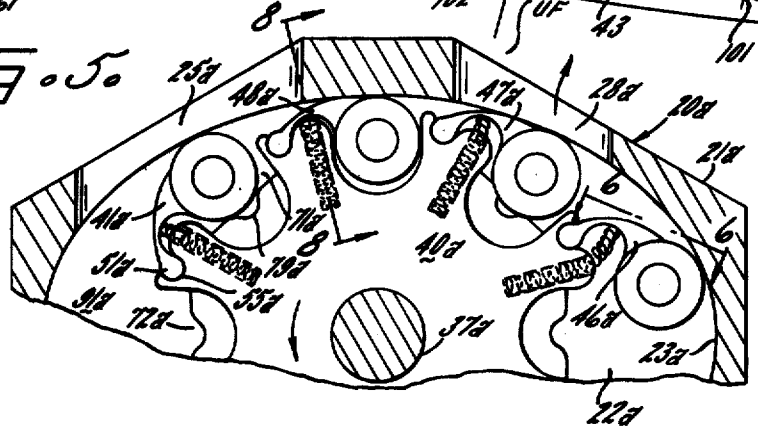


Fig. 6.

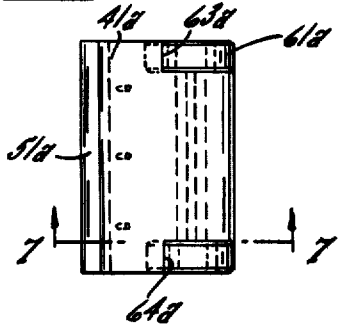


Fig. 7.

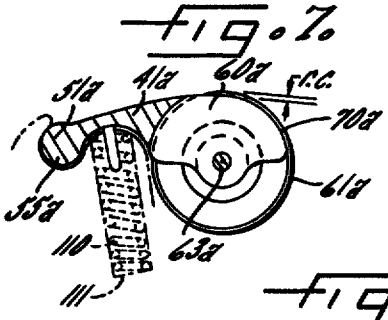


Fig. 8.

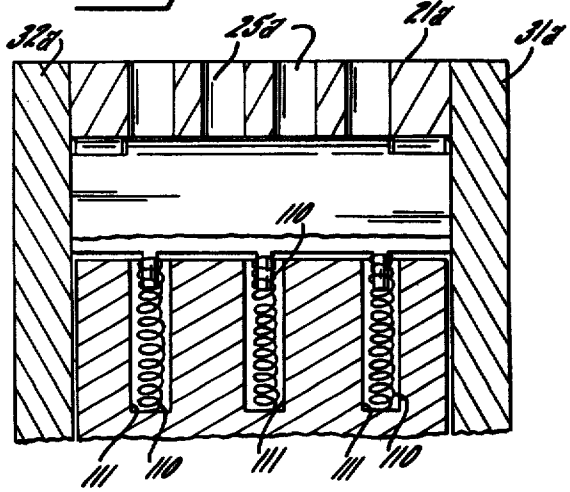


Fig. 9.

