June 13, 1950 A. BRAMLEY 2,511,691

CENTRIFUGAL DEHYDRATING AND COOLING SYSTEM

Filed Dec. 5, 1945 2 Sheets-Sheet 1

Fig. 1.

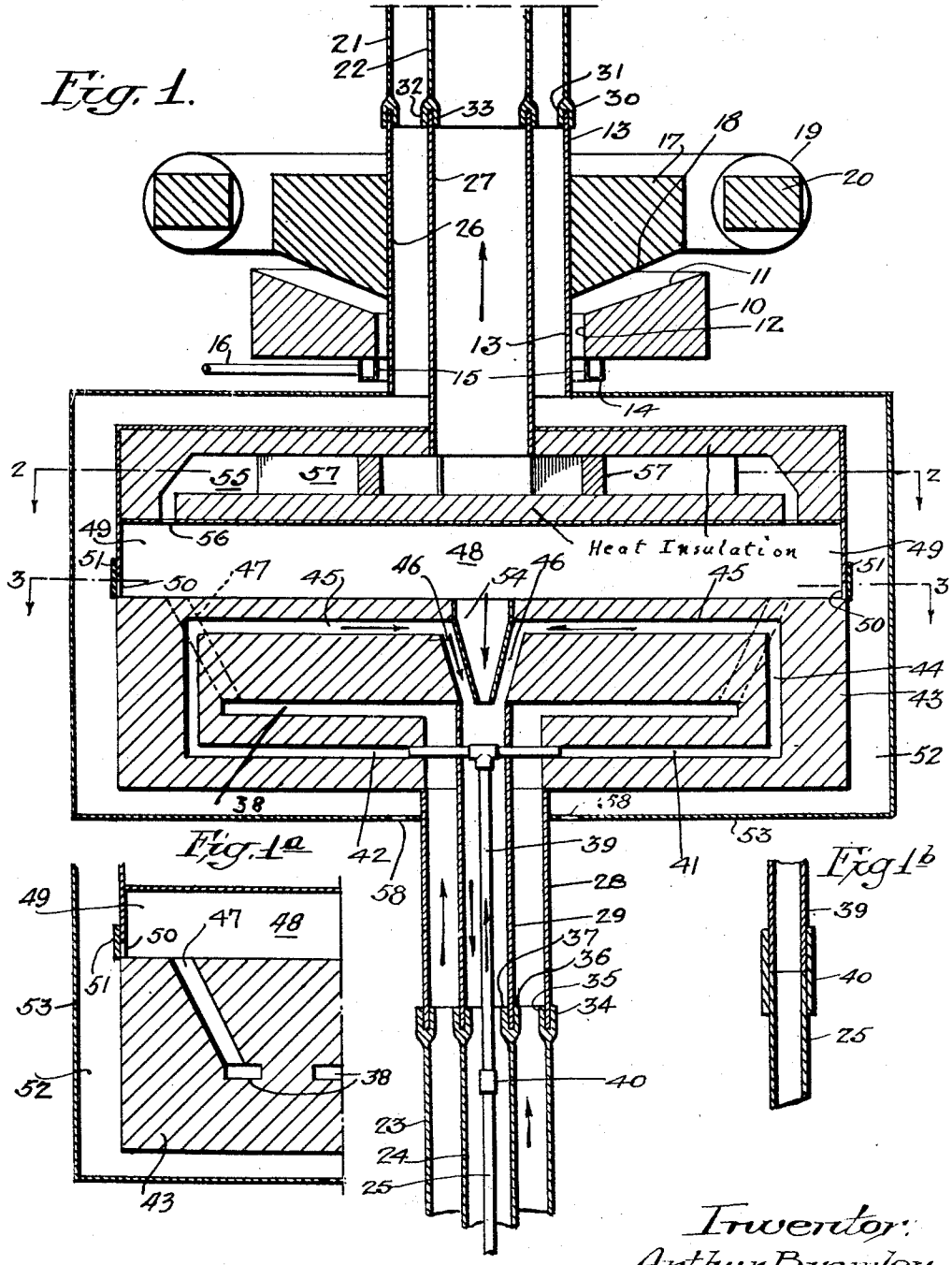


Fig. 1a

Fig. 1b

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Filed Dec. 5, 1945 2 Sheets-Sheet 2

Fig. 2.

