Aug. 3, 1965 C. E. OVER 3,197,969

HEATING AND COOLING OF AIR FOR VENTILATING, WARMING AND REFRIGERATING PURPOSES

Filed Feb. 24, 1964 4 Sheets-Sheet 1

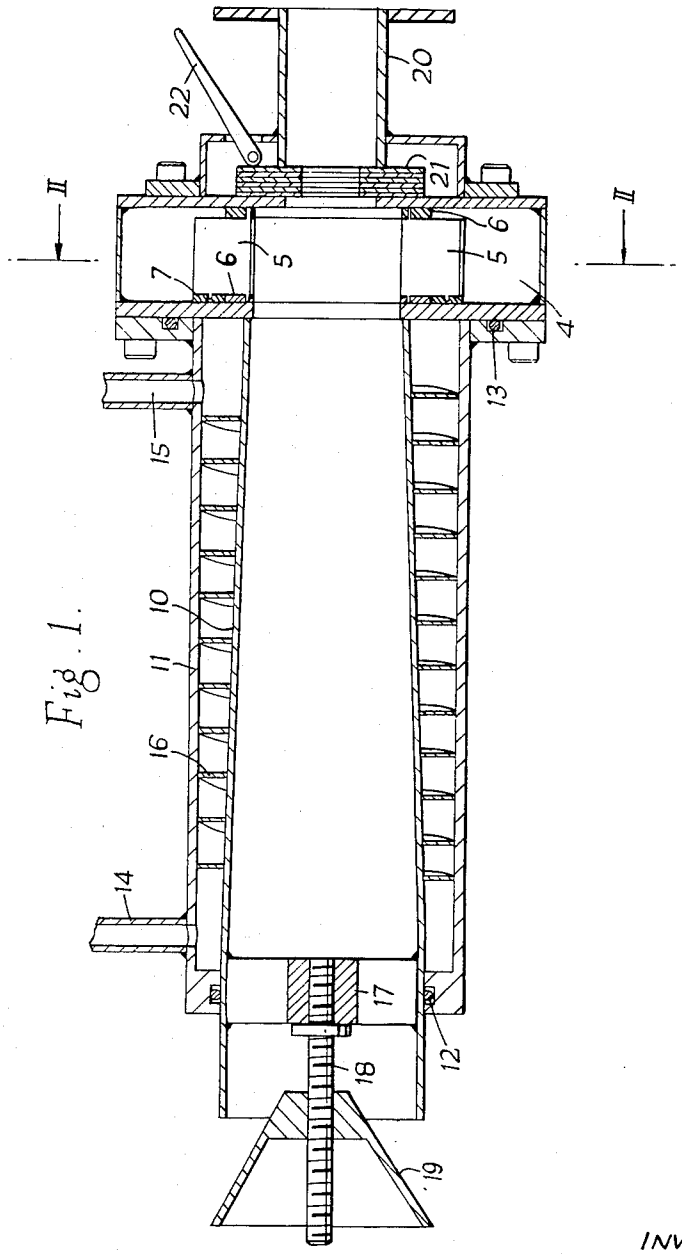


Fig. 1.

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Filed Feb. 24, 1964 4 Sheets-Sheet 2

