Jan. 22, 1946. J. R. ROEBUCK 2,393,338

THERMODYNAMIC PROCESS AND APPARATUS

Filed March 13, 1941 2 Sheets-Sheet 1

Fig.1.

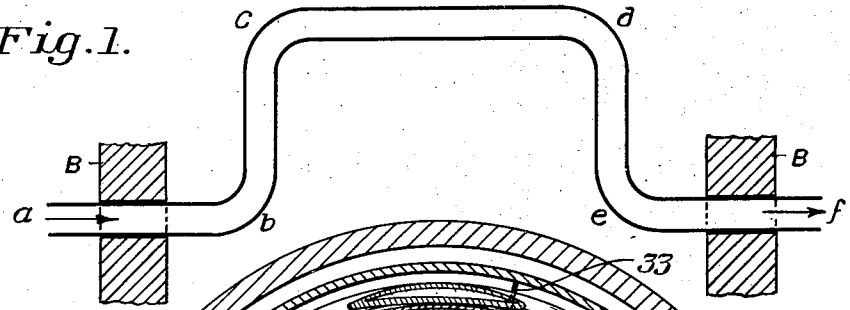


Fig.3.

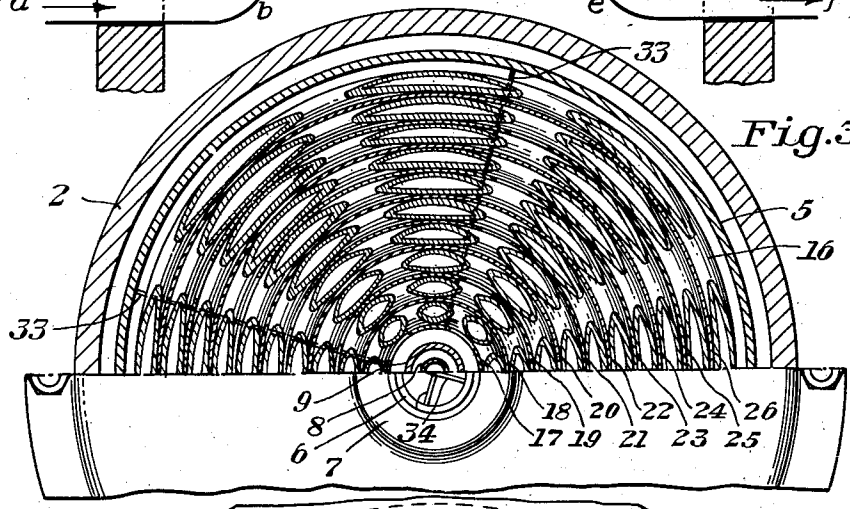


Fig.4.

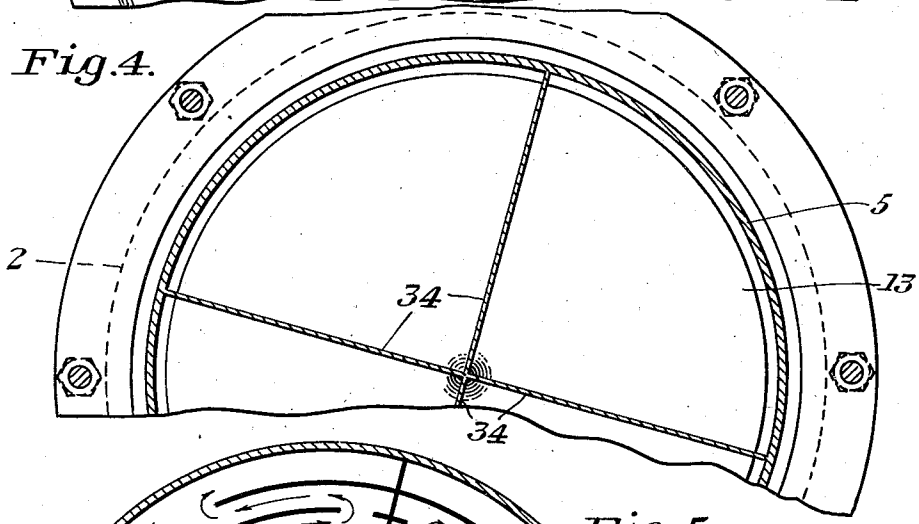
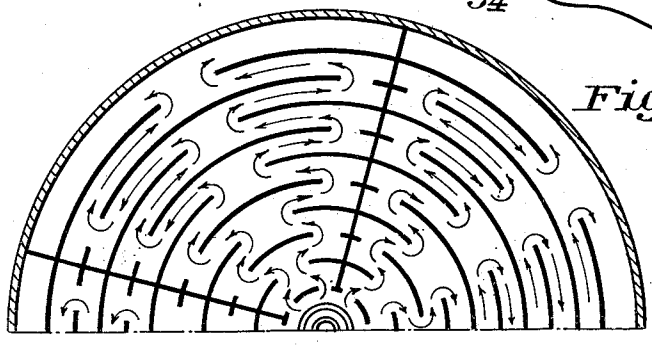


Fig.5.