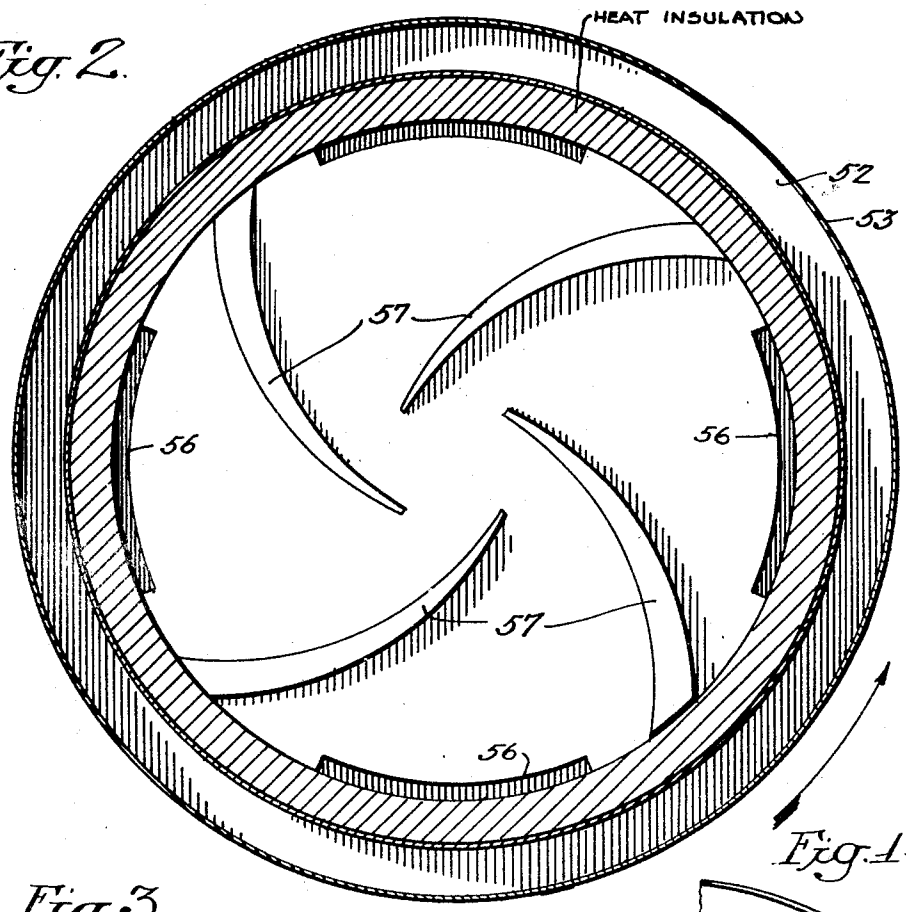


Fig. 1c

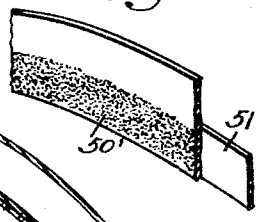


Fig. 3.

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2,511,691

CENTRIFUGAL DEHYDRATING AND COOLING SYSTEM

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Application December 5, 1945, Serial No. 632,825

10 Claims. (Cl. 62—137)

1

The present invention relates to processes and apparatus for cooling and purifying refrigerants, and particularly for cooling, purifying and dehumidifying air.

A purpose of the invention is to cool air by expansion as it enters a centrifugal cell to a point where it no longer can carry in suspension the quantity of water vapor which it previously contained, to force water collected from the excess water vapor content out to the periphery of the centrifuge and to withdraw the water collected through a port at the periphery.