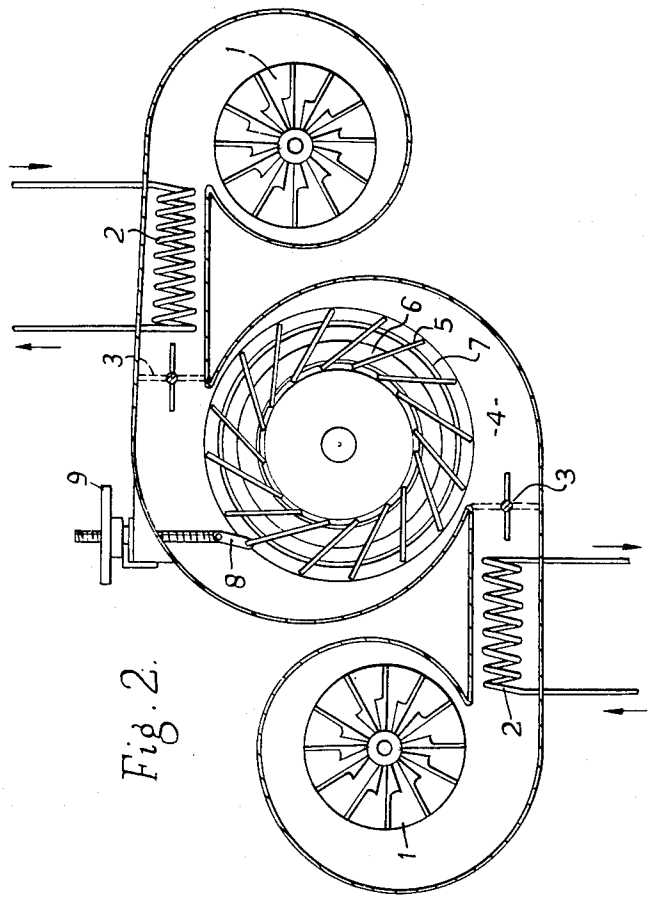


Fig. 2.

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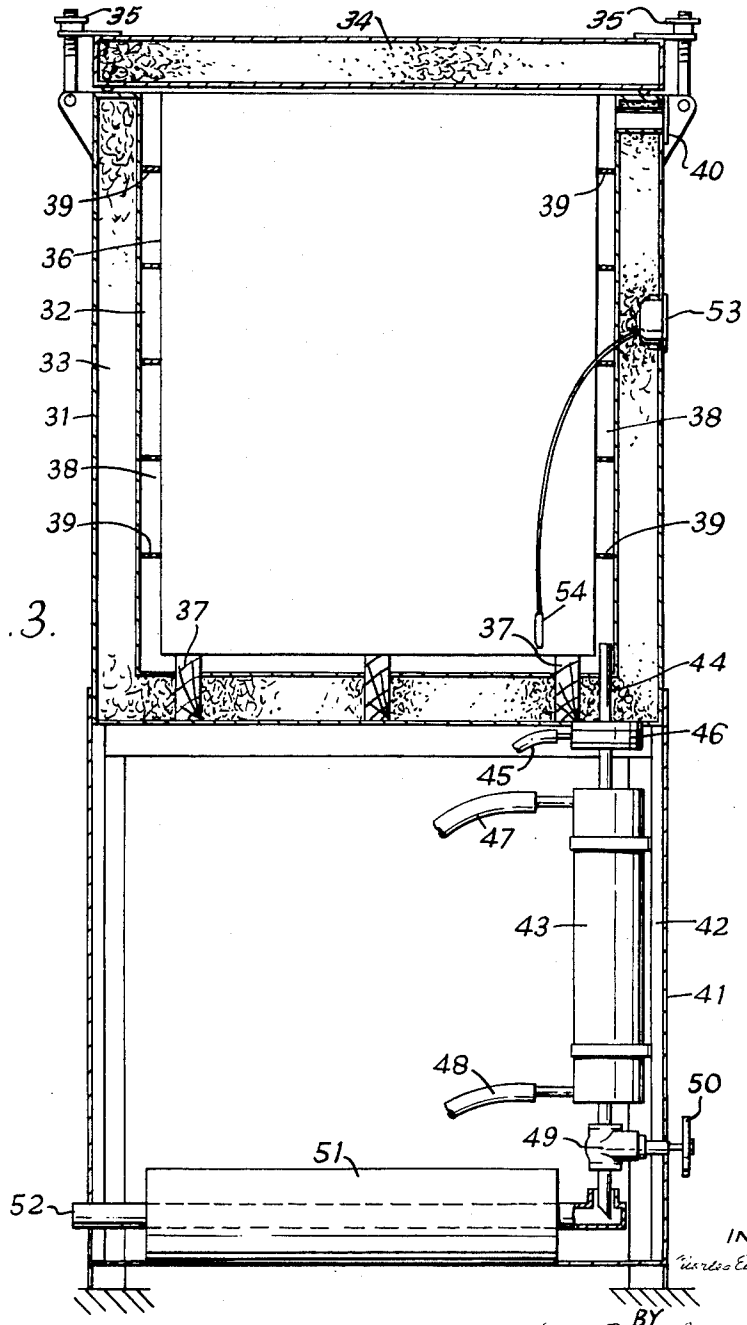
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Aug. 3, 1965 C. E. OVER 3,197,969

HEATING AND COOLING OF AIR FOR VENTILATING, WARMING AND REFRIGERATING PURPOSES

Filed Feb. 24, 1964 4 Sheets-Sheet 3

Fig. 3.



