June 19, 1951 C. W. MORRIS 2,557,100

AIR COOLING SYSTEM HAVING EXPANSION MEANS

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Fig. 1

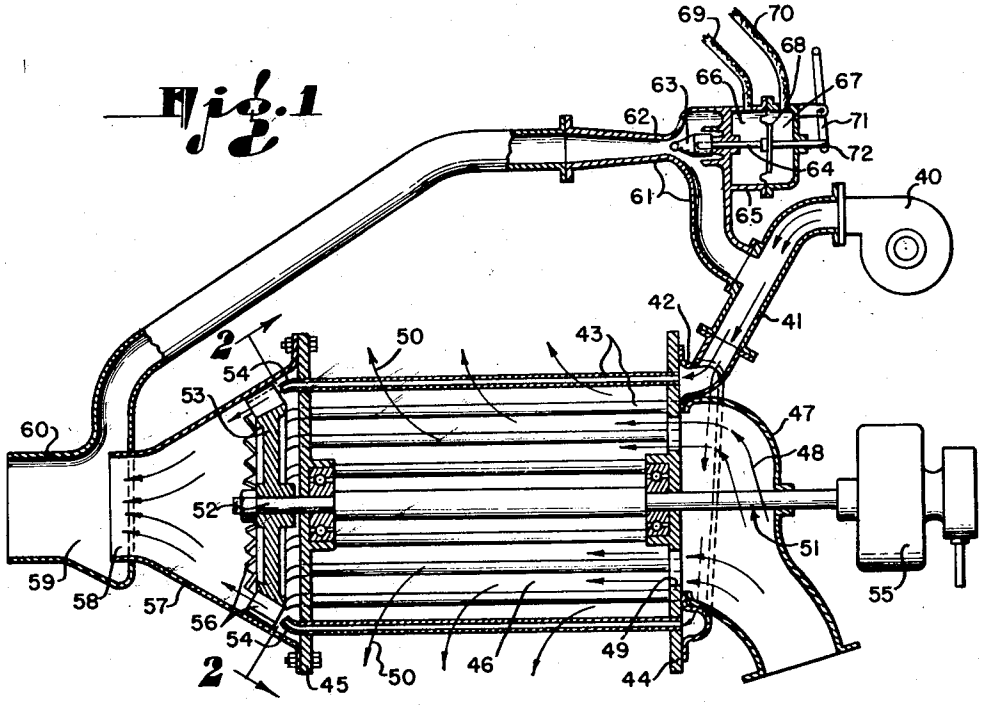
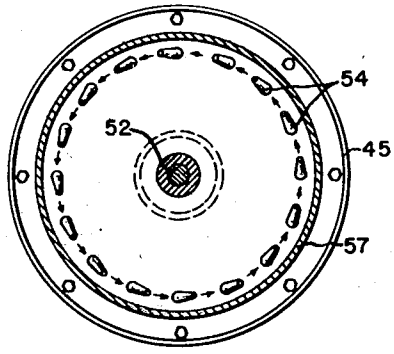


Fig. 2



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AIR COOLING SYSTEM HAVING EXPANSION MEANS

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15 Claims. (Cl. 62—136)

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My invention relates in general to air conditioning equipment and relates in particular to a simple device for reducing the temperature of air which need not involve the use of a condensable refrigerant.

This application is a division of my co-pending application, Serial No. 606,179, filed July 20, 1945, for Supercooler, now Patent No. 2,518,246, granted Aug. 8, 1950.

It is an object of the invention to provide an air cooler which uses atmospheric air as the coolant or heat abstracting medium, whereby a flow of air, also drawn from the atmosphere, is cooled.

A further object of the invention is to provide a device in which the air to be cooled is compressed so as to raise its temperature above that of the surrounding air, or atmospheric air from which the air to be cooled is drawn, the compressed air being then passed through a cooler, which employs atmospheric air as a coolant, and then reexpanded to the pressure of the chamber in which it is to be used, or which is to be air-conditioned, this reexpansion of the cooled, compressed air accomplishing a reduction in its temperature to a value below the temperature of the outer atmosphere and also recovering a usable portion of the power expended in the compression of the air.