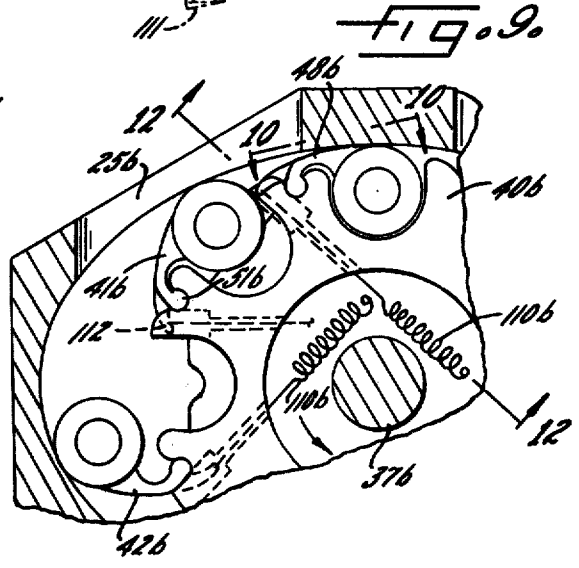


Fig. 10

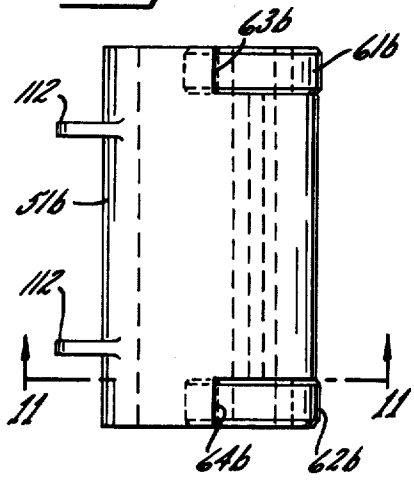


Fig. 11

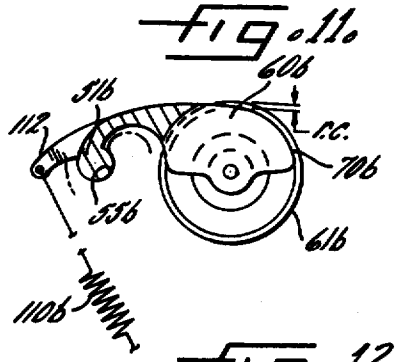


Fig. 12

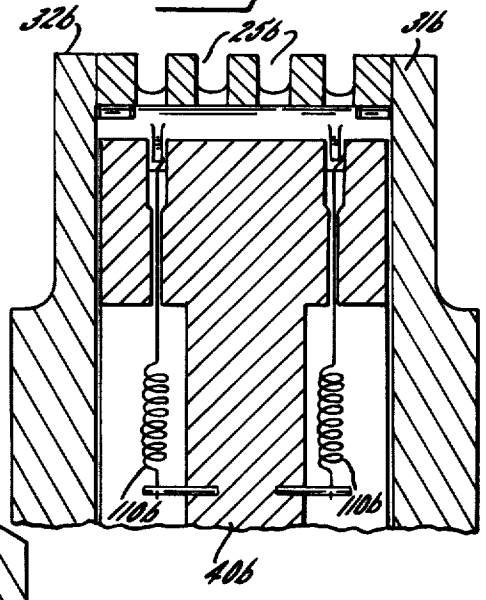


Fig. 13

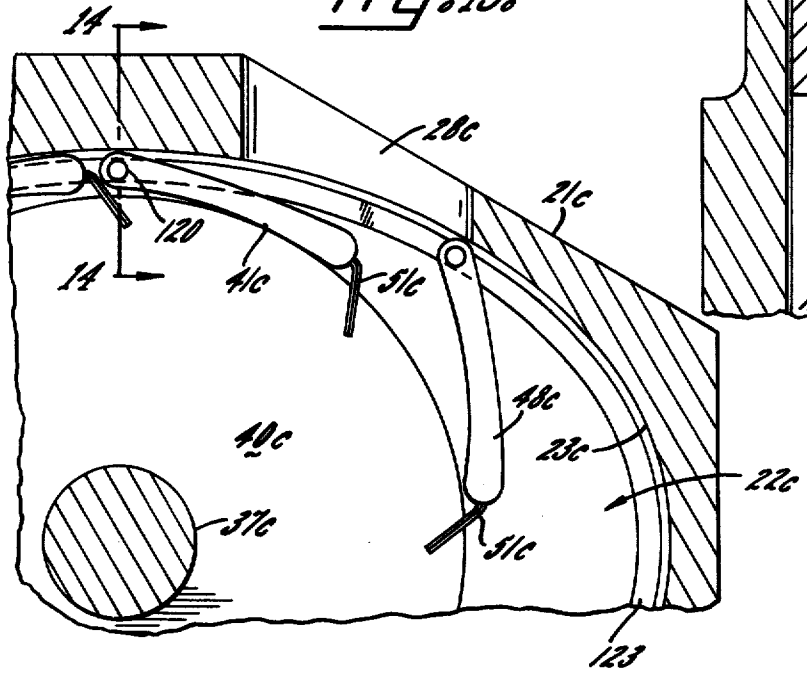
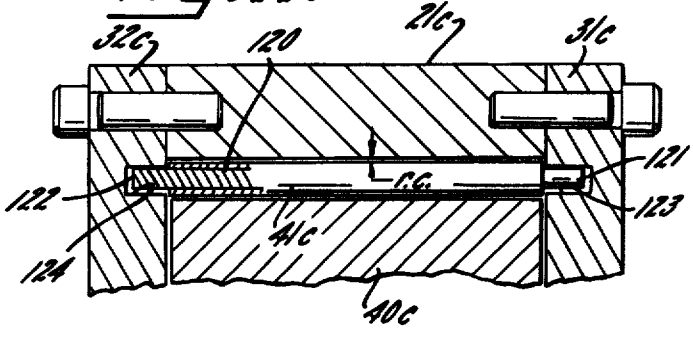


Fig. 14



COMPRESSOR-EXPANDER HAVING TILTING VANES FOR USE IN AIR CONDITIONING

A compressor-expander utilized in a novel and simple system of air conditioning is disclosed in my prior U.S. Pat. No. 3,686,893, which issued on Aug. 29, 1972. Such compressor-expander employed radially sliding vanes having means for biasing the vanes outwardly against the wall of an oval chamber. In my subsequent application Ser. No. 400,965, filed Sept. 26, 1973, each vane is provided with a set of rollers for establishing a condition of predtermined running clearance between the outer edges of the vane and wall of the chamber to reduce wear and to lower driving requirements.

