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ICE PREVENTION IN AIR CONDITIONING SYSTEMS

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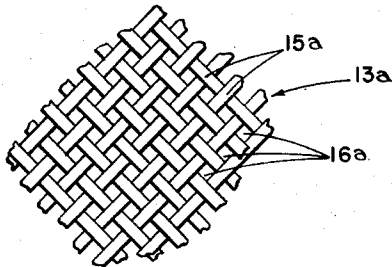
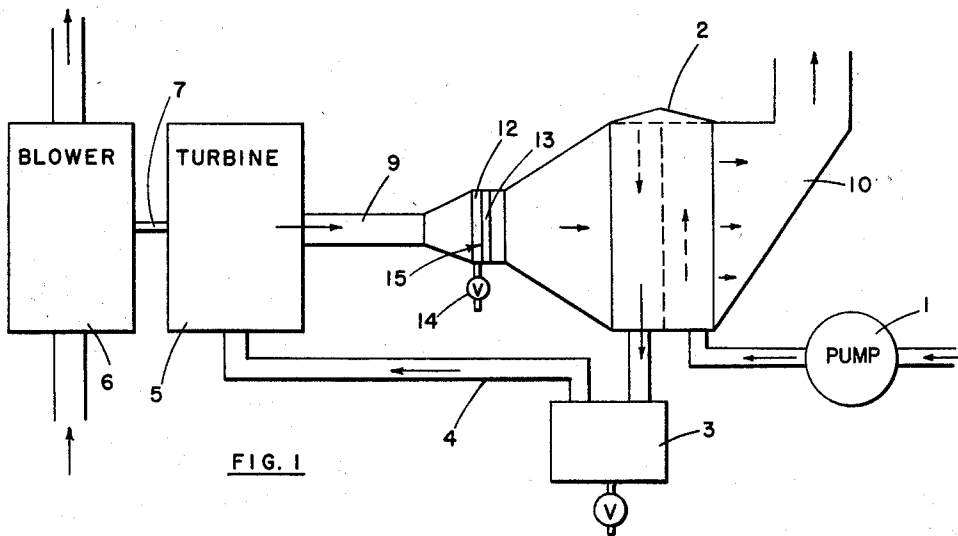


FIG. 2

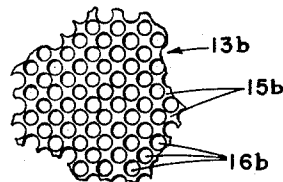


FIG. 3

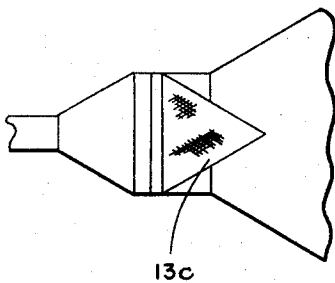


FIG. 4

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ICE PREVENTION IN AIR CONDITIONING SYSTEMS

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6 Claims. (Cl. 62-272)

This invention pertains to the removal of ice formations in an air duct. More particularly this invention pertains to a device to be installed in an air duct downstream of an expansion turbine and automatically operable to prevent ice formations by maintaining the air temperature above the freezing point of water.

It is common practice in air conditioning systems, particularly those used in aircraft, to provide an expansion turbine which cools air supplied from a suitable source of pressure for use in the cabin area. The turbine discharge air may be at very low temperatures so that it is necessary to prevent ice formations downstream of the turbine. Otherwise various elements in the air conditioning system would ice up and fail to operate properly. Many elaborate systems have been proposed to accomplish this, but they have not only been complicated and expensive, but have not functioned satisfactorily.

It is accordingly an object of this invention to prevent ice formations downstream of an air expansion device. A further object of this invention is to regulate the pressure drop across an expansion turbine to prevent its outlet temperature from falling below the freezing point of water. Yet another object of this invention is to provide a foraminous member in an air duct the openings of which will automatically change in size to control the pressure drop across an air expansion device to prevent temperatures below the freezing point of water. An additional object of this invention is to provide a temperature stabilizing and moisture removal device characterized by its simplicity, economy and compactness. These and other objects will become apparent from the following detailed description taken in connection with the accompanying drawing in which

Fig. 1 is a schematic view of a typical air conditioning arrangement employing the provisions of this invention; and

Figs. 2, 3 and 4 are enlarged detailed showings of modifications of the foraminous member employed for moisture removal and temperature control.