It is an object of the invention to provide a simple device which by itself is an important and independently usable air-conditioning unit, but which may be used with other air-conditioning equipment where a close control of temperature and humidity is required. An important usefulness of the invention, due to its small size and weight, is in connection with systems for pressurizing aircraft cabins, in which systems the compression of air results in a rise in its temperature so that unless the compressed air is cooled before it is delivered into the cabin, the cabin interior will be heated to a temperature higher than is comfortable for the occupants. The device shown herein may be connected in series into a duct through which air under pressure is delivered to a cabin or other space for the purpose of pressurization.

A further object of the invention is to provide an air cooler having a relatively light supporting structure which defines a central air space, there being air cooling means arranged on opposite sides of or around this air space, and simple means for directing air to be cooled through the cooling means and also for directing atmospheric air into the central space so that it will move in a generally radial direction through the coolant passages of the cooling means.

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A further object of the invention is to provide a device of the character set forth in the preceding paragraph wherein the supporting structure is provided with bearings for rotatably supporting a shaft which extends lengthwise through the central air space and has its rear end connected to the moving part of an air-operated engine through which the cooled compressed air is reexpanded, the power derived from such reexpansion of the air being carried by the shaft to a power utilizing means disposed at the front end of the supporting structure.

A further object is to provide in a device of this character a means whereby the recovered power which is transmitted to the shaft is utilized, at least in part, in the compression of the air to be cooled.

It is one of the objects of my invention to provide a method and apparatus whereby there is established a path of flow for replenishment air for the cabin and in which path there is located power absorbing parts which are driven by the flow of air in said path, the absorbing of power by said parts extracting heat from the replenishment air.

It is also an object of my invention to provide a method and apparatus of the character as pointed out in the preceding paragraph, in which there is a cooler means located in the path for the replenishment air located on the intake side of said means having the power absorbing parts.

A further object of the invention is to provide a simple air turbine arrangement whereby the cooled and compressed air is reexpanded so as to be further cooled and power is recovered as a result of such reexpansion.

Further objects and advantages of the invention will be brought out in the following part of the specification.

Referring to the drawings which are for illustrative purposes only:

Figure 1 is a sectional view constituting a simplified, somewhat schematic, showing of a preferred embodiment of my invention;

Figure 2 is a sectional view taken as indicated by the line 2—2 of Fig. 1.

In the drawings, I have shown in a somewhat schematic manner a form of the invention wherein many of the constructional characteristics of the device disclosed in said co-pending application, Serial No. 606,179 are repeated. In this form of the invention the means for compressing the air to be cooled is shown as a compressor 40 which delivers the compressed air through a duct 41 to an annular manifold 42 communicating with the front ends of cooler tubes 43 which ex-

tend from a plate 44 to a plate 45, these tubes 43 being arranged so as to form a cage around a central air space 46. A cooling air inlet housing 47 is connected to the front face of the plate 44 in a position to direct air, as indicated by arrows 48, through the air inlet openings 49 of the plate 44 to the air space 46, from which the air flows outwardly through the spaces between the tubes 43 as indicated by arrows 50.

A shaft 51 is extended through the space 46 defined by the supporting structure consisting of the end plates 44 and 45 and the tubes 43. This shaft 51 has on its front end 52 a means 53 for recovering power from the air which issues from nozzles 54 at the rear ends of the tubes 43. The opposite end of the shaft 52 is connected to a means 55 for utilizing the power recovered from the compressed air after it has passed through the cooling tubes 43. The power recovering means 53 consists of a rotor having vanes 56 positioned so as to be impinged by the jets of air which issue from the nozzle 54. As shown in Figure 2, the nozzles 54 are inclined in the direction of rotation desired for the rotor 53, and these nozzles are formed in a simple manner by tapering the rear ends of the tubes 43 which project through the plate 45 and then bending these tapered ends to the desired angle, thereby providing the diagonally directed nozzles 54. The power utilizing means 55, which places a load on the shaft 51 to resist free rotation of the rotor 53, may consist of any power-driven mechanism, such, for example, as an oil circulating pump.