A further purpose is to cause a fluid to expand bodily inwardly along the radius of a centrifuge while under the influence of a centrifugal force so that the adiabatic expansion of the fluid incident to its flow will cause a reduction in temperature.

A further purpose is to extract energy from the fluid and convert the energy of the fluid into mechanical energy of rotation by turbine-like baffles as the fluid flows from a radially outer to a radially inner position.

A further purpose is to refrigerate by adiabatic expansion of a fluid as it flows from a radially outer to a radially inner position in the annular passage or passages of a centrifuging rotor.

A further purpose is centrifugally to localize water vapor in air, to pump off a portion of air which is saturated with water vapor and to cool the air which remains by adiabatically expanding it toward the axis of a centrifuge against centrifugal force.

A further purpose is to use in the centrifuge cell radially outer orifices of such dimensions and orientation with respect to the direction of rotation that they function as ports, preferably covering them by a band when they are not in use.

A further purpose is to locate cooling passages in the distribution head of a centrifuge and thus to obtain a better isothermal flow of fluid.

In the dehumidifying of air, a further purpose is to withdraw moisture which is present in the air in liquid phase by centrifuging it to the outer part of the body of air being treated and then centrifugally forcing the water out through a port.

A further purpose is centrifugally to localize moisture which has been present in vapor phase in a body of air treated and then to withdraw the air containing the localized moisture vapor from a point at which it is localized.

A further purpose is to enhance the efficiency of a cooling and treating system for gases or

2

vapors by forcing the gas or vapor through an artificially cooled distribution head at a pressure above atmospheric pressure so as to improve the contact of the gas or vapor with the head and therefore improve the metal to gas or metal to vapor thermal conductivity.

A further purpose is to increase the pressure of a gas or vapor which is to be expanded for cooling purposes and therefore greatly increase the cooling benefit to be obtained by the expansion.

A further purpose is to introduce gas or vapor into an expansion chamber at such a low temperature that the rate of cooling is enhanced when the gas or vapor is expanded radially inwardly through a guided path.

A further purpose is to improve the efficiency of a cooling system using air as a refrigerant by greatly increasing the pressure of the air at the intake to get better cooling efficiency, thereby increasing the pressure at the exhaust of the cooled air, so as to give higher thermal conduction in the chamber cooled.

A further purpose is to cool air containing moisture to a point where it no longer will retain the same amount of moisture, to centrifuge the suspended water to the periphery of the centrifuge cell, while by the same centrifuging some moisture which is retained is localized near the axis of the centrifuge in a portion of the air having increased percentage of moisture content, to withdraw the water from the periphery and the air having increased moisture concentration from the axis of the centrifuge and to cool the dehydrated air remaining by adiabatic expansion from the outer part toward the center of the centrifuge against centrifugal force.

A further purpose is to introduce the gas or vapor, which is to be expanded for cooling purposes, into the rotor through an inlet near the axis of rotation at such a low temperature and high pressure of 5–30 atmospheres that the rate of cooling is enhanced when the gas or vapor is expanded radially inward through a guided passage. To obtain optimum efficiency, the temperature and pressure should be so chosen that the virial coefficients in the equation of state would be negative.

Further purposes appear in the specification and in the claims.

Reference is made to my application for Method of centrifuging and centrifuge, Serial No. 464,509, filed November 4, 1942, now Patent 2,422,882, issued June 24, 1947. See particularly columns 7 and 8 for the driving mechanism, and columns 1, 7 and 13 as to cooling mechanism.

Certain refrigeration, dehydration and liquefaction aspects of the present invention are included in my continuation in part application, Serial No. 706,739, filed October 30, 1946, for Dehydrating, liquefying or cooling gas and air. This case is a continuation in part of my application Serial No. 417,960, filed November 5, 1941, now abandoned, for Centrifuge and method.

In the drawings one only of the possible embodiments of the invention has been illustrated. The drawings have been chosen from the standpoint of convenience in illustration and satisfactory explanation of the principles involved.