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Aug. 3, 1965 C. E. OVER 3,197,969
HEATING AND COOLING OF AIR FOR VENTILATING, WARMING AND REFRIGERATING PURPOSES
Filed Feb. 24, 1964 4 Sheets-Sheet 4

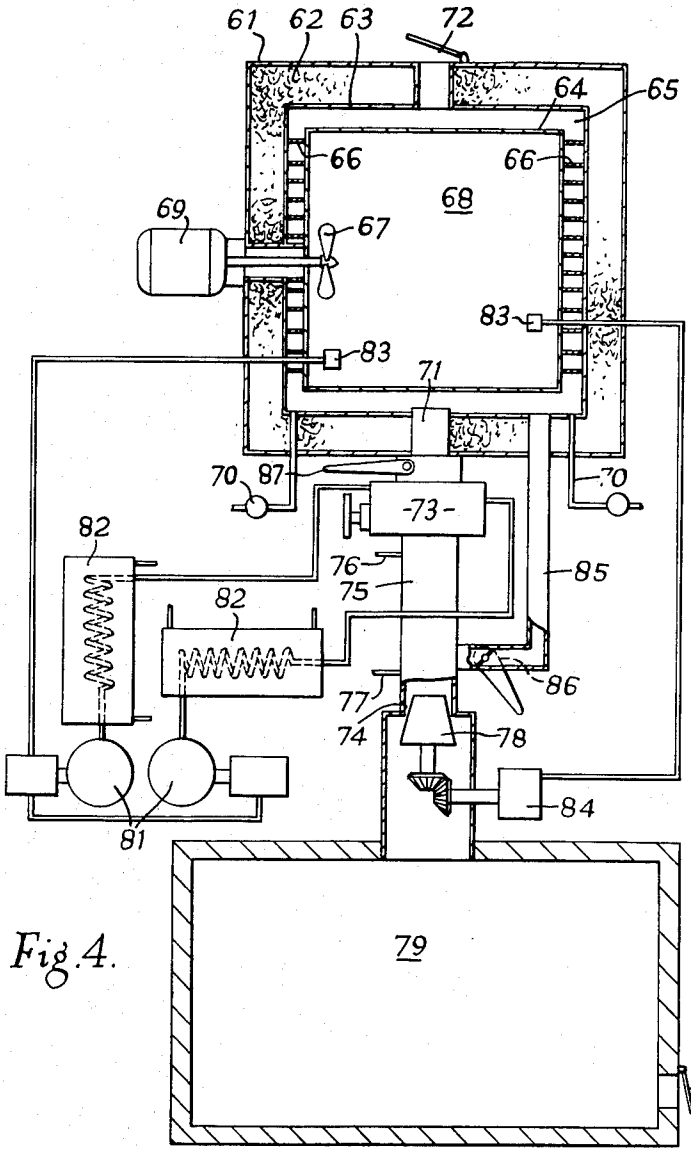


Fig. 4.

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3,197,969

HEATING AND COOLING OF AIR FOR VENTILATING, WARMING AND REFRIGERATING PURPOSES

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13 Claims. (Cl. 62—5)

The present invention relates to improvements in and relating to the heating and cooling of air for ventilating, warming and refrigerating purposes, and is concerned with air heating and cooling apparatus of the kind in which air is used as the working fluid.

Space-cooling refrigerators using air as the working fluid have been known for more than a century, but they have become obsolete due to their bulk, complication and thermodynamically inferior performance as compared with vapour compression refrigerators.

Nevertheless, an apparatus in which air is used as the working fluid has certain important advantages. For example, air is a chemically safe working fluid and costs nothing and there is no need in such an apparatus to have any moving parts other than a fan or compressor.

The operation of the present invention depends upon a phenomenon which has been observed in connection with inward radial flow turbines, namely that the temperature of the air in the center of a centrifugal field is less than that at the periphery thereof.

It is believed that the cause of this phenomenon may be described in general terms as follows:

If a stream of air (or other gas) is injected tangentially into a cyclone or volute, a centrifugal field or vortex will be established within the casing. The layer of air at the periphery will be retarded by friction with the walls of the casing. These molecules of air, being subject to the rules of centrifugal fields, will tend to move towards the center of the vortex.