A conoidal housing 57 is connected to the rear face of the end plate 45 in a position to cover the rotor 53. The reduced outlet 58 of the housing 57 projects into a housing 59 from which there extends an air outlet connection 60 adapted to be connected to a duct or other space which is to receive the cooled air. From the compressed air inlet duct 41 an air bypass duct 61 has therein a valve throat 62 controlled by a conical valve member 63 which is mounted on a slidably disposed shaft 64. This shaft 64 extends into a housing 65 which is divided into adjacent pressure chambers 66 and 67 by a diaphragm 68. The central portion of the diaphragm 68 is connected to the shaft 64, and the movement of the diaphragm by differential pressure between the chambers 66 and 67 is transmitted through the shaft 64 to the valve 63. Controlling air pressure is transmitted from a control unit, not shown, through air ducts 69 and 70. A lever 71 is pivotally mounted upon the housing 65 and one of its ends is connected to the projecting end 72 of the shaft 64, thereby providing externally of the housing 65 a member which has movement in accordance with the movement of the valve 63, to which the follow-up mechanism of the control unit may be connected.

The coolant air which is directed through the housing 47 may be derived from any source of air pressure. In an aircraft it may be obtained from an air rammed duct. It will be understood that in the operation of this device the proportions of air directed through the cooler and through the bypass 61 are varied in accordance with the deviation of the temperature in the air-conditioned space supplied by the device from the selected temperature. The control of the bypass valve 63 may be manual, or may be accomplished by use of automatic temperature responsive control mechanism not forming a part of this invention. In the invention shown herein the work done by the air in driving the reexpansion turbines constitutes an absorption of energy which has been converted from pressure energy to kinetic energy. Therefore this conversion of energy results in a cooling of the air in addition to the cooling effect resulting from the mere increase in volume of the air after it reaches the tubes of the coolers.

I claim:

1. In an air cooler, the combination of: a supporting structure defining an air space having an inlet at the front end thereof; a shaft member extending through said structure from the front to the rear end thereof; bearing means carried by said structure supporting said shaft member for rotation; cooling means arranged along said air space, said cooling means having first passages extending from the front end of said structure to the rear end thereof and second passages in crossing relation to said first passages, said second passages communicating with said air space; compressor means for compressing the air to be cooled and delivering the same into the front ends of said first passages; a reexpansion turbine at the rear end of said structure for receiving the cooled compressed air from said first passages, the rotor of said turbine being connected to the rear end of said shaft; power recovery means connected to said shaft so as to apply a load to said turbine; and means for bypassing a portion of the air from said compressor means around said cooling means.

2. In an air cooler, the combination of: a plurality of tubes arranged in side-by-side relation so as to form a cage around a central space; a wall closing one end of said space; means for delivering coolant air into the other end of said space so that it will flow out through the spaces between said tubes; compressor means for delivering air to be cooled into the front ends of said tubes; turbine means at the rear ends of said tubes to receive the air which has been cooled in passing through said tubes, said cooled air driving said turbine means; and means for bypassing a portion of the air from said compressor means around said turbine means so that the bypassed portion of the air will not be cooled.

3. In an air cooler, the combination of: a plurality of tubes arranged in co-extending relation so as to surround a central space; a front plate and a rear plate in spaced relation and having openings therein to receive the ends of said tubes; means for delivering coolant air into said space so that it will flow out through the spaces between said tubes; means for delivering air to be cooled into the front ends of said tubes; air nozzles at the rear ends of said tubes; and a rotatably supported turbine rotor having vane means disposed so as to receive air from said nozzles whereby said turbine rotor will be driven and said air from said nozzles further cooled.

4. In a system for cooling air to be delivered to a space in an aircraft having an air rammed duct and air compressing means for compressing said air; a cooler having cooling passages for the compressed air and other passages for coolant air; inlet means for delivering air from said air compressing means to said cooling passages of said cooler; work extracting means comprising an expansion engine receiving cooled air from said cooler; and means for directing coolant air from an air rammed duct of the aircraft through said other passages of said cooler.

5. In a system for cooling air to be delivered

to a space in an aircraft: air compressing means for compressing the air; duct means defining a path of flow for the air from said air compressing means to said space; a cooler in said path of flow downstream from said air compressing means; work extracting means comprising a cooling turbine in said path of flow downstream from said cooler; a bypass having its front end connected to said path of flow upstream from said work extracting means and its rear end connected to said path of flow downstream from said work extracting means; and control valve means adapted to control the proportions of the flows of air through said heat extracting means and said bypass.