However, the use of radial, sliding vanes has been found to be accompanied by a number of disadvantages. Not only is there expected friction between the vane and the rotor slot or groove in which it slides, but the force which is laterally applied to each vane, by the air which is compressed, is an unbalanced force causing the setting up of a couple within the groove which greatly magnifies frictional effects. In addition, the grooves, to accommodate the maximum insertion of the vanes during the minimum volume portions of the rotative cycle, must be so deep as to extend practically to the rotor shaft. This fact, combined with the chambering of the rotor necessary to accommodate the biasing springs, results in a sectored rotor which is inherently weak and in which the individual sectors may flex with respect to one another thereby changing the groove clearance dimensions during a single cycle of rotation.

It is accordingly, an object of the present invention to provide a compressor-expander which employs vanes which tilt with respect to the rotor surface instead of sliding within the body of the rotor thereby preserving the integrity of the rotor and substantially reducing the amount of energy which is lost in friction.

It is a related object of the invention to provide a compressor-expander which avoids radial sliding reception of the vanes but which is nevertheless formed with shallow axially extending grooves for accommodation of the vane structure, including the vane supporting rollers, so as to minimize the residual volume betwen adjacent vanes at their minimum volume point in the rotative cycle.

It is a more specific object of the present invention to provide a compressor-expander in which the vanes are in the form of leaf springs supported cantilever-fashion of the surface of the rotor and which have improved sealing means along the outer edge capable of maintaining optimum running clearance regardless of the range of angling of the vane between its extended and inwardly folded positions.

It is an object of the invention in one of its aspects to provide a rigid vane structure which is hinged along one edge to the rotor with a rockable tongue and groove connection but which nevertheless permits almost total reception of the vane into the surface of the rotor when the vane is in its inwardly folded condition for minimizing residual volume and hence improving the compression ratio.

It is an object of the invention in one of its aspects to provide a compressor-expander having outwardly biased tiltable vanes which are retreatingly angled to assist in maintaining the vane in sealing contact with the wall of the chamber notwithstanding the reaction force of the air which is being compressed and which requires only light spring biasing forces.

It is finally an object of the invention to provide a compressor-expander which is stronger and which has a longer life than similar devices available in the past, which is economical to manufacture, having a minimum of parts requiring close tolerance, and which is highly reliable requiring only minimal maintenance over long periods of time.

Other objects and advantages of the invention will become apparent upon reading the attached detailed description and upon reference to the drawings in which:

FIG. 1 is an elevational view taken along the section line 1—1 in FIG. 2.

FIG. 2 is a broken section looking along the line 2—2 in FIG. 1.

FIG. 3 is a fragmentary section looking along the line 3—3 in FIG. 1.

FIG. 4 is an enlarged section taken through the vane and looking along the line 4—4 in FIG. 3.

FIG. 4*a* is a diagram showing the forces acting on a typical vane in the act of compression.

FIG. 5 is an elevational view showing a modified form of the present invention using a rigid vane structure.

FIG. 6 is a face view of a vane looking along line 6—6 in FIG. 5.

FIG. 7 is a section taken transversely through a vane along line 7—7 in FIG. 6.

FIG. 8 is a fragmentary radial section taken along the line 8—8 in FIG. 5.

FIG. 9 is a fragmentary elevation showing showing a still further form of the invention using a different biasing spring arrangement.

FIG. 10 is a face view of a vane looking along line 10—10 in FIG. 9.

FIG. 11 is a transverse section along line 11—11 in FIG. 10. FIG. 12 is a fragmentary inclined section taken along line 12—12 in FIG. 9.

FIG. 13 is a fragmentary elevation of a final form of the invention having means for positively positioning the vanes at each point in the rotative cycle.

FIG. 14 is a fragmentary radial section looking along line 14—14 in FIG. 13.

While the invention has been described in connection with certain preferred embodiments, it will be understood that I do not intend to limit the invention to the particular embodiments which have been illustrated but intend, on the contrary, to cover the various alternative and equivalent forms of the invention included within the spirit and scope of the appended claims.

Turning now to FIGS. 1–4 in the drawings there is disclosed a compressor-expander unit **20** having a main housing **21** enclosing a chamber **22** defined by an outer wall **23** which is of oval, or elliptical, configuration. The left-hand side of the oval, in the discussion which follows, will be referred to as the "compression" side C and the right-hand side as the "expansion," side E. The compression side has an inlet port **25** and an outlet port **26** while the expansion side has an inlet **27** and an outlet port **28.** Connected between the compression side outlet port **26** and expansion side inlet port **27** is a heat exchanger **29.**

For enclosing the ends of the housing, frame or end plates **31, 32** are used held in position by screws **33** and

positioned by pins **34**. Mounted in bearings **35, 36** in the end plates is a shaft **37** providing a drive connection **38**.

Secured to the shaft is a rotor **40** mounting a plurality of vanes **41-48** which are anchored at their inner ends in the periphery of the rotor and which are tiltable with respect to the rotor, swinging outwardly and then inwardly, following the oval contour as the rotor revolves. As will be seen, the effect of this swinging movement is to vary the amount of volume between adjacent vanes over wide limits during the compression and expansion portions of the cycle. Taking the vane **41** as typical, and referring more particularly to FIGS. **3** and **4**, the vane will be seen as generally rectangular in shape having an inner edge **51**, and outer edge **52** and lateral edges **53, 54** which extend into close proximity with the end plates **31, 32**. The inner edge of the vane **41** is received cantilever-fashion in a groove **55** which is formed, preferably at an angle, in the surface of the rotor **40** where it may be retained by a series of pins **56**.