Referring now to Fig. 1 a typical air conditioning system is illustrated such as a type used in an aircraft. A suitable source of pressurized air 1 is provided which may be a conventional air compressor, or in the case of a jet propelled aircraft may be the compressor of the engine, a portion of the output of which will be bled away for the air conditioning system. From the air compressor the pressurized air is transmitted to a heat exchanger 2 which normally will have two passes. The air is partially cooled in heat exchanger 2 but still retains a relatively high temperature. From the heat exchanger the air is transmitted to a moisture removal device 3 and then through pipe 4 to the inlet of an expansion air turbine 5. The moisture removal device will not result in completely dry air, such devices generally leaving at least 15 percent of the original moisture.

As the air expands through the turbine it reaches a lower pressure on the outlet side and performs work in rotating the turbine. This will serve to lower the tem-

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perature so that the air from the turbine outlet is suitable for use in the air conditioning system. A blower 6 is coupled by shaft 7 to the turbine and rotated thereby. This absorbs the energy of the turbine and the blower may be used in any desired manner, in some cases serving as a boost for the air supply of the air conditioning system.

Outlet 9 of the turbine containing the refrigerated air therefrom passes back through heat exchanger 2 serving to cool the incoming air. After passing through the heat exchanger the cooled air is then led through duct 10 to the cabin area where it may serve as makeup air to maintain the cabin area at the desired temperature.

In a typical system the turbine outlet temperature may range as low as from 20° F. to -60° F. This is, of course, well below the freezing point of water and accordingly a difficulty from icing will be encountered in the duct downstream of the turbine. This will occur to a particularly objectionable degree at heat exchanger 2 where ice formations will build up over at least a portion of the heat exchanger thereby preventing air contact so that the heat exchanger cannot perform its function. Valving and other elements of the air conditioning system may be made inoperative by icing conditions.

According to the provisions of this invention, within expanded section 12 of the turbine outlet between the turbine and the heat exchanger there is disposed a foraminous member 13. This member is disposed entirely across the diameter of the air duct so that all of the air from the turbine must pass through the foraminous member. It may take a variety of forms and in a typical example comprises a screen of woven wire. The exact configuration of the foraminous member is not regarded as critical but certain considerations must be made when this member is selected. First it should have sufficient open area so that normally air will pass through this member without an appreciable resistance to its flow and there is little pressure drop across the foraminous member. However, the foraminous member must provide only relatively small passageways therethrough.

The effects of the foraminous member are twofold. First the relatively small apertures through this member, while serving to freely transmit the air, will prevent passage of some of the free moisture in the air which may be in the form of a fog or suspended droplets. The surface tension of the water will not allow the water to enter the small openings in member 13. Moisture thus collected will run to the bottom of the duct where it will be periodically dumped out of the duct through a suitable blow off valve 14. Design of a valve of this type may be found in U.S. Patent 2,610,645.

The second effect of the foraminous member is to prevent ice formations downstream thereof, thereby maintaining the heat exchanger and other elements of the system entirely free of ice. When the temperature at the turbine outlet falls below the freezing point of water, ice begins to build up on upstream surface 15 of the foraminous member. As this occurs the passageways through this member become partially blocked off by the accumulation of ice and restrict the flow of air through the duct. This automatically raises the back pressure on the turbine lowering the pressure drop across the turbine. As a result the outlet temperature of the turbine rises and will increase until it is above the freezing point of water. When the outlet temperature exceeds this value the ice on the foraminous member will begin to melt and the passageways through the member will open up, thereby reducing the back pressure on the turbine. The two effects will balance out so that on the downstream side of the foraminous member the temperature will stabilize at substantially the freezing point of water regardless of the inlet conditions to the expansion

turbine. This means that the moisture remaining in the air will not form as ice at the heat exchanger or other portion of the duct. The foraminous member will usually have a light formation of ice on it which will to a certain degree close off the openings therethrough.

Various modification of the foraminous members which may be successfully employed are illustrated in Figs. 2, 3 and 4. As shown in Fig. 2 a screen 13a is used as the foraminous member. In operation, ice will form on surface 15a of the screen, partially obstructing openings 16a therethrough. Screens have been successfully used having from 40 mesh to 400 mesh. With the latter, of course, there is less open area through the screen and a tendency toward an excessive pressure drop through the screen results. It is preferred in most installations to use a screen of around 100 mesh. The turbine has been run with as little as three pounds per square inch back pressure at 50 percent capacity and in excess of fourteen pounds per square inch back pressure at 100 percent turbine capacity, in both instances successfully maintaining the temperature downstream of the foraminous member at around 32° F.

The modification of Fig. 3 illustrates a different form of foraminous member in which a plate 13b is provided with a plurality of openings 16b therethrough. The plate and openings act much the same as a screen providing a surface 15b on the upstream side on which ice will accumulate as turbine outlet temperature drops.