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THERMODYNAMIC PROCESS AND APPARATUS

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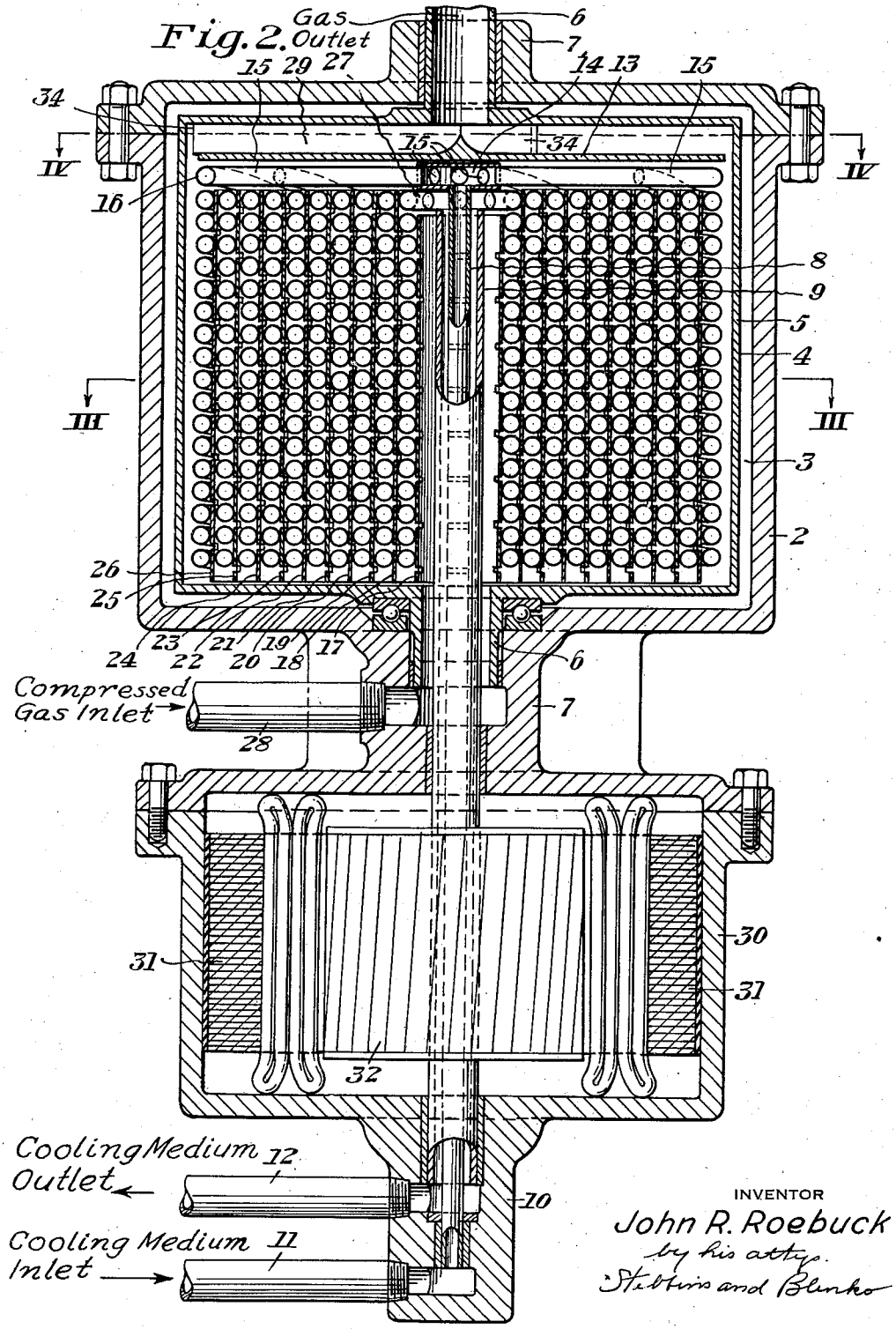
Fig. 2.