At the outer end of the vane **41** is a sealing member **60** in the form of an enlargement which extends in the axial direction and which supports a pair of rollers **61, 62** upon a shaft **63**. The rollers may be of the ball bearing type sealed with lubricant. The rollers are preferably included within the confines of vane **41**, the vane being notched out at the corners to accommodate the rollers as indicated at **64** (FIG. **3**). Accordingly, the sealing member **60** is foreshortened to have a dimension D which, added to the width W, of the rollers equals the axial length L of the vane.

For the purpose of securing the outer edge of the vane **41** to the sealing member **60**, the sealing member is provided with a slot **65** in which the spring is retained by a sereis of pins **66**.

In accordance with one of the aspects of the invention the vane **41** is preferably formed of thin spring laminations **67-69**, and the clearance holes which accommodate passage of the anchoring pins **56, 66** are preferably made oversized so that the laminations are free to slide slightly with respect to one another incident to flexing movement. To facilitate such sliding, a suitable lubricant is preferably interposed between the adjacent surfaces of the laminations.

In accordance with another aspect of the invention the sealing member **60** is provided with an outer sealing surface **70** which has a curved profile, looking in the axial direction, which follows the curved profile of the rollers having the same center, but which is radially inset a small amount, on the order of 5 to 10 tenthousandths of an inch, to provide a running clearance indicated at r.c. in FIG. **4**.

The curved surface **70** thus insures that the same running clearance will be preserved over the relatively wide range of swing of the vane **41** as it travels between its extended, or maximum volume, position and its inwardly folded, or minimum volume, position during the course of a rotative cycle.

In order to minimize the residual volume between adjacent vanes the surface of the rotor **40** is relieved to accommodate the sealing member **60** and rollers **61, 62**. Specifically, the rotor is formed with a series of longitudinally extending grooves **71-78** which register with, and receive the respective sealing members of vanes **41-48**. Since the sealing members, as shown in FIG. **4**, have a cross section which is semi-circular, the grooves **71-78** may be rather shallow and substantially flat-bottomed, with each groove having a centered root portion **79** for mating with the offset at the roller shaft.

For the purpose of almost total accommodation of the rollers **61, 62** there is provided, at the respective ends of the groove **71** taken as representative, deep, cylindrically bottomed roller recesses **81, 82**. Since the roller recesses substantially conform to the rounded shape of the roller, and are of the same axial dimension, there is very little residual volume defined between them.

In operation, the rotor is rotated in the direction shown at a speed which may, in a practical case, lie in the range of 500 to 7500 rpm. As the rotor traverses the phase position illustrated in FIG. **1**, a charge of air enters the inlet port **25** to occupy the expanding space **91** which is defined between the adjacent vanes **41, 42**. When the vane **41** has swung through an additional 20° or so it is at the end of the inlet opening **25**, so that a charge of air is trapped. As the rotor undergoes additional rotation, the space between the adjacent vanes is progressively reduced, resulting in compression of the trapped air. This process continues until all of the air forming the charge **91** is compressed to a small fraction of the original volume, substantially that which has been indicated at **93**, which forms a small residual. In a practical case compression ratios on the order of 2.5 to 5.0 may be readily obtained. During the course of compression the reduction in volume causes the pressure and temperature to use sharply, in a practical case to something on the order of 80° to 300°F., and the relatively hot compressed air is discharged through the compressor side outlet port into the heat exchanger **29**. The air flows through the heat exchanger at substantially constant pressure, with most of the energy of compression being subtracted by the heat exchange action. In a practical case the temperature of the air may be returned, by the exchanger, to within, say, 2° to 10°F. of the ambient temperature while the pressure remains at an elevated value on the order of, say 25 to 35 pounds per square inch, gage pressure.

The compressed air fed from the heat exchanger into the expansion side inlet port **27** passes into the space **94** defined by vanes **44, 45**. Upon continuation of the rotor movement the air in the space **94** is permitted to expand so that it occupies space **95** with abrupt reduction in both the pressure and temperature. Finally, at the end of the expansion process, the cold air is discharged through the expansion side outlet port **28** at substantially ambient pressure but at a temperature which may in a practical case be around 0° F. Such air contains the original moisture in the form of ice particles and is much too cold for comfort so that I provide means, as described in my copending application Ser. No. 420,712, filed Nov. 30, 1973, for removing the ice and for tempering the air by mixing it with such proportion of ambient air as will bring about a comfortable temperature at the vents which discharge into controlled space.