The foraminous member of Fig. 4 may be employed to obtain a finer size of opening through the foraminous member while at the same time allowing a free passage of air by having a large open area. Thus the foraminous member 15c is formed in the shape of a cone or similar arrangement which will elongate the member and thus provide more surface through which the air can pass. If the foraminous member has finer openings there is less possibility for the moisture to pass through the member and accordingly the moisture removal efficiency will be increased.

A particularly effective modification for achieving high percentages of moisture removal is the use of porous sintered metal as the foraminous member. This material, as described in patent 2,554,343, provides many minute passageways which will be permeable to a fluid such as air. However, free moisture in the air will be prevented from passing through these small openings. The porous sintered metal has the disadvantage of offering a greater resistance to the flow of air.

It can be seen from the foregoing that I have provided an improved moisture removal and ice prevention arrangement for an air conditioning system which although simple in construction is automatic in its operation. The unit is compact, quite economical to fabricate, very light in weight and yet automatically regulates the turbine pressure while blocking off free moisture particles thereby to remove moisture from the air and prevent icing of the air conditioning system downstream of the turbine.

The foregoing detailed description is to be clearly understood as illustrative only, the spirit and scope of this invention being limited only by the appended claims.

I claim:

1. A substantially constant discharge-temperature air expansion refrigeration device comprising means for expanding moisture-laden, high-pressure, high-temperature air to a lower pressure and a temperature below the freezing point of water; and means for automatically regulating the pressure drop across said expansion means to prevent the outlet air temperature from said expansion means from falling below the freezing point of water, said means comprising a foraminous member having openings which allow substantially unimpeded flow of all of the discharge air therethrough and which presents a large surface area surrounding said openings for the reception of moisture-laden particles thereon whereby said particles are frozen to restrict the openings through

the foraminous member when the air discharge temperature drops below the moisture freezing temperature, thereby reducing the pressure drop across said expansion device and increasing the outlet temperature to maintain a substantially constant outlet temperature of not less than the moisture freezing temperature downstream of said foraminous member.

2. A device as recited in claim 1 in which said foraminous member comprises a screen.

3. A device as recited in claim 2 in which said screen is within the range of approximately 40 mesh to approximately 400 mesh.

4. A source of dried non-icing air comprising compressor means; air turbine means connected therewith capable of discharging moisture laden air at below the freezing point of water; an outlet duct connected to said air turbine means for receiving air discharged therefrom; and foraminous means in said outlet duct arranged to transmit all of the air discharged by said air turbine means, said foraminous means having openings therethrough sufficient to transmit air from said turbine means without appreciable pressure drop while being sufficiently small to block off free moisture in said air, said foraminous means having a surface for receiving ice formations when air from said turbine means is below the freezing point of water thereby to partially close said openings and raise the back pressure on said turbine to cause the discharge temperature of the same to increase to a temperature sufficient to maintain the air temperature downstream of said foraminous means substantially constant at a temperature not less than the freezing temperature of the moisture.

5. A device for providing air at a temperature substantially not less than the freezing point of water comprising a source of moisture laden pressurized air; an expansion turbine connected therewith for receiving air therefrom and expanding such air to a condition of lower temperature and pressure with such temperature being below the freezing point of water; outlet means for said turbine; and a foraminous member in said outlet means arranged so that all air passing through said outlet means must pass therethrough, said foraminous member having aperture means therethrough of sufficient size only to provide a substantially unrestricted path for said air, and having an upstream surface means around said aperture means for receiving ice formations when said turbine discharge temperature is below the freezing point of water, said ice formations thereby restricting the size of said aperture means for raising the back pressure on said turbine outlet means and raising the temperature of the air downstream of said foraminous member to substantially not less than the freezing point of water.

6. A substantially constant discharge-temperature air expansion refrigeration device comprising means for expanding moisture-laden, high-pressure, high-temperature air to a lower pressure and a temperature below the freezing point of water; and a permeable means for maintaining the temperature of air discharged therethrough at substantially the freezing temperature of the moisture contained in the air, said means comprising a foraminous member positioned fully across the air turbine outlet and having sufficient pore area to normally allow substantially unimpeded air flow therethrough, an accumulation of ice on said foraminous member partially blocking said pore area, said ice accumulation automatically decreasing and increasing in extent in response to the air turbine inlet conditions to thereby increase and decrease the foraminous member open pore area to regulate the air turbine discharge temperature to maintain a substantially constant outlet air temperature downstream of said foraminous member approximately equal to the freezing temperature of the moisture in the air.

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