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UNITED STATES PATENT OFFICE

2,393,338

THERMODYNAMIC PROCESS AND APPARATUS

John R. Roebuck, Madison, Wis.

Application March 13, 1941, Serial No. 383,146

22 Claims. (Cl. 62—176)

This invention relates to a thermodynamic process and apparatus and more particularly to a process and apparatus wherein work is transformed into heat energy or vice versa. The invention in certain present preferred forms may be embodied in either a heater or a refrigerator and a single apparatus may be employed for both heating and refrigeration. The invention effects heat transfer at high efficiency and consequently at low cost.

The invention will be described as embodied in a refrigeration process and apparatus in which a flowing gas is subjected to centrifugal action and thereby compressed, after which the compressed gas is expanded with attendant cooling. Preferably the gas being compressed by centrifugal action is subjected to a cooling medium so that the compressed gas is at a temperature lower than the temperature which it would otherwise attain. The cooling effect may be sufficient to bring about substantially isothermal compression, which is desirable for most efficient results. When the thus compressed gas is expanded relatively low temperatures can be obtained.

Preferably the gas serving as the refrigerant in a refrigeration apparatus flows or is recirculated through the apparatus, being centrifugally compressed while heat is abstracted therefrom and then being expanded and passing through the cooling coil. The gas itself may serve as the ultimate refrigerant or it may be used to cool brine or other refrigerating medium. I preferably employ a rotor through which the gas passes to be centrifugally compressed and cooled and from which the expanded relatively cold gas is delivered. The cooling medium in the rotor is preferably circulated therein during operation of the rotor and I provide apparatus for carrying out the operation with high efficiency.

Other details, objects and advantages of the invention will become apparent as the following description of a present preferred embodiment of the invention and a present preferred method of practicing the same proceeds.

In the accompanying drawings I have shown a present preferred embodiment of the invention and have illustrated in present preferred method of practicing the same, in which:

Figure 1 is a diagram to aid in explaining the principle of operation;

Figure 2 is a cross-sectional view of apparatus for carrying out the invention, the section being taken axially therethrough;

Figure 3 is a view partly in end elevation and partly in transverse cross section, the section being taken on the line III—III of Figure 2;

Figure 4 is a transverse cross-sectional view t ken on the line IV—IV of Figure 2; and

Figure 5 is a diagram indicating the manner in which the gas flows through the apparatus.

Referring now more particularly to the drawings and referring first to the diagram Figure 1, there is shown in such figure a bent tube *abcdef* provided with bearings B on *ab* and *ef*, the tube intermediate the bearings being of generally U form at *bcde*. Let it be assumed that the tube may be rotated very rapidly in the bearings B. Let a moderate flow of air be introduced at *a*. As the air passes along *bc* outwardly from the axis *ab*—*ef* it will be subjected to a centrifugal force toward *c* which compresses the air along *bc* and in *cd* to a pressure above that in *ab* and raises its temperature. As this compressed warmer air moves back toward the axis along *de* it is progressively relieved of the centrifugal force and expands back to its former pressure and temperature by the time it enters *ef*.

Now put in *bc* and, if needed, somewhat into *cd* a coil of pipe supplied with a cooling liquid by inlet and exit tubes along *ab* and which is circulated through the coil. Now as the gas is compressed along *bc* at least a portion of the heat of compression will be absorbed by the cooling liquid and carried away. Assume that the cooling effect is sufficient to maintain the temperature of the gas during compression substantially constant. In such case the compressed gas approaches *d* with approximately the same temperature as it had at *b* and prior to compression and as it expands adiabatically along *de* the temperature of the gas is considerably reduced. The temperature drop will depend on the ratio of the pressures at *d* and *e* and the character of the gas used. Under favorable circumstances a temperature drop of about 175° C. may be obtained.

The gas along *de*, being colder at corresponding points than the gas along *cb*, will be denser also. Thus under flowing conditions the pressure gradient along *de* will be greater than that along *bc* produced by the centrifugal force and hence for flow to be maintained the pressure of the gas at entry at *a* must be sufficiently greater than the pressure at *f* to overcome this opposing pressure and also to overcome the friction of the gas in the tube. The mechanical energy provided by this raised pressure at *a* is also that required by the second law of thermodynamics for the lifting of the heat from the temperature of the

discharge gas to that of the liquid absorbing the heat of compression.