In accordance with one of the aspects of the invention the vanes are retreatingly angled with respect to the direction of rotor movement for the purpose of utilizing the crowding action of the oval profile for retention of pressure and in order to make it possible to employ only a relatively small biasing force and therefore relatively light biasing springs. The effect of the vane orientation will be seen in FIG. **4***a* which illustrates the

pressures acting upon a typical vane such as **42** during the act of compression. In this figure the spring which forms the vane is assumed to be rigid and to provide a lever arm **100** swingable about a virtual center **101**. Tending to unseat the vane from its contact against the wall of the chamber is a force **102** due to pressure reaction which may be referred to as the unseating force UF. There are, in opposition to this unseating force, three forces having components nominally perpendicular to the lever arm **100**, namely, a spring biasing force **103**, centrifugal force **104** and a crowding force **105**, not all necessarily coplanar. The centrifugal force, as will be understood, is that which tends to hold the vane in its outermost position by reason of the inward acceleration due to the relatively high speed of rotation of the rotor. While centrifugal froce is radially directed, the vector **104** shows only that component of the radial force which is perpendicular to the lever arm **100**. it will be understood that the force **104** would be effective even though the chamber were of circular profile.

However, since the chamber is of oval shape there is an additional force vector acting upon the vane, at **105**, due to crowding action. That is to say, not only does the vane with its rollers swing about a center but it is, during the lower lefthand or "compressing" quadrant, accelerated radially inward by reason of the decreasing radius of the surface **23** which the rollers engage. This inward acceleration results in a reaction force which is of substantial magnitude and which has a component, nominally perpendicular to the lever arm **100**, which is additive to the forces **103, 104** to produce a large total seating forces SF. Because of the high total selaing force SF, and its greater mechanical advantage, being applied at the end of the lever arm, the seating force previals over the unseating force, keeping the vane is engagement with the wall and permitting development of substantial maximum pressures with only relatively small spring biasing force. In short, the present construction, by reason of the direction of angling of the vanes and utilization of the crowding effect of the oval, enables high pressures to be developed using only relatively light leaf springs.

The importance of the angling of the vanes will be further understood by considering what transpires in the third quadrant, that is, where the high pressure air is fed into the inlet port **27** at the expansion side. It will be apparent that in this quadrant the oval profile, instead of producing a crowing action actually "retreats," that is, becomes of greater radius which, it might be thought, would make maintenance of sealing engagement more difficult. This would be true for the angling of the vanes which causes the pressure of the air, in the third quadrant, to be applied on the top, or inside, surface of the vane (e.g. vane **45** in FIG. 1) in a direction to seat the vane against the surface of the chamber. Thus while force **105** has in effect, changed direction to become an unseating force, force **102** has also changed its direction, and prevails, so that the contained pressure, combined with spring force and centrifugal force, maintains the vane firmly seated.

In addition to the running clearance r.c. (FIG. **4**) along the outside edge of the vane there will be running clearances along the lateral edges and in the notches **63, 64** which accommodate the rollers and through which leakage might be expected to take place. However, because of throttling action the contained air cannot be leaked instantaneously, and the compressive cycle and expansion cycle are completed before any appreciable amount of leakage can occur. The sealing member at the outer edge of each vane is preferably of enlarged, bulbous cross section to provide a relatively long throttling path. Thus while the present compressor-expander is a device capable of achieving high pressures, it is not necessary, for successful use, to adhere to extremely close tolerances in design and manufacture.

ALTERNATIVE EMBODIMENTS

While it is preferred to employ a leaf spring as a vane, as described above, the invention is by no means limited thereto and the invention may be utilized in the alternate form shown in FIGS. **5–8**, in which similar elements are designated by the same reference numeral with the addition of subscript *a*.

Thus a frame **21***a* is provided having a central chamber **22***a* with an outer wall **23***a* of oval profile. Mounted for rotation within the housing is a rotor **40***a* having a plurality of vanes of which the vane **41***a*, shown in FIGS. **6** and **7**, is representative. Such vane has a tongue **51***a* of rounded profile along its inner edge which mates with a similarly formed groove **55***a* on the rotor, with the tongue being held captive in the groove. At its end the vane **41***a* has a sealing member in the form of an integral enlargement **60***a* which mounts a shaft **63***a* holding rollers at its ends as that shown at **61***a*. The sealing member **60***a* has a rounded profile **70***a* which follows the curvature of the roller **61***a* to define a running clearance r.c.

Just as in the case of the preceding embodiment, the sealing member **60***a* is foreshortened thereby defining notches **63***a*, **64***a* (FIG. **6**) having a relatively close running clearance with respect to the rollers. For the purpose of biasing the vane **41***a* outwardly, a spring **110** is provided in the form of a coil spring **110** seated in a bore **111** bored into the rotor. As illustrated in FIG. **8** a total of three springs **110** may be used to insure that balanced forces are applied to the vane.

