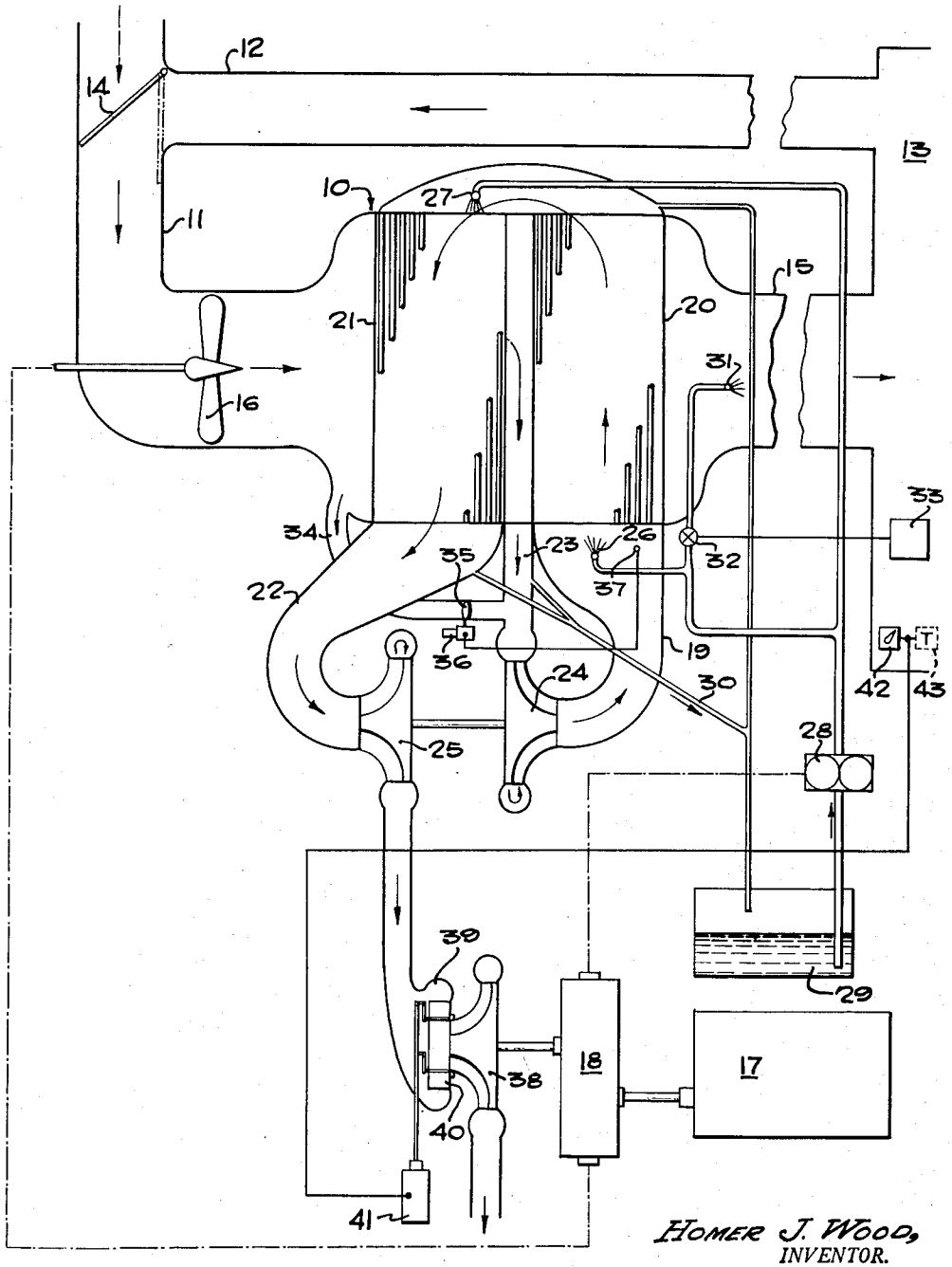
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AIR CONDITIONER HAVING AIR EXPANSION MEANS

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AIR CONDITIONER HAVING AIR EXPANSION MEANS

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The present invention relates generally to an air conditioner, and is more particularly concerned with means for cooling air for enclosures.

It is an object of the herein described invention to provide an air conditioner which is especially suited for the cooling of enclosures, such as embodied in aircraft, which is susceptible of being incorporated into a compact self-contained unit suitable for mounting upon a truck or trailer, by means of which it is readily mobile for movement from one location to another for connection through flexible ducts with an aircraft enclosure during ground operations in hot or arid areas.

A further object is to provide novel means in an air conditioner for controlling the temperature and humidity of the conditioning air delivered to the enclosure.