The fast-moving molecules just inside the peripheral layer transfer some of their energy to this layer by bombarding some of its slower-moving molecules and speeding them up. The net result of this process is the accumulation of slow-moving low-energy particles at the center of the cyclone or volute and of fast-moving high-energy particles at the periphery.

In the thermodynamics of gases, the terms "high-energy" and "high-velocity" denote high temperature and "low-energy" and "slow-moving" denote low temperature. Consequently, there exists in such a cyclone or volute, a rotating core of relatively cold air surrounded by a rotating belt or rim of relatively hot air.

The references in the preceding paragraph to "hot air" and "cool air" are to be intepreted as referring to heating or cooling of the air by as little as 1° or 2° F. or as much as 100° F., depending upon the choice of dimensions and pressure variables in the apparatus under consideration.

In the improved apparatus according to this invention at least one compressor or blower is arranged to discharge air in a substantially tangential direction into a volute chamber containing a ring of guide vanes arranged to deflect air from the vortex formed in the circumferential region of the volute chamber into a central region thereof within the guide vane ring, a cold air outlet opening of considerably smaller diameter than the inner diameter of the guide vane ring is formed centrally in one end wall of the volute chamber and a warm air outlet opening of substantially the same diameter as the inner diameter of the guide vane ring is formed centrally in the other end wall of the volute chamber.

Preferably two compressors or blowers are arranged to

deliver compressed air into the volute chamber through tangential inlets on opposite sides respectively of its circumference. The greater the temperature difference required between the air discharged through the cold air and warm air outlet openings and the ambient temperature, the higher must be the pressure of the air delivered to the volute chamber by the compressors or blowers. For a high pressure difference, up to a limit of 100 lb. per square inch, it will be necessary to use reciprocating compressors, rotary sliding-vane blowers or Rootes blowers. Where, however, a large volumetric flow is required with a smaller temperature difference, centrifugal compressors or fan type blowers delivering air at pressures of, for example, from 2 to 10 lb. per square inch may be used.

The air under pressure from the or each compressor or blower is advantageously passed through a heat exchanger before entering the volute chamber, whereby the heat of compression is removed from it, either by water cooling or by fan cooling.

The guide vanes of the guide vane ring are preferably inclined so that the air passing between them is given a tangential component of motion relative to the inside circumference of the guide vane ring. Thus, for example, the angle between the air stream discharged from between any two adjoining guide vanes and a corresponding tangent to the inside circumference of the guide vane ring is preferably less than 20°. Consequently, a rotating vortex of air is formed within the guide vane ring.

In large installations, the guide vanes may be pivotally adjustable about their inner edges by means of a common control member, so that their angle of inclination can be varied simultaneously to suit various different working conditions.

The warm air outlet opening preferably opens into the inlet end of a warm air outlet pipe, the length of which is advantageously 25 to 30 times greater than the inner diameter of the guide vane ring. The bore of this warm air outlet pipe may, at its inlet end, be of the same diameter as the warm air outlet opening and the walls of this bore may taper outwardly in the direction towards its outlet end at an included angle of 5° to 8°.

The warm air outlet pipe may be water-cooled, for which purpose it may be surrounded by a water jacket with a helical partition to cause the cooling water to flow helically around the pipe from one end thereof to the other.

An adjustable throttling device is advantageously provided at the outlet end of the warm air outlet pipe, so that a variable back pressure can be imposed on the warm or hot air discharge. In small installations, this can be a sluice or butterfly valve, but in larger installations it should take the form of a variable aperture of the spear type which gives an annular orifice at the periphery of the outlet pipe.

The cold air outlet opening may also be fitted with an outlet pipe or duct. The most suitable diameter for this opening in relation to the diameter of the guide vane ring will vary widely, depending upon the inlet air pressure and other operating variables. In large installations, the diameter of this opening may therefore be made adjustable, e.g. by using an adjustable iris diaphragm.

As a general and approximate guide, it is found that the coldest air temperature is obtained when the fraction of cold air is about one third of the total quantity of inlet air, but appreciable and useful cooling effects are obtained with considerably higher proportions of cold air to hot air. This variation in the ratio of hot air to cold air is produced by altering the back pressure in the hot air outlet pipe and also the size of the aperture of the cold air outlet.