The operation, from a functional point of view, is the same as that described for the previous embodiment

A still further, but similar, embodiment is set foth in FIGS. **9–12** where corresponding elements have been indicated by the same reference numeral with additional of subscript *b*. The main difference between this embodiment and that just described is in the nature and anchoring of the biasing springs. In the embodiment of FIG. **5** compression coil springs **110** are used which requires that the tongue and groove connection, at the inside edge of the vane, be captive. In the embodiment of FIGS. **9–12** tension springs **110***b* are employed which are connected to the vane by corresponding integral arms or brackets **112**. The direction of the force is to seat the tongue **51***b* and the groove **55***b* so that a captive connection at this point is not necessary.

A still further embodiment of the invention is illustrated in FIGS. **13** and **14** in which similar elements carry similar reference numerals with addition of subscript *c*. In the prior embodiments internally generated forces are relied upon to maintain sealing engagement, namely the resilient force, centrifugal force and the crowing force due to the oval shape. In accordance with one of the aspects of the invention means may, if desired, by provided to positvely position each of the vanes, that is, to hold the vanes inwardly so that they have running clearance and do not scrape the wall **23***c*

of the chamber and to hold the vanes outwardly into sealing engagement with such wall in the face of the unseating force of the compressed air during one of the quadrants of the cycle. In the construction of FIGS. **13** and **14** a typical vane indicated at **41***c* has a hinge in the form of a leaf spring **51***c*. Extending transversely at the outer end of the vane **41***c* is a pin **120**, which may be unitary or in two separate sections having axially presented ends **121, 122**. The ends of the pins are received in oval grooves **123, 124** respectively which are formed in the end plates **31***c*, **32***c*. It will be apparent that the surfaces of the grooves which lie radially outward prevent the vane from moving outwardly into scraping engagment with the wall of the chamber, in other words, a minimum running clearance r.c. (FIG. **14**) is established. However in the event that the vane **41** tends to become unseated from the wall of the chamber by reason of the reaction pressure of the compressed air, the radially inward surfaces of the grooves **123, 124** serve to prevent inward movement.

It is obviously necessary in the embodiment of FIGS. **13, 14** to provide good lubrication in the grooves **123, 124** and to make the pin projections **121, 122** of hard material so as to resist wear. Alternatively anti-friction means may be used at the pins **121, 122** in the form of rollers of small diameter. Aside from the positive control of position of the vanes, the device as disclosed in FIGS. **13** and **14** works the same and has many of the same advantages, as the preferred embodiment described above.

It may be noted that the vanes of the embodiment of FIG. **13**, as represented by the vane **41***c*, are of curved configuration so that when the vane is in its inwardly folded condition it tends to nest against the surface of the rotor assisting in minimizing the residual volume. Such curvature, and nesting, characterizes each of the embodiments which has been described.

The amount of spring bias to be used in a particular design is a matter well within the skill of the art. In the case of the preferred embodiment the amount of spring force is dependent not only upon the number, thickness and modules of the spring laminations but upon the degree of pre-stress which is imparted to the springs prior to assembly.

It is found that the described constructions adequately carry out the objects of the invention. All of the embodiments are substantially free of frictional loading within the rotor and permit use of a rotor of inherently greater strength and integrity than where the rotor must be deeply slotted to accommodate vanes of the sliding type.

While the invention has been described in connection with air as the refrigerating medium, it will be understood that use of the device, particularly where employed in a closed system, is not limited to air and that other gases may be utilized without departing from the invention. The term "anti-friction means" as applied to the outer edges of the vanes includes any means for reducing friction in this region. Also the term "engagement" or "sealing engagement," referring to the cooperation of the vanes with the wall of the chamber does not imply actual contact but rather proximity which is sufficiently close as to make use of throttling forces in the containment of the compressed air. Since both rollers and pins are used in the disclosed embodiment for vane positioning purposes, it will be understood that the two terms are used interchangeably. The term "hinging" includes any means for achieving vane articulation at or near the roller surface. The term "air conditioning" as used herein includes use of the invention in refrigeration or as a heat pump.

I claim as my invention:

1. In a compressor-expander for use in air conditioning, the combination comprising a housing defining a chamber of oval cross section having a compression side and an expansion side and enclosed by end plates, a cylindrical rotor extending between the end plates and having shafts journaled therein, means defining compression side inlet and outlet ports as well as expansion side inlet and outlet ports, a heat exchanger interposed between the compression side outlet port and the expansion side inlet port, the rotor having a plurality of axially-extending vanes secured to its periphery and extending between the end plates, the vanes being retreatingly angled with respect to the direction of rotor rotation, each of the vanes being in the form of a laminated leaf spring secured cantilever-fashion to the rotor along its inner edge, each of the vanes having a sealing member in the form of an enlargement extending along the outer edge for sealing against the wall of the chamber the sealing member carrying rollers at its ends for riding against the wall of the chamber and for establishing running clearance between the sealing member and the wall, the sealing member having a curved profile as viewed axially generally following the contour of the rollers so that the running clearance of the vane with respect to the wall of the chamber remains substantially constant in all phase positions of the rotor.