Another object is to provide a novel primary and secondary compressor arrangement in the coolant circuit of a heat exchanger, and novel means for controlling the pressure differential between the primary and secondary compressors in such a way as to control and regulate the temperature of conditioning air delivered to the enclosure with which the conditioner is connected.

Still another object is to provide in an air conditioner novel de-icing means in the coolant circuit.

Briefly, the present invention comprises a portable or mobile air conditioner wherein the conditioning air is cooled and humidified in an evaporative heat exchanger having a coolant circuit arranged to take coolant air from the conditioning air path through the heat exchanger, this coolant air being passed through power recovery means, such as an expansion turbine placed in the coolant flow path to the heat exchanger. A primary compressor is connected at the outlet of coolant flow from the heat exchanger, in series with a secondary compressor. The primary compressor is driven by the power recovery device, whereas the secondary compressor is driven by an independent power source which is also utilized to pump water or other evaporative medium to the heat exchanger and into the conditioning air duct leading to the enclosure, as well as drive a fan for circulating air for the air conditioning through the heat exchanger.

A pre-swirl device is provided at the inlet of the secondary compressor, by means of which the flow may be varied in accordance with a control characteristic, such as temperature variations in the enclosure, whereby flow through the coolant circuit is controlled, and the concomitant temperature of the conditioning air delivered to the enclosure.

A controlled bypass is also provided to conduct inlet conditioning air into the expansion turbine, instead of partially cooled air, thus providing a novel arrangement for preventing de-icing on the exhaust or discharge side of the expansion turbine.

Further objects of the invention will be brought out in the following part of the specification, wherein detailed description is for the purpose of fully disclosing the invention without placing limitations thereon.

Referring to the accompanying drawing, which is for illustrative purposes only, the single figure schematically represents the component parts and interconnections thereof in an air conditioner embodying the features of the present invention.

More specifically, the invention is shown as comprising an evaporative heat exchanger **10** in which a source of conditioning air is conducted into heat transfer relation with a suitable coolant. The heat exchanger is arranged with an inlet duct **11** for conditioning air, which may be selectively connected to take air directly from the surrounding atmosphere, or through a branch duct **12** recirculate air from an enclosure **13** with which the air conditioner is to be utilized.

The air supply may be regulated and controlled by means of conventional means, in this case illustrated as a valve **14** which may be so adjusted that the entire supply is made up of fresh air, or may be adjusted so that the entire supply constitutes air which is recirculated from the enclosure **13**. Moreover, if desired, the fresh air and recirculated air may be proportioned.

The heat exchanger is provided with an outlet duct **15** for the enclosure conditioning air, and the inlet duct **12** and outlet duct **15** may be connected by means of flexible duct connections with the enclosure which is to be conditioned. Movement of enclosure conditioning air through the heat exchanger is accomplished by means of a suitable fan **16** in the inlet duct **11**, this fan being driven by suitable independent power means **17**, such as a reciprocating engine, which is connected with the fan through a suitable transmission **18**.

The fan **16** raises the pressure of supplied air sufficiently to overcome subsequent pressure losses due to the passage of the air through the air ducts, heat exchanger, filters, etc. in the flow path of enclosure conditioning air. From the fan, the air passes into the heat exchanger **10**, where the required reduction in temperature and humidity takes place, and then is discharged into the enclosure. From the enclosure it may be recirculated or discharged directly to atmosphere.

The coolant medium, in this instance air, is supplied to an inlet duct **19** from which it is conducted through a first pass **20**, and thence through a second pass **21** to an outlet duct **22**.

Normal supply of coolant air is bled from the conditioning air passage of the heat exchanger from a point between the passes **20** and **21** through a bleed duct **23**, so that the coolant air will have been partially cooled by having passed through the coolant pass **21**.

The coolant air is conducted to a power recovery device **24** which consists of an air expansion turbine which acts to further cool the coolant air and in so doing convert energy from the coolant into mechanical energy which may be utilized for a useful purpose. The discharge side of the power recovery device is connected to the inlet duct **19**.

Th outlet duct **22** is connected with the inlet of a primary compressor **25** which is motivated by the power recovery device **24**.

The coolant air discharge from the power recovery device **24**, prior to its entering the respective passes **20** and **21**, is thoroughly saturated with water which is introduced through nozzles **26** and **27** by means of which the water is sprayed into the heat exchanger tubes where its evaporation results in further cooling. Water is supplied to the nozzles **26** and **27** from a suitable pump **28**, which is also driven from the transmission **18**, this pump having its inlet connected with a suitable source as represented by the tank **29**. Excess water from the heat exchanger drains back into the tank **29** through drain lines **30**.

In addition to the introduction of water into the coolant circuit, water is also sprayed into the outlet duct **15** for enclosure conditioning air from a nozzle **31**. The supply to the nozzle **31** is regulated by means of a suitable valve **32** under the control of a humidity sensing device **33** located in the enclosure **13**.