The variable apertures specified above enable these pro-

portions of cold air to hot or warm air to be varied to suit the prevailing ambient conditions. For example, if the apparatus is used for ventilating and air conditioning, a greater cold air discharge will be required in hot weather than in cooler weather, which will also necessitate additional blower power to augment the inlet air quantity, since to obtain a greater quantity of cold air at the cold end more hot air must be discharged at the hot end.

The air cooling and warming apparatus according to this invention may be utilized in ventilating and air conditioning installations. For this purpose, it may be located either outside or inside the space to be air-conditioned, but the air supply for the or each air compressor or blower is taken from outside this space. Thermostats situated in the space to be air conditioned are linked with suitable actuating devices in a temperature-responsive manner, to operate the throttle at the hot discharge end and possibly the variable orifice at the cold discharge end, in order to maintain the required temperature in the space.

In very hot weather, one or more additional compressors or blowers may be switched in to discharge into the vortex chamber for feeding through the guide vane ring, to compensate for the reduction in volume of cold air which would otherwise be produced by the necessity of diminishing the cold fraction to reduce its temperature. To accommodate this additional volumetric flow of inlet air, provision may be made for opening additional nozzle passages leading to the volute chamber.

In cold weather, on the other hand, when ventilation has to be combined with warming, means, including return ducts and flap valves, can be provided for discharging the hot air discharge into the space and the cold air discharge into the atmosphere. Since, at the optimum setting, the fraction of hot air discharged is about two thirds of the inlet air, the apparatus performs more efficiently under these conditions than as a cooler.

There are many other applications particularly suited to this apparatus in which one space requires to be cooled and another adjacent space simultaneously requires to be heated. In many industrial processes it is required to produce a heating effect in one part of the process and a simultaneously cooling effect in another part of the same process. By passing the hot and cold air discharges through separate heat exchangers this simultaneous heating and cooling can be achieved, thereby enabling the apparatus to be run at maximum efficiency.

The air cooling and warming apparatus according to this invention can also be employed for refrigeration purposes.

In domestic refrigerators and cold and cool rooms it is desirable to avoid direct contact between the air from the apparatus and the contents of the cold chamber, since the air from the apparatus will have passed through the compressors or blowers and may be contaminated with oil or atmospheric impurities.

The cold chamber, therefore, is preferably provided with an inner metal lining, leaving a circulation space around the outside of the lining between it and the inner wall of the chamber, which may vary from about half-an-inch in a domestic refrigerator to several inches in a cold room. One or both sides of the metal lining may be provided with extended surface fins to augment the heat transfer area. The inner chamber may, for cold and cool rooms, be provided with one or more circulating fans, so that the air in the inner chamber may be circulated against the inner surface of the metal lining to ensure maximum heat transfer for the air to the metal lining.

The air cooling apparatus is advantageously arranged so that the cold discharge is directed into the circulation space between the chamber walls and the inner lining, at the bottom. For a small chamber or domestic refrigerator, one cold air appaartus will be sufficient; for larger cold chambers more than one apparatus may be arranged to discharge into the bottom of the circulation space at equidistant discharge points. The outer walls of the chamber are insulated in the usual manner.

The cold air blown into the bottom of the circulation space displaces the warmer air situated there initially. The warmer air is allowed to escape from one or more points at the top of the circulation space through flap valves or lightly spring-loaded vents. The cold air may be caused to circulate in the space between the chamber walls and the inner lining by suitably disposed splitters or dividing plates, to cause the cold air to pass over the entire surface of the inner lining.

The sealed air in the inner chamber then gives up its heat, through the metal inner lining, to the cooler air in the circulation space. Hence as cold air is discharged from the apparatus into the bottom of the circulation space, an equal mass of warm air is discharged through the vents at the top of the circulation space.

One or more temperature-sensitive devices or thermostats have their sensing elements situated in the inner chamber. When the temperature in this chamber reaches the required lower value, the thermostat actuates a cut-out switch or other mechanism which stops the compressor or blower supplying air to the apparatus, or otherwise diverts the inlet air supply to the vortex chamber or opens a vent valve in the cold air supply pipe. Alternatively, the thermostatic control is arranged to regulate the variable apertures so as to reduce the cold air input to a level just sufficient to balance the heat leakage into the chamber.