2. The combination as claimed in claim **1** in which the sealing member is of shorter axial dimension than the leaf spring by the total thickness of the rollers and in which the leaf spring is notched out at the corners to accommodate the rollers.

3. In a compressor-expander for use in air conditioning, the combination comprising a housing defining a chamber of oval cross section having a compression side and an expansion side and enclosed by end plates, a cylindrical rotor extending between the end plates and having shaft journaled therein, means defining compression side inlet and outlet ports as well as expansion side inlet and outlet ports, a heat exchanger interposed between the compression side outlet port and the expansion side inlet port, a plurality of axially extending vanes secured to the periphery of the rotor extending between the end plates and into engagement with the outer wall of the chamber, anti-friction means at the outer edges of the vanes for supporting the outer edges in close sealing proximity to the wall, means at the inner edges of the vanes for hinging them to the rotor for relative tilting movement so that a charge of air drawn in between adjacent vanes at the compressor side inlet port when the rotor is rotated is (1) compressed, (2) flows at substantially constant pressure through the heat exchanger where theheat of compression is removed and then (3) expands on the expansion side for discharge in the cold state through the expansion side outlet port.

4. The combination as claimed in claim **3** in which rollers are mounted at the outer edges of the vanes for supporting the outer edges with respect to the outer wall of the chamber.

5. The combination as claimed in claim **4** in which the rollers occupy positions at the outer corners of each

vane and with each of the vanes being notched out to accommodate the rollers and to provide close running clearance therewith.

6. The combination as claimed in claim 5 in which the rotor is formed with radial recesses along its edges for registering with and receiving the rollers thereby to permit the vanes to nest against the rotor for minimizing the residual volume between adjacent vanes.

7. The combination as claimed in claim 3 in which each vane has a body which is thin and of curved profile to approximately conform to the surface of the rotor and in which each vane has a sealing member of enlarged, bulbous cross section for engaging the wall of the chamber thereto to provide a relatively long throttling path.

8. The combination as claimed in claim 3 in which the vanes are retreatingly angled on the rotor with respect to the direction of rotor rotation and in which the vanes viewed axially are of curved profile for mating with the curvature of the rotor periphery thereby to minimize the residual volume between adjacent vanes at the minimum volume points in the rotative cycle of the rotor.

9. The combination as claimed in claim 3 in which the hinge means at the inner edge of each vane is in the form of a leaf spring, the leaf spring being mounted cantilever fashion in the rotor.

10. In a compressor-expander for use in air conditioning, the combination comprising a housing defining a chamber of oval cross section having a compression side and an expansion side and enclosed by end plates, a cylindrical rotor extending between the end plates and having shaft means journaled therein, means defining compression side inlet and outlet ports as well as expansion side inlet and outlet ports, a heat exchanger interposed between the compression side outlet port and the expansion side inlet port, the rotor having a plurality of axially-extending vanes secured to the periphery of the rotor extending between the end plates and into engagement with the outer wall of the chamber, means at the inner edges of the vanes for securing them to the periphery of the rotor for relative tilting movement so that a charge of air drawn between adjacent vanes at the compression side inlet port (1) is compressed, (2) flows at substantially constant pressure through the heat exchanger and then (3) expands on the expansion side for discharge in the cold state, rollers mounted at the outer corner positions of each vane for rolling against the outer wall of the chamber thereby to establish running clearance between the outer edge of the vane and the wall of the chamber, each of the vanes being formed with an enlargement extending along the outer edge thereof having a curved surface which, when viewed axially, generally follows the contour of the rollers so that the running clearance of the vanes remains substantially constant in all phase positions.

11. The combination as claimed in claim 10 in which the rotor is formed with longitudinal grooves for registering with and receiving the enlargements along the outer edges of the vanes and in which the rotor is formed with notches at the ends of the grooves for registering with and receiving the rollers thereby to minimize the residual volume between adjacent vanes at the minimum volume points in the rotative cycle.

12. The combination as claimed in claim 3 in which the vanes are angled retreatingly with repsect to the direction of rotor rotation.

13. The combination as claimed in claim 3 in which the vanes are retreatingly angled with respect to the direction of rotation and in which biasing springs are interposed between the vanes and the rotor for urging the vanes outwardly against the wall, the biasing springs being so designed and constructed that the sum of the (a) spring biasing force, (b) centrifugal force and (c) force due to the inward acceleration of the vane caused by the inwardly crowding oval shape of the chamber wall at a predtermined normal running speed exceeds the unseating force due to compression so that each vane is maintained in sealing engagement with the wall of the chamber until the end of the compression stroke.