In order to obviate any tendency for ice to form in the inlet duct **19**, means are provided for controlling the temperature of coolant air supply to the power recovery device **24**. For such purpose, a bypass **34** is connected from the inlet duct **11** of the heat exchanger to the bleed duct **23**, thus enabling coolant air to be supplied directly to the power recovery device prior to its being partially cooled in the pass **21**. Flow of air through the bypass **34** is controlled by a suitable valve **35** which is motivated by an actuator **36** under the control of a thermostat **37** positioned in the inlet duct **19**.

The present invention employs a unique arrangement

for controlling the flow of coolant through the cooling passages of the evaporative heat exchanger **10**, and concomitant temperature of conditioning air delivered to the enclosure. If a secondary compressor **38** is now connected in series with the primary compressor **25**, as shown, any change or variation of flow through the secondary compressor will have a regulating effect upon the flow through the primary compressor.

Various means may be utilized to change the flow through the secondary compressor. For example, the compressor speed may be varied or conventional throttle valves may be utilized. In the illustrated embodiment, the primary compressor **25** is shown as having its outlet connected to the inlet of the secondary compressor **38** through a pre-swirl device **39** having a plurality of angularly adjustable vanes in the path of flow of air entering the secondary compressor.

The angular position of these vanes varies the amount of swirl and has a controlling effect on the flow through the secondary compressor. The suction created by the secondary compressor is thus varied, and by varying the discharge pressure head existing at the outlet of the primary compressor **25**, the flow of coolant through the cooling passages of the evaporative heat exchanger is effectively controlled. The use of a pre-swirl device is advantageous in that it substantially reduces the part-load power demand upon the power means **17**, in contrast to the action of simple throttling means such as, for example, a valve placed in the connection duct between the primary compressor **25** and the secondary compressors **38**.

The position of the vanes **40** is controlled by means of a suitable power actuator **41** arranged to be adjusted to a desired vane setting means of a manually operable temperature selector **42**, or automatic regulation may be obtained by controlling the actuator **41** from a conventional temperature sensing device **43**, as shown in dotted lines.

The components of the air conditioner, as described above, are of such character as to enable their being assembled into a compact unit which may be mounted on a truck or trailer to permit ease of portability and movement to the aircraft where it is to be utilized for conditioning enclosures during ground operations.

Various modifications may suggest themselves to those skilled in the art without departing from the spirit of my invention, and, hence, I do not wish to be restricted to the specific form shown or uses mentioned, except to the extent indicated in the appended claims.

I claim:

1. An air conditioner, comprising: a heat exchanger having a conditioning air passage selectively connectable on its inlet side with an enclosure and with atmosphere, and on its outlet side with said enclosure, and having a coolant passage; means for moving air through said conditioning air passage; an expansion turbine having an inlet connected to receive conditioning air from said air moving means, and an outlet connected to discharge into said coolant passage; first and second compressors connected to successively receive coolant from said coolant passage, one of said compressors being driven by said turbine; independent power means for driving the other of said compressors and said air moving means; and means for regulating the air flow through the compressor driven by said power means.

2. An air conditioner, comprising: an evaporative heat exchanger having a conditioning air passage, the outlet of which is adapted for connection with an enclosure, and a coolant passage; conduit means for conducting an evaporative medium to said coolant passage and to the outlet of said air conditioning passage; an expansion turbine having an inlet connected to receive partially cooled conditioning air from said heat exchanger and an outlet connected to discharge into said coolant passage; a compressor connected to receive coolant from said coolant passage, said compressor being driven by said turbine; a secondary compressor driven by independent power means, connected to receive the discharge from said first compressor; means for varying the flow through said secondary compressor; a pump for said evaporative medium driven by said power means, said pump having its discharge connected to said conduit means; and means for controlling the supply of evaporative medium to said air conditioning passage outlet in response to humidity conditions in said enclosure.

3. An air conditioner, comprising: an evaporative heat exchanger having a conditioning air passage, the outlet of which is adapted for connection with an enclosure, and a coolant passage; conduit means for conducting an evaporative medium to said coolant passage and to the outlet of said air conditioning passage; an expansion turbine having an inlet connected to receive conditioning air from said heat exchanger and an outlet connected to discharge into said coolant passage; a compressor connected to receive coolant from said coolant passage, said compressor being driven by said turbine; a secondary compressor driven by independent power means, connected to receive the discharge from said first compressor; means for varying the flow through said secondary compressor; and a pump for said evaporative medium driven by said power means, said pump having its discharge connected to said conduit means.