Figure 1 is a diagrammatic central vertical section of a rotor embodying the invention.

Figure 1[a] is a fragmentary section corresponding to a part of Figure 1 but taken through an air passage, whereas Figure 1 is taken between the passages.

Figure 1[b] is a fragmentary section of a pipe coupling seen in Figure 1.

Figure 1[c] is a fragmentary side elevation of an outer wall of the centrifuging cell showing capillary openings instead of the ports in Figure 3.

Figure 2 is a horizontal section of the rotor of Figure 1 taken along the line 2—2.

Figure 3 is a fragmentary section upon line 3—3 in Figure 1.

The section upon line 1[a]—1[a] in Figure 3 is shown in Figure 1[a].

In the drawings like designations, such as letters and numerals, refer to like parts.

The present invention is directed particularly to the dehumidifying, purifying and cooling of air. The invention can be applied to other fluids (i. e. gases or vapors or mixtures thereof) which are suitable as refrigerants.

In diagrammatic Figure 1, I illustrate a supporting ring 10 of phenol-formaldehyde plastic (Bakelite) or other suitable material dished at 11 and having suitable clearance at 12 from the wall of the outer centrifuge supporting tube 13. The ring 10 is mounted on stationary structure not shown. An annular jet 14 mounted on the lower surface of the ring 10, and having orifices 15, introduces air in the space within and above the ring 10. Air is supplied to the annular jet 14 by a tube 16. Co-operating with the ring 10 is a tapered upper metallic ring 17 suitably fastened to the supporting tube 13 of the centrifuge. The lower conical surface 18 of the ring 17 co-operates with the upper surface 11 of the ring 10 and the air film between these two surfaces supports the centrifuge in operation.

The ring 17 is desirably the rotor of an induction motor whose field winding 19 and field core 20 are shown. The field winding 19 and core 20 are mounted on suitable supporting structure, not shown.

The mechanism just described is intended to be any conventional means of rotating and supporting a centrifuge. It represents a power plant and support of any suitable centrifuge which is to be rotated by it.

The device may suitably be fluid (air) supported and air driven, steam driven or electrically driven in accordance with the proposals of Beams et al. See article by Skarstrom and Beams, Review of Scientific Instruments, volume 11, page 298 (December 1940); and article by Beams and Snoddy, Science, volume 85, page 185 (1937). It will be evident that in the driving means will be required only to the extent that the reaction from the gas issuing from the passages 47 and through the blades 57 is insufficient to rotate the device.

The structure which is rotated together as a unit is included in Figure 1 as extending from but not including stationary coaxial pipes or ducts 21 and 22 at the top down to but not including stationary coaxial pipes or ducts 23 and 24 and pipe 25 at the bottom.

Whatever the type of motor used, it should be adapted to obtain a centrifugal force of the magnitude of at least two thousand times gravity. The number of revolutions per second may therefore be two hundred or five hundred. The rotor in the main will be made of any suitable alloy such as stainless steel.

The invention is primarily applied in cleansing and refrigerating air and in distributing the air to areas of intended use. Since the refrigeration effected is much more effective at increased air pressures, it is intended that a differential between the pressures of raw air intake and of discharging refrigerated air be secured either by introducing raw air under pressure to the centrifuging unit or by withdrawing air at reduced pressure from the discharge of the centrifuging unit or as indicated in Figure 1 by both of these methods. Raw air may be cooled within the rotary unit or may be cooled in advance of introduction to this unit or by a combination of these means.

In purification of the air, the start is made with a normal air product, which for the lack of a better term, will be called "raw" air. The air has an indefinite quantity of moisture in vapor phase.

As a result of its difference in specific gravity from the air, the water vapor, being only about two-thirds of the weight per volume of the lighter component of the air, will consequently be concentrated at or close to the axis of rotation.