The mechanical system just explained comprises a compressor with a current abstraction of compressional heat in *bc* and an adiabatic expansion engine in *de*. The compressor and expansion engine are directly coupled mechanically. In a steady running state every gas particle in moving from *b* to *c* acquires substantial kinetic energy due to the high circumferential velocity Along *cd* this kinetic energy does not change. As the gas particle moves back toward the axis along *de* it loses this energy to the tube. Since the number of particles in unit time moving out across any cross section in *bc* must be exactly equal to the number moving in across any cross section in *de* the steady flow of the gas makes no major demands on the rotary energy of the tube. If ω is the angular velocity of *bc* and *de* and *bc* equals *de* equals *r*, then the work done by the rotor in compressing a unit mass of gas in *bc* is $\frac{1}{2}\omega^2r^2$. Since this work is the product of the force and the displacement along *bc* and the force is identical point for point as along *ed* the work extracted by the rotor from unit mass of gas along *de* is also $\frac{1}{2}\omega^2r^2$. As a first approximation the drop in temperature along *de* is given by

$$\frac{\omega^2r^2}{2C_pJ}$$

where C_p is the mean specific heat of the gas in heat units.

The process above described is close to thermodynamically reversible. If with all the conditions of pressure, temperature and flow in the steady state described above the pressure supplied at *a* is alone decreased a little the flow of gas will reverse, going now from *f* towards *a*, abstracting heat from the liquid flow and delivering the gas at *a* with a pressure raised over that at *f* and thus converting some heat into mechanical work. If now with a suitable supply of gas at *f* to maintain the reversed flow the fluid entry temperature be raised a little the flow will be accelerated so that the pressure previously at *a* may be restored and the flow remain reversed. Thus by manipulation of the pressure (work) and temperature (heat) variables the process may be run in either direction with relatively small changes.

The cooling liquid is also compressed and expanded as it moves out to the periphery and back again. The temperature of most liquids rises on compression but by only a small fraction of that experienced by gas. Since liquid normally is much denser than gas it rises in pressure in the rotor much more than gas. If the liquid flow is so arranged that it does its heat absorbing as it returns toward the axis the returning liquid will be less dense than the outgoing liquid and thus will be driven around its circuit with very considerable pressure. The energy for this driving, as in ordinary convection flows, will be drawn from the heat energy causing the expansion making the return liquid less dense.

In Figures 2, 3 and 4 of the drawings I have shown more or less diagrammatically one form of apparatus which I term a rotor-cooler. There is provided a heavy stationary sectional metal casing 2. This casing is formed to provide a generally cylindrical chamber 3 within which a rotor designated generally by reference numeral 4 is adapted to be rotated at high speed. The rotor is contained within a jacket 5, which is of generally cylindrical shape with axial trunnion-like hollow projections 6 at its opposite ends. These trunnion-like projections 6 are disposed within bearing portions 7 of the casing 2. The jacket 5 is made of exceptionally strong material, as, for example, chrome-nickel steel, and is adapted to rotate with moderate clearance in the casing 2. The casing 2 allows the rotor to be run in a vacuum and serves as a guard against flying parts in the event of failure.

There are provided two coaxial pipes, an inner pipe 8 and an outer pipe 9, which extend into the rotor axially from one end thereof. The cooling medium is adapted to enter through the pipe 8 and to leave outside the pipe 8 but within the pipe 9. The casing 2 has an extension 10 provided with a connection 11 to the pipe 8 and a connection 12 to the pipe 9. The pipe 8 passes axially into the packet 5 and extends therethrough for the greater portion of the length of the jacket. Mounted in the jacket and extending transversely of the axis of the rotor is a baffle 13. The baffle may be attached to the jacket 5 by brackets (not shown) fastened to the interior of the jacket and to the baffle. The baffle is preferably imperforate and of circular shape with its periphery spaced somewhat from the inner peripheral surface of the jacket as shown in Figure 2. The pipe 8 extends through the jacket 5 to a point immediately in front of the baffle 13 where it enters an inlet manifold 14. The manifold comprises a central hub or connecting portion into which the pipe 8 extends and a plurality, for example, eight, of radially outwardly extending pipes 15. The pipes 15 are equally spaced circumferentially of the manifold. Each of the pipes 15 extends straight out parallel to the baffle 13 substantially to the periphery of the baffle where it merges into a coil 16 which extends about the axis of the rotor and also progresses longitudinally of such axis from top to bottom viewing Figure 2. Thus there are actually as many individual coils as pipes 15 extending spirally within the jacket 5 and interfitting with one another.