6. In a system for cooling air to be delivered to a space in an aircraft having air compressing means for compressing the air and a source of coolant air: duct means defining a path of flow for the air from said air compressing means to said space; a cooler downstream from said air compressing means having passages for the compressed air in said path of flow, and having coolant air passages; means for directing air from said source of coolant air through said coolant air passages; work extracting means comprising a cooling turbine in said path of flow downstream from said cooler; a bypass having its front end connected to said path of flow upstream from said work extracting means and its rear end connected to said path of flow down stream from said work extracting means; and control valve means adapted to control the proportions of the flows of air through said heat extracting means and said bypass.

7. In a system for cooling air to be delivered to a space in an aircraft having air compressing means for compressing the air and a source of coolant air: duct means defining a path of flow for the air from said air compressing means to said space; a cooler downstream from said air compressing means having passages for the compressed air in said path of flow, and having coolant air passages; means for directing air from said source of coolant air through said coolant air passages; and work extracting means comprising a cooling turbine in said path of flow downstream from said cooler.

8. In a system for cooling air to be delivered to a space in an aircraft: air compressing means for compressing the air; a cooler having cooling passages for the compressed air; inlet means for delivering air from said air compressing means to said cooling passages of said cooler; work extracting means comprising a cooling turbine receiving cooled air from said cooler; and outlet means receiving cooled air from said work extracting means and adapted to be connected to the space to be cooled.

9. In a system for cooling air to be delivered to a space in an aircraft: air compressing means for compressing the air; a cooler having cooling passages for the compressed air; inlet means for delivering air from said air compressing means to said cooling passages of said cooler; work extracting means comprising a cooling turbine receiving cooled air from said cooler; outlet means receiving cooled air from said work extracting means and adapted to be connected to the space to be cooled; a bypass connecting said inlet and said outlet means; and means having a movable wall adapted to control proportionate flow of air through said bypass.

10. In a system for cooling air to be delivered to a space in an aircraft: air compressing means

for compressing the air; a cooler having cooling passages for the compressed air; inlet means for delivering air from said air compressing means to said cooling passages of said cooler; work extracting means comprising an expansion engine receiving cooled air from said cooler; outlet means receiving cooled air from said work extracting means and adapted to be connected to the space to be cooled; a bypass connecting said inlet and said outlet means; valve means adapted to control proportionate flow of air through said bypass; and temperature controlled valve actuating means connected to said valve means.

11. In a system for cooling air to be delivered to a space in an aircraft: air compressing means for compressing the air; duct means defining a path of flow for the air from said air compressing means to said space; a cooler in said path of flow downstream from said air compressing means; work extracting means comprising an expansion engine in said path of flow downstream from said cooler; and a bypass having its front end connected to said path of flow upstream from said work extracting means and its rear end connected to said path of flow downstream from said work extracting means.

12. In a device for cooling air to be delivered to a space in an aircraft, the combination of: a cooler having passage means for the air and other passage means for a coolant; inlet means for conducting said air under pressure to the inlet of said cooler; a turbine connected so as to receive and be driven by the air leaving said cooler; means coupled to said turbine to utilize power developed by said turbine; and an outlet member to receive said air which has passed through said turbine, adapted for delivery of said air to said space.

13. In a system for cooling air to be delivered to a space in an aircraft, the combination of: duct means defining a path for the flow of air to said space; a cooler in said path of flow for cooling said air; work extraction means comprising an expansion turbine in said path of flow on the downstream side of said cooler; means coupled to said turbine to utilize power developed by said turbine; air compression means connected to said duct means on the upstream side of said cooler; and a bypass connected to said duct means whereby air may be bypassed around said cooler and said turbine.

14. Mechanism for conditioning compressed air which is conducted from a source of compressed air to a cabin, comprising: cooler means having first and second passage means in heat transfer relation to each other; means for directing a flow of compressed air from said source through said first passage means to said cabin; means for directing a flow of coolant through said second passage means for cooling said compressed air flowing through said first passage means; a cooling turbine in the path of flow of at least a part of the compressed air for cooling the same; and means for bypassing air from said first passage means around said turbine to said cabin.

15. Mechanism for conditioning compressed air which is conducted from a source of compressed air to a cabin, comprising: cooler means having first and second passage means in heat transfer relation to each other; means for directing a flow of compressed air from said source through said first passage means to said cabin; means for directing a flow of coolant through said second passage means for cooling said compressed air flowing through said first passage means; a

cooling turbine in the path of flow of at least a part of the compressed air for cooling the same; and means responsive to the temperature of air which has been cooled by said turbine for bypassing air from said first passage means around said turbine to said cabin.

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