In the present invention it is intended not only to keep the raw air cool while centrifuging to get rid of water in liquid phase but to crowd the water vapor into a zone near the axis and to withdraw the water as water at the periphery and the water vapor with whatever oxygen and nitrogen and in whatever proportion from this inner zone. The heavier constituents of the centrifuging are taken out of this first cell of the centrifuge into a second cell which is an integral part of the unit; i. e. rotates at the same speed and about the same axis, i. e., the dehydrated air is withdrawn from one centrifuge chamber to another through ports near the periphery.

Within the first chamber and during the centrifuging, the constant travel of the air outwardly toward the periphery will tend to heat up the air. From the periphery the ports will carry it into another chamber without change in the heating content since it will travel from the periphery of one to the periphery of the other. In the later cell of the unit we have dehydrated air largely. The air is then led from the outer periphery of the later cell toward the center either by the pressure from the first cell or by suction from the ultimate chamber into which it is being led, or a combination of these two.

The rotor carries coaxial ducts 26 and 27 which are upwardly directed and which correspond in size and position with the fixed ducts 21 and 22. The rotor also carries downwardly directed coaxial ducts 28 and 29 which are of the same size and position and correspond therefore with the lower fixed ducts 23 and 24. One or other of the pairs of ducts at the upper end and also at the

lower end carries couplings adapted effectively to seal with the mating ducts by means of flanges 30 and 31, 32 and 33, shown as carried by the fixed ducts above, and 34, 35, 36 and 37 rigid with the lower and upwardly directed fixed ducts in Figure 1. These flanges seal effectively against leakage at the high rate of speed intended.

In Figures 1 and 1b are shown fixed and rotatable pipes 25, 39 for a cooling liquid, along with a sleeve coupling 40 united to the lower pipe and embracing the upper pipe so as to permit the upper pipe to rotate with respect to the lower pipe while supplying cooling water to passages 41, 42 within a distributing head 43. The passages are shown as upwardly directed at 44 and thence transversely turned at 45 so as to discharge at 46 down into the inner of the two ducts. This cooled distributing head is used to prevent increase of temperature of the raw air introduced through pipe 23. It is needed because the passage 38 provides for expansion outwardly of the air before it is delivered through passage 47 into the centrifuging compartment 48 which it enters near the periphery.

In the passages 38 and 47 the air is forced to the periphery and expanded as it flows outwardly, cooling the air and eliminating evaporation of moisture, preferably further condensing the moisture. The passages 38 will in one embodiment be spiral channels which conduct the air isothermally to the periphery.

Since the air introduced into the distributing head has been cooled before entry, some of the water vapor in the air will have been condensed into water in the liquid phase and this will be thrown outwardly at the periphery into the space 49, from which this water can be drained by opening ports 50 closed by a movable band 51. This affords a means of getting rid at intervals of the water in liquid phase which will be thrown out into a space 52 between the body of the centrifuge and an enclosing shell 53.

Microporous porcelain with an average of a billion pores per square inch, bonded onto a metal backing perforated with fine holes or ports is another suitable medium for permitting the passage of water or liquid while constituting an air seal.

In many applications to refrigerants the enclosing shell 53 should be a heat insulator, its main purpose being to maintain the rotor as near the temperature of the distributing head as possible and thus minimize the amount of cooling required for the distributing head.

To provide for excess water thrown out through the ports 50, above that which will evaporate within the shell 53, openings 58 are provided for drainage which takes place when the centrifugal unit is stopped. Instead of the ports 50, capillary passages 50' may be provided as shown in Figure 1c, used with or without the valve band 51.

Instead of discharging the moisture in liquid phase through the ports 50 or through the capillary passages at 50', the centrifuge unit may be stopped, permitting all of the water accumulated to drain through the passage 54 and the ducts 29 and 24.

The porous walls were mentioned in Patent No. 2,422,882 previously referred to and may be fabricated in various ways. One way is by spraying or plating low temperature metals or alloys upon rubber molds spiked with a network of fibers or very fine wires which may be dissolved out of the plated material to leave pores of the desired diameter.