14. In a compressor-expander for use in air conditioning, the combination comprising a housing defining a chamber of oval cross section having a compression side and an expansion side and enclosed by end plates, a cylindrical rotor extending between the end plates and having shafts journaled therein, means defining compression side inlet and outlet ports as well as expansion side inlet and outlet ports, a heat exchanger interposed betwen the compression side outlet port and the expansion side inlet port, the rotor having a plurality of axially-extending vanes secured to the periphery of the rotor extending between the end plates and into engagement with the outer wall of the chamber, antifriction means at the outer edges of the vanes for supporting the outer edges in sealing proximity to the wall, the vanes being in the form of outwardly sprung leaf springs supported in the rotor cantilever-fashion for relative tilting movement and inclined retreatingly with respect to the direction of rotation so that a charge of air drawn in between adjacent vanes at the compression side inlet port when the rotor is rotated (1) is compressed, (2) flows at substantially constant pressure through the heat exchanger where the heat of compression is removed and then (3) expands on the expansion side for discharge from the expansion side outlet port in the cold state.

15. The combination as claimed in claim 14 in which each leaf spring is formed of a plurality of thin laminations which are received along the inner edge in a groove formed in the rotor surface and in which there is a sealing member in the form of an enlargement secured to the outer edge of the spring to provide sealing engagement with the wall of the chamber.

16. The combination as claimed in claim 15 in which the sealing member viewed axially has a curved outer surface for mating with the wall of the chamber and in which the rotor has longitudinally extending grooves for nested reception of the sealing members when the vanes are in inwardly folded position thereby to minimize the residual volume at the minimum volume points of the rotative cycle.

17. The combination as claimed in claim 16 in which the spring laminations are free to move parallel to one another incident to the flexing of the spring and in which lubrication is interposed between the adjacent surfaces of the laminations.

18. The combination as claimed in claim 3 in which the vane is of rigid construction and in which a tongue and groove connection is provided between the inner edge of the vane and the periphery of the rotor, the tongue being of rounded profile for free tilting movement of the vane with respect to the rotor, and a spring interposed between each vane and rotor for biasing the vane outwardly toward the wall of the chamber, each

vane being retreatingly angled with respect to the direction of rotation of the rotor.

19. The combination as claimed in claim **18** in which the tongue is formed on the edge of the vane and in which the groove is formed in the periphery of the rotor and in which a tension spring is employed for biasing the vane and for keeping the tongue seated in the groove as the rotor rotates.

20. In a compressor-expander for use in air conditioning, the combination comprising a housing defining a chamber of oval cross section having a compression side and an expansion side and enclosed by end plates, a cylindrical rotor extending between the end plates and having shafts journaled therein, means defining compression side inlet and outlet ports as well as expansion side inlet and outlet ports, a heat exchanger interposed between the compression side outlet port and expansion side inlet port, the rotor having a plurality of rigid outwardly biased vanes extending axially between the end plates and retreatingly angled with respect to the direction of rotation of the rotor, the vanes having a rounded tongue along the inner edge engaging respective mounting grooves axially formed in the periphery of the rotor for relative rocking movement, each vane having rollers in the outer corner positions for rolling against the outer wall of the chamber to establish running clearance of the vane, and with the vane being notched out at the corners to accommodate the rollers, each vane having a sealing member in the form of an enlargement along its outer edge, the enlargement having a curved profile, as viewed axially, which follows the periphery of the rollers thereby to maintain the same degree of running clearance over a large angle of tilt of the vane, the rotor having axially extending grooves for registering with and receiving the sealing members and having recesses at the ends of the grooves for registering with and receiving the rollers thereby to minimize the residual volume between adjacent vanes at the minimum volume points in the rotative cycle.

21. The combination as claimed in claim **3** in which the anti-friction means at the outer edges of the vanes are in the form of projections on the vanes riding in engagement with channels formed in the end plates for maintaining a small running clearance between the outer edges of the vanes and the outer wall of the chamber, the vanes retreatingly retreatting angled with respect to the direction of rotation of the rotor.

22. In a compressor-expander for use in air conditioning, the combination comprising a housing defining a chamber of oval cross section having a compression side and an expansion side and enclosed by end plates, a cylindrical rotor extending between the end plates, a cylindrical rotor extending between the end plates and having shafts journaled therein, means defining compression side inlet and outlet ports, as well as expansion side inlet and outlet ports, a heat exchanger interposed between the compression side outlet port and the expansion side inlet port, the rotor having a plurality of axially extending vanes hinged to the periphery of the rotor and extending between the end plates, and means including projections on the ends of the vanes riding in tracks formed in the end plates for holding the vanes inwardly into a condition of running clearance with respect to the wall of the housing as the rotor rotates and for holding the vanes outwardly to maintain the vanes in sealing engagement with the wall of the rotor notwithstanding the pressure of the air confined between the vanes so that a charge of air drawn between adjacent vanes at the compression side intake port when the rotor is rotated (1) is compressed, (2) flows at substantially constant pressure through the heat exchanger for subtracting the heat of compression and the (3) expands on the expansion side for discharge in the cold state.

23. The combination as claimed in claim **22** in which the vanes are provided along their outer edges with respective pins which extend axially beyond the vane a short distance in each direction, the ends of the pins being received in respective oval channels formed in the end plates and which correspond to the oval shape of the chamber.

* * * * *