Disposed within the jacket 5 and suitably supported therein as, for example, by brackets connected with the jacket and by spacers, is a plurality of coaxial perforate metal cylinders. In Figures 2 and 3 these cylinders are designated, respectively, by reference numerals 17 to 26, inclusive, starting with the inside cylinder and progressing outwardly. The perforations in the cylinders are preferably narrow slots running circumferentially for short angular distances and are staggered as shown in Figure 2. They serve as baffles for directing the gas flow in contact with the coils and they also assist in positioning and spacing the coils. The outer wrap of each coil is wound about the cylinder 26 from top to bottom viewing Figure 2. Adjacent the bottom of the jacket 5 each coil then passes inwardly and is wrapped from bottom to top viewing Figure 2 about the cylinder 25 and within the cylinder 26. Thus the coils progress gradually back and forth along the axis of the jacket 5 and also toward such axis. Each of the coils enters an outlet manifold 27 similar to the inlet manifold 15 except that provision is made for passage through the manifold 27 of the pipe 8. Connected with the manifold 27 to receive the outflowing cooling medium and also disposed about the pipe 8 as above described is the pipe 9. Thus the cooling medium enters through the connection 11, passes upwardly viewing Figure 2 through the pipe 8 to the manifold 14, thence through the pipes 15 and

the coils 16 and into the manifold 27 and out through the pipe 9 and the connection 12.

The casing 2 is provided with a gas inlet 28 communicating with the interior of the lower projection 6 of the jacket 5 viewing Figure 2. Gas enters through the inlet 28 and the lower hollow projection 6 and thence passes outwardly among the coils 16 through the perforations in the cylinders 17 to 26, inclusive. The diagram Figure 5 indicates how the gas flows outwardly through the perforations in the cylinders 17 to 26, inclusive, and among the coils. Figure 3 is partly in cross section on the line III—III of Figure 2 and does not show clearly the path of the gas because of the fact that the coils are inclined to the axis of the rotor. Radial septa 33 which extend longitudinally of the axis of the rotor are provided to assist in distributing gas circumferentially of the rotor and insure that the gas will always move around with the same angular speed as the rotor. Four such septa are preferably employed, although the number may be increased or decreased. The gas finally passes through all of the cylinders and reaches the inner peripheral surface of the jacket 5 whence it passes along such surface upwardly viewing Figure 2 past the edge of the baffle 13 and thence inwardly toward the axis of the rotor through a passage 29 within which are four radial septa 34 and out axially of the rotor and upwardly viewing Figure 2 through the upper hollow projection 6 of the jacket 5. During such passage the gas is cooled as above explained and the relatively cold gas passing out through the upper hollow projection 6 is used for refrigeration in any well known manner.

A means for driving the rotor is shown diagrammatically in Figure 2. The casing 2 has a cylindrical portion 30 which may be the casing of a high frequency induction motor, the field magnets of the stator of which are shown at 31 and the squirrel cage rotor of which is shown at 32. The motor is supplied with alternating current of sufficient frequency to drive it at high speed. The rotor 32 of the motor is fastened directly to the pipe 9 and upon operation of the motor the pipe 9 is turned thereby. Thus the pipe 9 serves as the driving shaft for the rotor. No attempt has been made to show structural details which may be employed to fasten together the various parts and provide sufficient strength to enable the device to operate satisfactorily at high speeds. If constructed as shown in the drawings the device will operate as described and in actual quantity production the parts will be designed and assembled in accordance with good engineering practice.

Instead of employing an induction motor for driving the rotor any other suitable driving means may be employed, as, for example, a synchronous single or multiple phase motor driven by high frequency alternating current or a de Lavel type air or steam turbine. The cooling fluid may be water, alcohol or other light mobile fluid.

As the gas moves outwardly within the rotor it is guided by the perforate cylinders and septa so as to flow parallel to the coils in each layer for short angular distances before advancing to the next outer layer. If these angular distances be kept alike the linear distances through which the gas moves increase with the radius. Since the work done in compressing the gas along the radius increases proportionately with the radius the heat to be transferred per unit area of tube remains the same. Since the gas density increases with radius the gas velocity past the adjacent metal parts decreases in successive layers toward the periphery. Moreover, the huge artificial gravity field greatly exaggerates convective movement in the gas. Thus any small mass of gas cooled by contact with the coils becomes thereby denser than its neighboring gas and moves violently outwardly. The cooling surfaces of the coils are thus swept by movement of the surface gas layer and the heat exchange is greatly accelerated. Thus both the mass contact of the gas and its convective movement combine to make the heat exchange very effective.