The following is a practical example of the application of the present invention to a 12 cubic foot capacity domestic type refrigerator with an air supply at 80 lb. per sq. inch. This air was supplied to the vortex chamber of the apparatus through ⅛" diameter tangential nozzle. The hot and cold air pipes were ½" diameter and the cold air escaped from the vortex chamber through a 3/16" diameter opening, the throttle on the hot pipe being approximately ⅞ths shut. The cold air was discharged into a ½" wide circulating space between the metal inner lining and the chamber walls and allowed to escape from a ½" diameter flap valve at the top. Under these conditions, the chamber was cooled from 60° F. to 25° F. in 60 minutes.

The hot air discharge may be vented to atmosphere, but is preferably utilized for heating purposes. For example, in the case of a domestic type refrigerator, the hot air discharge may be used to heat an airing cupboard or to heat water. To obtain hot air temperatures suitable for heating water, the air supply to the vortex chamber will be of the order of 70 to 100 lb. per sq. inch, in which case temperatures of over 100° F. can be expected. In the case of high pressure air supply where the hot air is vented to atmosphere, a silencing device may be fitted to reduce the noise level.

In such refrigerating applications as those described above, the circulation space and the inner chamber may gradually become choked with frost and ice. Defrosting is accomplished with this apparatus by a series of flap valves, or other type of diverting device, whereby the cold air is shut off from the cold chamber and the hot air discharge, or a fraction of it, is directed into the circulation space. The hot air flow melts the frost and ice and the resulting water is removed through a drain valve or valves fitted at the bottom of the circulating space and inner chamber.

The invention will now be described by way of example with reference to the accompanying drawings, in which:

FIG. 1 is a longitudinal section through an apparatus for cooling and warming air,

FIG. 2 is a cross-section on the line II—II in FIG. 1,

FIG. 3 is a cross-section through a small domestic refrigerator or industrial cooling cabinet,

FIG. 4 is a diagram illustrating a large scale installation for cooling and heating adjacent chambers.

Referring more particularly to FIG. 2, air is compressed

by two rotary compressors 1 and is passed by pipes or ducting, through heat exchangers 2, in which the heat of compression is removed from it.

Leaving the heat exchangers 2, the air passes through buttterfly valves 3 and is then discharged into a volute 4. Although two compressors are shown discharging into the volute 4 in FIG. 1, any number of compressors from one upwards may be employed as the duty warrants. These compressors are capable of being started or stopped, or of having their speeds regulated separately.

The volute contains a ring of guide vanes 5 pivoted at their inner ends to end plates 6. The outer parts of the guide vanes 5 pass through slots in a ring 7, which can be caused to rotate by a link and screw mechanism 8, operated by a hand-wheel 9. When the hand-wheel 9 is rotated, the link 8 causes the ring 7 to rotate through a small arc and and the guide vanes 5, pivoting about their inner parts, with their outer edges sliding through the slots in the ring 7, are caused to alter their angle with respect to a tangent to the inside circumference of the vane ring. Consequently, the area and angle of incidence of the guide vanes can be altered.

In FIG. 1, a divergent pipe 10 is attached to one end of the vortex chamber 4, the angle of divergence being about 3½ degrees. The length of the divergent portion of the pipe 10 may be 25 to 30 times the the inner diameter of the guide vane ring. A water jacket 11 is fitted over the divergent pipe 10, forming water-tight joints with it at each end. In FIG. 1, these water-tight joints are formed by O ring seals 12 and 13. Inlet and outlet pipes 14 and 15 are fittted to the water jacket 11. A helical strip 16 may with advantage be wound around between the divergent pipe 10 and the water jacket 11 to ensure that the water effectively cools the outer surface of the divergent tube 10.

At the outer end of the divergent tube 10 is a spider having a central boss 17 into which a stud 18 is screwed. A cone 19 can be screwed along the stud 18 so that the annular area between the cone and the end of the tube can be varied in order to give a greater or smaller throttling effect on the warm air leaving the tube.

In FIG. 1, on the other end of the vortex chamber is bolted a parallel pipe or duct 20. The diameter of this duct is less than that of the inner diameter of the guide vane ring, but may vary between wide limits depending upon the air supply pressure and other operating characteristics of the particular system involved.

To allow for the alteration of this effective diameter, an adjustable aperture 21 of the iris type is fitted to the duct 20 adjacent to the vortex chamber 4. This adjustable aperture, which is preferably of circular or near-circular shape, can be adjusted in diameter by an operating lever 22.