When the device is used as a refrigerator rather than as an air conditioning unit there is no discharge of fluids from a position near the axis of rotation of the centrifuge cell. Referring to Figure 1, this means that the exhaust ports 54 will be closed.

The water vapor and lighter air constituents are withdrawn in an axial zone by an exhaust 54 through duct 24.

The heavier constituents of the air which were delivered to the centrifugal cell 48 at the start remain in the outer part of the cell except as they pass on to the second centrifugal cell, the expansion cell 55 through port 56.

The centrifugal action which keeps the heavier fraction out near the periphery crowds out to this position the dehydrated heavier constituents of the air from within the cell 48, so that as the heavier constituents crowd more and more to the outer part of this centrifuge cell, the lighter constituents and the water vapor are crowded toward the axis, from which point they are ultimately discharged through the passage 54.

Centrifuging would itself set up a definite pressure near the periphery and to this pressure is added the initial pressure applied to the air at its time of insertion into the rotor. Its transfer through the ports 56 does not make any change in the temperature as the transmission at this point is at the same diameter as had been occupied by the denser air fraction previously. However, the air is discharged adiabatically inwardly toward the center with resultant cooling or refrigerating effect.

As the dehydrated air, somewhat overcharged with oxygen, is driven from its position under some pressure near the periphery of the centrifuging cell and discharged through ports 56 into the expansion cell, it is met by centrifugal pressure in a reverse direction. Turbine-like blades or vanes 57 tend to force the air outwardly but do allow passage inwardly between the blades and the wall through which the discharge may become effective. The movement of the blades prevents the air from lagging circumferentially in its motion in the cell and requires that the air perform work.

The progress of the discharging air through the compartment 55 is due in part to the pressure at which the raw air enters the centrifuge unit—where this pressure is used—in part to the concentration of the heavier dehumidified constituents and in part to vacuum conditions at the discharge if a vacuum be applied there. The fact that work is required of the discharging air reduces the temperature.

The parts cross-hatched in Figures 1 and 2 are heat insulation.

From Figure 3 it will be evident that the discharge of the inlet air into the earlier of the two centrifuging compartments is close to the periphery and that the cooling function of the distribution head is effective to keep cool the air which is cool before its admission but which is being led outwardly radially and therefore has a tendency to heat.

It will be evident that the blades, extending the full height of the later centrifuge unit or cell have a direction of rotation such that they tend to have a pumping action in a direction reverse to the discharge and tend to back up the content toward the ports as if they were parts of a centrifugal pump, the pumping action of the blades further eliminating condensed material by backing it up toward the ports 50. The blades tend

to act as guides for the discharging air and to prevent it from whirling.

But for the blades there would be a tendency to have succeeding swirls of decreasing generating radius, each succeeding loop of a spiral lying within the next outer loop as in an Archimedes spiral. Without the blades there would be a very high angular relative speed close to the discharge ports. The blades have two important functions. They reduce the speed of these whirls, that is, reduce the angular speed of the radially inwardly moving dehydrated air and they cause increased speed of the unit. They keep the air at the same angular speed near the axis as the centrifuge, preventing excess speed of the interior convolutions of the spiral as they approach the axis. This reduces turbulence.

It will be evident that the cooling depended upon for air conditioning or other purposes to which the final discharge is applied is secured by a combination of initial cooling of the raw air, maintenance of the low temperature by the cooling of the distributing head, concentration of the dehydrated heavier constituents of the air at a pressure in part attained by the initial pressure of introduction and finally adiabatic discharge of the air radially toward the center.

It will be evident that the perforations at the periphery for the discharge of moisture in liquid phase may not only be relatively large holes or capillary openings but may be of fine grill size if desired.

It will be evident that the cooling cell will be of the same general character whether the purpose be to cool and purify air which itself is used in air conditioning or for a refrigerant use to handle a gas or vapor other than air which is used as a refrigerant fluid and is not mixed with the air of a room.