For the same gas the cooling obtained is a function of ωr, that is of the linear peripheral velocity. So long as ωr is kept unchanged the diameter and length of the rotor may be determined by the amount of gas to be passed through it. The cooling could also be obtained by using several jets arranged symmetrically about the periphery to discharge the gas tangentially in the opposite direction to the linear peripheral velocity, so driving the rotor and cooling the gas. Such jets do not have 100% efficiency and the expansion of the gas as above explained is preferred.

For particular purposes any gas having appropriate properties may be passed through my rotor cooler to obtain a particular temperature drop. Any liquid adapted to the pressure and temperature situation involved may be used as the cooling medium. The cooling may be used for any purpose for which cooling is needed or desirable.

A rotor may be built within the strength of available materials to (1) use argon to go from temperatures readily and cheaply available with ice machines (minus 40° C.) to nearly the boiling temperature of liquid air or nitrogen or to the boiling temperature of liquid oxygen, (2) use neon to go from the nitrogen boiling point to the neon boiling point, (3) use helium to go from the neon boiling point to the hydrogen boiling point and (4) use helium to go from the hydrogen boiling point to the helium boiling point. Thus it is possible to use my refrigeration process and apparatus for the cooling and air conditioning of buildings, the cooling of refrigerators, the production of ice, the recovery by cooling of vapors as casing head gasolene and laundry cleaning fluids, the cooling of reaction vessels in chemical work, the cooling of gases for their ultimate liquefaction and many similar uses.

It is possible to use the heat delivered by a refrigeration machine for the heating of buildings. When coal is burned under the best conditions in a modern power plant the work resulting if supplied to an effective refrigeration machine will allow of raising a much larger quantity of heat than that coming from the burning of coal over the small temperature rise needed for heating buildings. Since liquid water is normally available in quantity the year round in modern communities the heat of freezing delivered at the freezing temperature provides an effective source of heat, from which temperature it has to be raised somewhat above the desired building temperature. Since my rotor cooler is perhaps the most efficient refrigerator available it is very effective for heating buildings by using the heat delivered by a refrigeration machine.

For the purpose of heat delivery the rotor heater is preferably arranged somewhat differently from the rotor cooler. The gas should be compressed adiabatically (instead of nearly isothermally) and the resultant higher temperature heat will be exchanged with the liquid flow only near the periphery of the rotor, with the liquid

flow so adjusted that as nearly as possible it exchanges temperatures with the hot gas. The gas after adiabatic expansion may be used to freeze water to restore the heat content to the gas. Cold outdoor air could be used for its heat supply and the complication in the use of the water avoided with the accompanying loss of power efficiency.

While I have shown and described a present preferred embodiment of the invention and a present preferred method of practicing the same it is to be distinctly understood that the invention is not limited thereto but may be otherwise variously embodied and practiced within the scope of the following claims.

I claim:

1. Thermodynamic apparatus comprising a rotor, means for rotating the rotor, means for guiding a flowing gas generally axially into the rotor during rotation of the rotor, thence generally away from the axis of the rotor, thereafter generally toward the axis of the rotor and thence generally axially out of the rotor at the end of the rotor opposite that at which the gas entered and means rotating with the rotor for guiding a flowing thermoconductive substance generally axially into the rotor during rotation of the rotor and while within the rotor in thermoconductive relationship with the flowing gas and thence generally axially out of the rotor at the same end thereof as that at which the thermoconductive substance entered the rotor.

2. Refrigeration apparatus comprising a rotor, a baffle within the rotor extending transversely of the axis thereof, means for guiding a gas generally axially into said rotor, around the edge of said baffle and thence generally axially out of said rotor at the end thereof opposite the end at which said gas entered and cooling means with which said gas is adapted to contact within said rotor at the side of the baffle facing toward the end of the rotor at which said gas entered.

3. Thermodynamic apparatus comprising a rotatable enclosure, a conduit within the enclosure rotating therewith and having an inlet and an outlet extending from the enclosure generally along its axis so that a thermoconductive substance can be circulated in the conduit during rotation of the enclosure, means for guiding a flowing gas into, within and out of the enclosure during rotation of the enclosure and while within the enclosure in thermoconductive relationship with said conduit and means for rotating the enclosure at such very high speed as to substantially compress the gas by centrifugal action.

4. A refrigeration process comprising circulating a coolant in a sinuous conduit disposed within and rotating with a rapidly rotating rotor and simultaneously flowing a gas through said rotor while first guiding the gas generally away from the axis of the rotor in thermoconductive relationship with the outside of said sinuous conduit and thereafter guiding the gas back toward the axis of the rotor while out of thermoconductive relationship with the outside of said sinuous conduit.