An example of such a small apparatus will now be described with reference to FIG. 3.

In FIG. 3, an insulated container is constructed from an outer skin 31 and an inner skin 32 between which is sandwiched a thermal insulating material 33. A lid 34 of similar sandwich construction is attached to the top of the container by screwed fastenings 35.

Inside the inner skin 32 of the insulated container is an inner lining 36 of thin sheet metal, supported by blocks 37 so as to leave a circulating space 38 between the inner lining 36 and the inner skin 32. A series of baffles 39 attached to the inner lining 36 subdivide the circulating space 38 so as to form a labyrinth passage for cold air from the bottom to the top thereof. At the top of one side wall of the container is a non-return flap valve 40, opening outwards, through which air from the circulating space, under slight pressure, can escape to the atmosphere.

The insulated container is supported on a stand 41, provided with a sound-absorbing lining 42, to bring the container to a convenient height. A cooling apparatus 43, with its water jacket, is attached to the stand so that its cold air discharge pipe 44 passes through the sandwich construction wall of the container into the bottom of the circulating space 38.

Cooled air under pressure is supplied through an inlet pipe 45 to a vortex chamber 46, which may have a single tangential nozzle and fixed diameter orifices. The cold air generated in the vortex chamber passes into the circulating space 38 through the pipe 44 and circulates upwards around the baffles 39 and out of the non-return flap valve 40. The warmed air from the vortex chamber passes downward through the water jacket, which has inlet and outlet cooling-water connections 47 and 48, to a throttling valve 49 which may be a conventional gate or sluice valve, having a handwheel 50 which can be adjusted from outside the casing. The hot air outlet is led through a right-angled bend into a silencer 51 which may be of the conventional motor vehicle type and is finally discharged to atmosphere through an exhaust pipe 52.

It is assumed that, in this example, there is no use for the warm exhaust air. As described above this could have been passed through a heat exchanger instead of the exhaust silencer 51 and could have heated water or performed other heating duty. If required, arrangements can be made to return this hot air to the circulating space 38, through a system of shut-off valves, for defrosting purposes.

A dial thermometer 53 is fitted to any convenient part of the container, with its bulb 54 inside the container, to register the temperature therein. Alternatively, this temperature-sensitive element could be used to shut off the air supply when the required low temperature is attained.

In the large-scale installation illustrated in FIG. 4, the walls of a cold chamber are constructed conventionally with an outer skin 61, an intermediate layer of insulation 62 and an inner skin 63. An inner lining 64 is arranged within the inner skin 63 so as to provide a circulation space 65. The inner lining 64 is of thin sheet metal having baffles 66 attached to it in the circulation space 65 which define a circulatory path for the air passing from the bottom of this space to the top. A fan 67 situated in the inner cold chamber 68 is driven by a motor 69 to circulate the air in the inner chamber against the inner surface of the metallic lining 64. At the bottom of the circulation space are water drains 70 fitted with shut-off valves.

Cold air is discharged into the bottom of the circulation space 65 through a duct 71 and passes upwards through the circulation space 65 through passages defined by the divisions 66 and is discharged to atmosphere at slight positive pressure through a non-return flap valve 72.

The cold air is generated by apparatus similar to that described with reference to FIGS. 1 and 2, consisting of the cold air discharge pipe 71, a volute 73, a warm air discharge pipe 74 with a water-jacket 75 and cooling water inlet and outlet pipes 76 and 77 and a throttling device 78. The warm air discharge pipe 74 discharges into a warm room 79 and leaves it through a non-return flap valve 80.

Air is compressed in two compressors 81, and passes through heat exchangers 82, in which the heat of compression is removed and then enters the volute 73. Thermostats 83 are located in the inner chamber and operate in one case an electrical actuator 84 which adjusts the position of the warm end throttling device 78 and in the other case is arranged to switch one or more compressors on and off, according to the temperature level required in the cold room.

To defrost the circulation space 65, a branch pipe 85 is led from the warm end outlet into the said circulation space and in this branch pipe 85 is arranged a valve 86 which can be opened to admit warm air to the circulation space, the variable orifice operated by a lever 87 being closed during the defrosting process.