It will be evident that where a blade is used, engagement of the fluid cooled with the turbine blades tends to rotate the centrifuge and for this reason the motor used need not be as large as would otherwise be required.

It will be evident that the blade action in the present case and the blade action in my Patent 2,422,882 are closely similar and that this is true notwithstanding the slight difference in the gases handled and in the ultimate purpose attained.

It will be evident that the separation of the water from the raw air is attained in part by cooling the air to a point where it will no longer carry the water which it previously contained so that a considerable part of the water can be centrifuged out in liquid phase to and away from the periphery and crowding the lighter constituents in toward the center where in vapor phase they may be removed along with the lighter constituents, that is, air enriched with nitrogen.

In operation, it will be evident that air introduced at the axis, and containing moisture, is conducted radially outwardly through passages 38 and 47. The passages will expand the air, converting part of its heat content to velocity, and cooling the air. The net effect will be either isothermal flow of the air to the periphery, preventing vaporization of moisture, or actual reduction in temperature, condensing more moisture. The air when it enters the centrifuging cell, will have liquid moisture thrown off at the periphery. The dehydrated air will be conducted into the expansion cell, where it is further cooled while flowing inwardly between the blades, the energy of the gas being converted into energy of the rotor.

It will be evident that the cooling effect of the cooled distribution head may be that required merely to provide for isothermic passage of the raw air from the axis to the periphery or may be sufficient desirably to further reduce the temperature of the raw air.

It will be further evident that the guiding effect of the turbine blades will reduce turbulence in the air or gas handled and will thus greatly lessen heat transfer conditions in the expansion cell.

It will be evident that there is an advantage in carrying the raw air out to the periphery of the rotor while maintaining it within the distributing head so that it will be introduced within the centrifuge cell at or near the periphery of that cell.

It will be evident that the quantity of moisture in the air will affect slightly the rate at which the raw air can be handled since all of the raw air must pass through the distributing head notwithstanding that the discharge after purification is confined almost wholly to an oxygen-enriched, purified air product.

It will be evident that my combination of centrifuging and cooling cells is highly beneficial whether it handle air which has or has not previous been cleansed and use it for air conditioning or handle a refrigerant fluid not intended to be mingled with air nor useful for air conditioning.

Having thus described my invention what I claim as new and desire to secure by Letters Patent is:

1. Steps in the method of air conditioning using a centrifuge unit having axial inlet and outlet, a distributing head, a centrifuging cell and an expansion cell, which comprise supplying raw air having moisture content to the unit at pressures above atmospheric pressure, expanding the raw air away from the axis of the unit and thereby cooling in the distributing head, supplying this cooled air to the centrifuging cell near the periphery, concentrating the heavier constituents of the air near the periphery and the lighter constituents near the axis of the centrifuging cell, removing moisture in liquid phase from the heavier constituents at the periphery and moisture in vapor phase along with the lighter constituents at the axis of the centrifuging cell, transferring the heavier constituents in the air to the expansion cell and expanding the heavier constituents radially inwardly to discharge near the axis.

2. Steps in the method of air conditioning using a centrifuge unit having axial inlet and outlet, a distributing head, a centrifuging cell and an expansion cell, which comprise supplying raw air having moisture content to the unit at pressures above atmospheric pressure, forcing the raw air away from the axis of the unit through the distributing head toward the periphery of the centrifuging cell while expanding the raw air and thereby cooling, concentrating the air near the periphery, removing moisture in liquid phase from the air at the periphery, transferring the air to the expansion cell and expanding the air radially inwardly to discharge near the axis.

3. Steps in the method of air conditioning using a centrifuge unit having axial inlet and outlet, a distributing head, a centrifuging cell and an expansion cell, which comprise supplying raw air having moisture content to the unit at pressures above atmospheric pressure, expanding the raw air away from the axis of the centrifuge unit and thereby cooling in the distributing head, supplying this cooled air at high density at the periphery to the centrifuging cell, concentrating

the air in the centrifuging cell near the periphery, removing moisture in liquid phase from the air at the periphery, transferring the air to the expansion cell and expanding the air radially inwardly to discharge near the axis.