4. An air conditioner, comprising: an evaporative heat exchanger having a conditioning air passage, the outlet of which is adapted for connection with an enclosure, and a coolant passage; conduit means for conducting an evaporative medium to said coolant passage; an expansion turbine having an inlet connected to receive conditioning air from said heat exchanger and an outlet connected to discharge into said coolant passage; a compressor connected to receive coolant from said coolant passage, said compressor being driven by said turbine; a secondary compressor driven by independent power means, connected to receive the discharge from said first compressor; means for varying the flow through said secondary compressor; and a pump for said evaporative medium driven by said power means, said pump having its discharge connected to said conduit means.

5. An air conditioner, comprising: a heat exchanger having a conditioning air passage, the outlet of which is adapted for connection with an enclosure, and a coolant passage; an expansion turbine having an inlet connected to receive partially cooled conditioning air from said heat exchanger and an outlet connected to discharge into said coolant passage; a compressor connected to receive coolant from said coolant passage, said compressor being driven by said turbine; a controlled supply bypass connecting said expansion turbine inlet with the conditioning air inlet of said heat exchanger; a secondary compressor driven by independent power means connected to receive the discharge from said first compressors; and temperature control including means for varying flow through the secondary compressor.

6. An air conditioner, comprising: a heat exchanger having a conditioning air passage, the outlet of which is adapted for connection with an enclosure, and a coolant passage; an expansion turbine having an inlet connected to receive partially cooled conditioning air from said heat exchanger and an outlet connected to discharge into said coolant passage; a compressor connected to receive coolant from said coolant passage, said compressor being driven by said turbine; means for variably controlling flow of said coolant; a controlled supply bypass connecting said expansion turbine inlet with the conditioning air inlet of said heat exchanger; and means controlling said bypass in accordance with temperature conditions associated with the discharge from said turbine.

7. An air conditioner, comprising: a heat exchanger having a conditioning air passage, the outlet of which is adapted for connection with an enclosure, and a coolant passage; an expansion turbine having an inlet connected to receive partially cooled conditioning air from said heat exchanger and an outlet connected to discharge into said coolant passage; a compressor connected to receive coolant from said coolant passage, said compressor being driven by said turbine; means for variably controlling the flow of said coolant; and a controlled supply bypass connecting said expansion turbine inlet with the conditioning air inlet of said heat exchanger.

8. An air conditioner, comprising: a heat exchanger for conducting conditioning air for an enclosure and a coolant into heat transfer relation; work extraction means driven by flow of coolant to said heat exchanger; a primary compressor driven by the work extraction means positioned in the flow of coolant from said heat exchanger; a secondary compressor connected in series with said primary compressor; and angularly variable vanes associated with the inlet of said secondary compressor for varying its flow characteristics.

9. An air conditioner, comprising: a heat exchanger

for conducting conditioning air for an enclosure and a coolant into heat transfer relation; expansion cooling means driven by flow of coolant to said heat exchanger; means for compressing the coolant from the heat exchanger in successive stages; and means for variably throttling flow through a compressing stage subsequent to the first stage in accordance with temperature variations from a predetermined norm.

10. An air conditioner, comprising: a heat exchanger for conducting conditioning air for an enclosure and a coolant into heat transfer relation; expansion cooling means driven by flow of coolant only to said heat exchanger; means for compressing the coolant from the heat exchanger in successive stages; and means for variably throttling flow through a compressing stage subsequent to the first stage to vary the cooling effect of said coolant in said heat exchanger.

11. An air conditioner, comprising: a heat exchanger for conducting conditioning air for an enclosure and coolant into heat transfer relation; work extraction means driven by flow of coolant to said heat exchanger; means for compressing the coolant from the heat exchanger in successive stages, said compressing means being motivated in part by said work extraction means; and means for controlling flow in a final stage of said compressing means.

12. An air conditioner, comprising: a heat exchanger for conducting conditioning air for an enclosure and a coolant into heat transfer relation; work extraction means driven by flow of coolant to said heat exchanger; a primary compressor driven by the work extraction means

positioned in the flow of coolant from said heat exchanger; an independently driven secondary compressor in series with said primary compressor; and means for varying flow through said secondary compressor in accordance with enclosure temperature variations.

13. An air conditioner, comprising: a heat exchanger for conducting conditioning air for an enclosure and a coolant into heat transfer relation; work extraction means driven by flow of coolant to said heat exchanger; a primary compressor driven by the work extraction means positioned in the flow of coolant from said heat exchanger; a variable flow secondary compressor connected in series with said primary compressor; and means for adjusting the secondary compressor flow in accordance with different temperatures.

14. An air conditioner, comprising: a heat exchanger for conducting conditioning air for an enclosure and a coolant into heat transfer relation; work extraction means driven by flow of coolant to said heat exchanger; a primary compressor driven by the work extraction means positioned in the flow of coolant from said heat exchanger; and a variable flow secondary compressor connected in series with said primary compressor.

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