5. A thermodynamic process comprising flowing into, within and out of a rotating enclosure a gas and a cooling liquid, guiding the gas while within the enclosure generally away from the axis of the enclosure and substantially compressing it and thereafter guiding the gas while within the enclosure generally toward the axis of the enclosure, delivering the gas from the enclosure in a direction generally parallel to the axis of the enclosure and guiding the cooling liquid while within the enclosure in thermoconductive relationship with the gas.

6. A thermodynamic process comprising flowing into, within and out of a rotating enclosure a gas and a cooling liquid, guiding the gas while within the enclosure generally away from the axis of the enclosure and substantially compressing it and thereafter guiding the gas while within the enclosure generally toward the axis of the enclosure and guiding the cooling liquid while within the enclosure in thermoconductive relationship with the gas.

7. Thermodynamic apparatus comprising a rotor, means for rotating the rotor, a conduit within the rotor rotating therewith and having an inlet and an outlet extending from the rotor generally along its axis so that a thermoconductive substance can be circulated in the conduit during rotation of the rotor, means for guiding a flowing gas into the rotor during rotation of the rotor, means for guiding the gas within the rotor in thermoconductive relationship with said conduit but segregated from said thermoconductive substance, the gas being compressed while within the rotor by centrifugal action due to rotation of the rotor, and means for delivering the gas from the rotor when the gas is at or adjacent the axis of the rotor.

8. Thermodynamic apparatus comprising a rotating enclosure and means therein rotating with the enclosure for guiding separately two flowing substances and connections with said means for guiding said substances into and out of the enclosure during rotation of the enclosure, said connections comprising generally axial passages at opposite ends of the enclosure and annular passages surrounding at least one of said generally axial passages.

9. A thermodynamic process comprising subjecting a gas flow to centrifugal force while (1) guiding the flow generally radially away from the axis of revolution, during which the radially increasing centrifugal force substantially compresses the flow, tending to heat it, and (2) guiding the flow radially toward the axis of revolution, during which the radially decreasing centrifugal force allows the flow to expand, tending to cool it, and conducting a liquid flow to absorb the heat of compression in thermoconductive relationship but out of contact with the gas flow during the compressional movement of the gas away from the axis.

10. A refrigeration process comprising subjecting flowing gas to centrifugal action while (1) guiding the gas generally away from the axis of centrifugal action, during which the progressively increasing centrifugal action substantially compresses the gas, tending to heat it, and (2) guiding the gas generally toward the axis of centrifugal action, during which the progressively decreasing centrifugal action allows the gas to expand, tending to cool it, and conducting a liquid coolant in thermoconductive relationship with the flowing gas where the gas is being guided generally away from the axis of centrifugal action during the subjecting of the gas to centrifugal action.

11. A refrigeration process comprising subjecting flowing gas to centrifugal action while (1) guiding the gas generally away from the axis of centrifugal action, during which the progressively increasing centrifugal action substantially compresses the gas, tending to heat it, and (2) guiding the gas generally toward the axis of cen-

trifugal action during which the progressively decreasing centrifugal action allows the gas to expand, tending to cool it, and extracting heat from the gas by a liquid coolant where it is being guided generally away from the axis of centrifugal action.

12. A refrigeration process comprising subjecting flowing gas to centrifugal action while (1) guiding the gas generally away from the axis of centrifugal action, during which the progressively increasing centrifugal action substantially compresses the gas, tending to heat it, and (2) guiding the gas generally toward the axis of centrifugal action, during which the progressively decreasing centrifugal action allows the gas to expand, tending to cool it, and extracting heat from the gas by a liquid coolant where it is being guided generally away from the axis of centrifugal action to such an extent as to maintain the temperature of the gas generally the same when it reaches the point most remote from the axis of centrifugal action as prior to being guided generally away from the axis of centrifugal action.

13. A refrigeration process comprising subjecting flowing gas to centrifugal action while (1) guiding the gas generally away from the axis of centrifugal action, during which the progressively increasing centrifugal action substantially compresses the gas, tending to heat it, and (2) guiding the gas generally toward the axis of centrifugal action, during which the progressively decreasing centrifugal action allows the gas to expand, tending to cool it, and circulating a liquid coolant in a conduit in thermoconductive relationship with the gas and thereby extracting heat from the gas during the subjection of the gas to centrifugal action and prior to said expansion and cooling thereof.