What is claimed is:

1. Air-heating and cooling apparatus, comprising:
a volute chamber

having an inlet which opens tangentially into a circumferential region thereof,
a warm air outlet in one end wall thereof and
a cold air outlet in its other end wall of substantially smaller flow area than the warm air outlet,
both of said outlets being in communication with a central region of said volute chamber;
means for supplying compressed air to the circumferential region of the volute chamber through the inlet thereof; and
a ring of guide vanes arranged within the volute chamber in an annular zone between the circumferential and central regions thereof,
the individual guide vanes of said guide vane ring being inclined so as to reflect air from the circumferential region into the central zone.

2. Apparatus as claimed in claim 1, wherein said volute chamber includes two inlets which open tangentially into the circumferential region thereof on opposite sides respectively of its circumference, wherein said means for supplying compressed air includes two air compressors connected respectively to said two inlets.

3. Apparatus as claimed in claim 1, including a heat exchanger positioned between said compressed air supplying means and the inlet of said volute chamber for removing the heat of compression from the compressed air.

4. Apparatus as claimed in claim 1, wherein said individual guide vanes of the guide vane ring are inclined so that the air passing between them is given a tangential component of motion relative to the inside circumference of said guide vane ring.

5. Apparatus as claimed in claim 1, wherein the angle between each said individual guide vane and a corresponding tangent to the circumference of the guide vane ring is less than 20°.

6. Apparatus as claimed in claim 1, wherein a common control member is connected to all the guide vanes of the guide vane ring and the individual guide vanes are pivotally adjustable about their inner edges by means of the said common control member to vary the angle between them and corersponding tangents to the inside circumference of the guide vane ring.

7. Air-heating and cooling apparatus, comprising:
a volute chamber
having an inlet which opens tangentially into a circumferential region thereof,
a warm air outlet in one end wall thereof and
a cold air outlet in its other end wall of substantially smaller flow area than said warm air outlet,
both of said outlets being in communication with a central region of said volute chamber;
means for supplying compressed air to the circumferential region of the said volute chamber through the inlet thereof,
a ring of guide vanes arranged within said volute chamber in an annular zone between the circumferential and central regions thereof;
the individual guide vanes of said guide vane ring being inclined so as to deflect air from
the circumferential region into the central zone, and a warm air outlet pipe communicating with said warm air outlet and having a length 25 to 30 times greater than the inner diameter of said guide vane ring.

8. Apparatus as claimed in claim 7, wherein the bore of the warm air outlet pipe at its inlet end is of the same diameter as the warm air outlet opening and the walls of the said bore taper outwardly in the direction towards its outlet end at an included angle of 5° to 8°.

9. Apparatus as claimed in claim 7, wherein said warm air outlet pipe is surrounded by a water-cooling jacket with a helical partition positioned in the space between said outlet pipe and said jacket forming a helical passage for the flow of cooling water from one end of the said pipe to the other.

10. Apparatus as claimed in claim 7, including an adjustable throttling device positioned at the outlet end of said warm air outlet pipe.

11. Apparatus as claimed in claim 7, wherein means are also provided for switching in one or more additional compressors to discharge into the circumferential region of the volute chamber.

12. A refrigerating apparatus, comprising:
a volute chamber
having an inlet which opens tangentially into a circumferential region thereof,
a warm air outlet in one end wall thereof and
a cold air outlet in its other end wall of substantially smaller flow area than said warm air outlet,
both of said outlets being in communication with a central region of said volute chamber;
means for supplying compressed air to the circumferential region of said volute chamber through the inlet thereof;
a ring of guide vanes arranged within the volute chamber in an annular zone between the circumferential and central regions thereof,
the individual guide vanes of said guide vane ring being inclined so as to deflect air from the circumferential region into the central zone;
a cold chamber having heat-insulated main walls;
an inner metal lining located within said cold chamber and in spaced relation with respect to the main walls thereof; and
dividing plates arranged between the main walls and the metal lining providing a cold air channel extending in adjoining convolutions around the metal lining from the bottom to the top of said cold chamber,
the cold air outlet of the volute chamber being in communication with the lower end of said cold air channel and the upper end of said cold air channel being open to the atmosphere.

13. Apparatus as claimed in claim 12, comprising in addition defrosting means operative when actuated, to shut off said cold air outlet from and connect the warm air outlet to the lower end of said cold air channel.

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