4. In a centrifuge unit having a distributing head, an intermediate centrifuging cell and an expansion cell, a hollow shaft having air inlet and air discharge, rotating with the centrifuge unit, means consisting of walls in the distributing head for expanding the air and guiding it outwardly to the periphery of the centrifuging cell, discharge connections from the centrifuging cell near the axis to the air discharge, outlet connections for water at the periphery of the centrifuging cell adapted to allow outlet of water, passages for conducting the heavier fraction of the air from the periphery of the centrifuging cell to the periphery of the expansion cell and blades in the expansion cell inclined with respect to the radius and against which the compressed heavier fraction of the air expands axially toward the axis adiabatically.

5. In a centrifuge unit having a distributing head, an intermediate centrifuging cell and an expansion cell, a hollow shaft having air inlet, rotating with the centrifuge unit, means consisting of walls in the distributing head for expanding the air and guiding it outwardly to the periphery of the centrifuging cell, outlet connections for water at the periphery of the centrifuging cell, adapted to allow outlet of water, passages conducting the air from the periphery of the centrifuging cell to the periphery of the expansion cell, and blades in the expansion cell inclined with respect to the radius and against which air expands axially toward the axis adiabatically.

6. A centrifuge including a rotor having a distributing head, a centrifuging cell and an expansion cell, and containing air of high density at the periphery of the two cells, a hollow rotor shaft upon which the rotor is mounted, spiral channel means for introducing air into the head through the shaft and for conducting it isothermally to the periphery of the centrifuging cell, axially located means for discharging a lighter fraction of the air from the centrifuging cell, means for conducting a heavier fraction of the air from the periphery of the centrifuging cell to the periphery of the expansion cell, means circumferentially spaced around the periphery of the rotor for eliminating condensed water vapor from the rotor and blades within the path of fluid flow through the expansion cell for utilizing the work done by the expansion of the air through reaction against the blades.

7. A centrifuge including a rotor having a distributing head, a centrifuging cell and an expansion cell, containing air of high density at the periphery of the two cells, a hollow rotor shaft upon which the rotor is mounted, spiral channel means for introducing air into the head through the shaft and for conducting it isothermally to

the periphery of the centrifuging cell, means for conducting air from the periphery of the centrifuging cell to the periphery of the expansion cell, means circumferentially spaced around the periphery of the rotor for eliminating condensed water vapor from the rotor and blades within the path of fluid flow through the expansion cell for utilizing the work done by the expansion of the air through reaction against the blades.

8. A centrifuge including a distributing head, a centrifuging cell and an expansion cell, and having air of high density existing in the periphery of the centrifuging cell, a hollow shaft upon which the centrifuge is mounted, means for introducing air into the rotor through the shaft and for expanding it isothermally through the distributing head to the periphery of the centrifuging cell, channel walls for conducting the air from the periphery of the centrifuging cell to the periphery of the expansion cell, means at the periphery of the centrifuging cell for eliminating condensed water vapor and blade means for utilizing work done by the expansion of the air in the expansion cell.

9. In a centrifuge unit, including a distributing head, a centrifuging cell having an open interior space and an expansion cell, a shaft having an air inlet, expansion means comprising walls forming curved passages for the air inlet leading from the inner part of the distributing head outwardly to the periphery of said head for expanding flow with resulting temperature fall, and connecting passages between the air in the distributing head and the periphery of the centrifuging cell.

10. In a centrifuge unit, including a distributing head, a centrifuging cell having an open interior space and an expansion cell, a shaft having a gas inlet, expansion means comprising walls forming passages for the gas inlet leading from the inner part of the distribution head outwardly to the periphery of said head for expanding flow with resulting temperature fall, and means at the periphery of the centrifuging cell for eliminating condensed vapor.

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