14. A refrigeration process comprising subjecting a gas in a conduit to a pressure difference to cause it to flow in said conduit, while the gas is thus flowing in said conduit subjecting it to centrifugal compression while guiding it generally away from the centrifugal axis, the progressively increasing centrifugal action substantially compressing the gas, while thus guiding the gas bringing it into thermoconductive relationship but not into contact with a heat extracting liquid so that the heat of compression of the gas is at least largely carried away by the liquid whereby the temperature of the gas is maintained approximately constant and thereafter guiding the gas generally toward the centrifugal axis, during which the progressively decreasing centrifugal action allows the gas to expand, tending to cool it, and delivering the gas adjacent the centrifugal axis.

15. A thermodynamic process comprising flowing into, within and out of a rotating rotor and rotating therewith a working substance consisting entirely of gas and which throughout the process remains entirely in gaseous form and a thermoconductive substance, guiding the gas while within the rotor successively (1) generally away from the axis of the rotor and (2) generally toward the axis of the rotor, guiding the thermoconductive substance in thermoconductive relationship but out of contact with the gas where the gas is being guided within the rotor in one direction only relatively to the axis of the rotor.

16. A refrigeration process comprising flowing into, within and out of a rotating rotor a gas and a coolant, guiding the gas while within the rotor successively (1) generally away from the axis of the rotor and (2) generally toward the axis of the rotor, and guiding the coolant in thermoconductive relationship with the gas only where the gas is being guided within the rotor generally away from the axis of the rotor.

17. Thermodynamic apparatus comprising a rotor, means for rotating the rotor, a conduit within and rotating with the rotor and having an inlet and an outlet extending from the rotor generally along its axis so that a thermoconductive substance can be circulated in the conduit during rotation of the rotor and means for guiding a flowing gas into, within and out of the rotor during rotation of the rotor and while within the rotor successively (1) generally in a direction away from the axis of the rotor and (2) generally in a direction toward the axis of the rotor and while moving in one only of said directions in thermoconductive relationship with said conduit.

18. Thermodynamic apparatus comprising a rotor, means for rotating the rotor, a coil within and rotating with the rotor and having an inlet and an outlet extending from the rotor generally along its axis so that a thermoconductive substance can be circulated in the coil during rotation of the rotor and means for guiding a flowing gas into, within and out of the rotor during rotation of the rotor and while within the rotor successively (1) generally in a direction away from the axis of the rotor and (2) generally in a direction toward the axis of the rotor and while moving in one only of said directions passing successively about the convolutions of said coil.

19. Thermodynamic apparatus comprising a rotor, means for rotating the rotor, means for guiding a flowing gas into, within and out of the rotor during rotation of the rotor and while within the rotor successively (1) generally away from the axis of the rotor and (2) generally toward the axis of the rotor, means for delivering the gas from the rotor when the gas is at or adjacent the axis of the rotor and means for guiding a flowing thermoconductive substance into, within and out of the rotor during rotation of the rotor and while within the rotor in thermoconductive relationship with the flowing gas while the gas is being guided generally away from the axis of the rotor but not while the gas is being guided generally toward the axis of the rotor and for rotating said thermoconductive substance with the rotor, said means for guiding the flowing thermoconductive substance guiding such substance out of the rotor generally along the axis of the rotor.

20. Refrigeration apparatus comprising a rotatable enclosure, means for rotating the enclosure, a conduit within the enclosure and having an inlet and an outlet extending from the enclosure generally along its axis so that a coolant can be circulated in the conduit during rotation of the enclosure and means rotating with the enclosure for guiding a flowing gas into, within and out of the enclosure during rotation of the enclosure and while within the enclosure successively (1) generally away from the axis of the enclosure and in thermoconductive relationship with said conduit and (2) generally toward the axis of the enclosure.

21. Thermodynamic apparatus comprising a rotor, a baffle within the rotor extending transversely of the axis thereof, means for guiding a fluid generally axially into said rotor substantially at the axis of the rotor, around the edge of said baffle and thence generally axially out of said rotor at the end thereof opposite the

end at which said fluid entered and a heat transfer conduit with which said fluid is adapted to contact within said rotor at one side of said baffle.

22. A thermodynamic process comprising subjecting a gas to centrifugal action in a rotating enclosure and thereby compressing the gas, simultaneously with said compressing passing a coolant in thermoconductive relationship with the gas to maintain the gas at substantially constant temperature, removing the gas from thermoconductive relationship with the coolant and after such removal of the gas expanding and thereby cooling the gas.

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