Oct. 7, 1969 LIAN-TONG WEN 3,470,703

HYPERSONIC COOLING DEVICE

Filed Jan. 16, 1968 3 Sheets-Sheet 1

FIG. 1

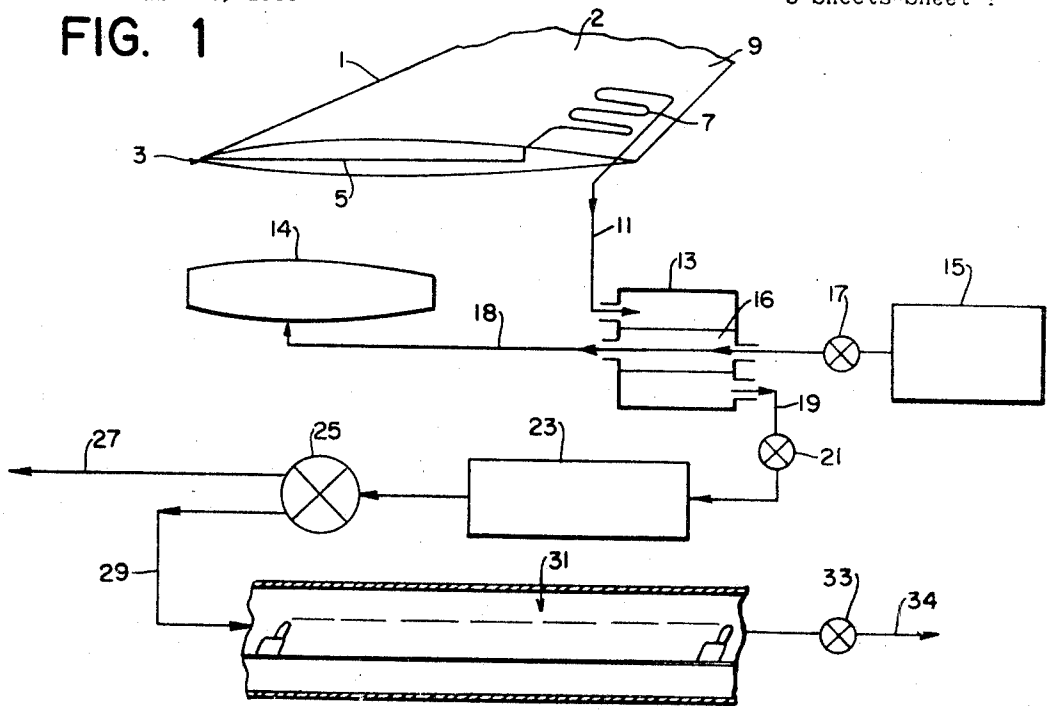
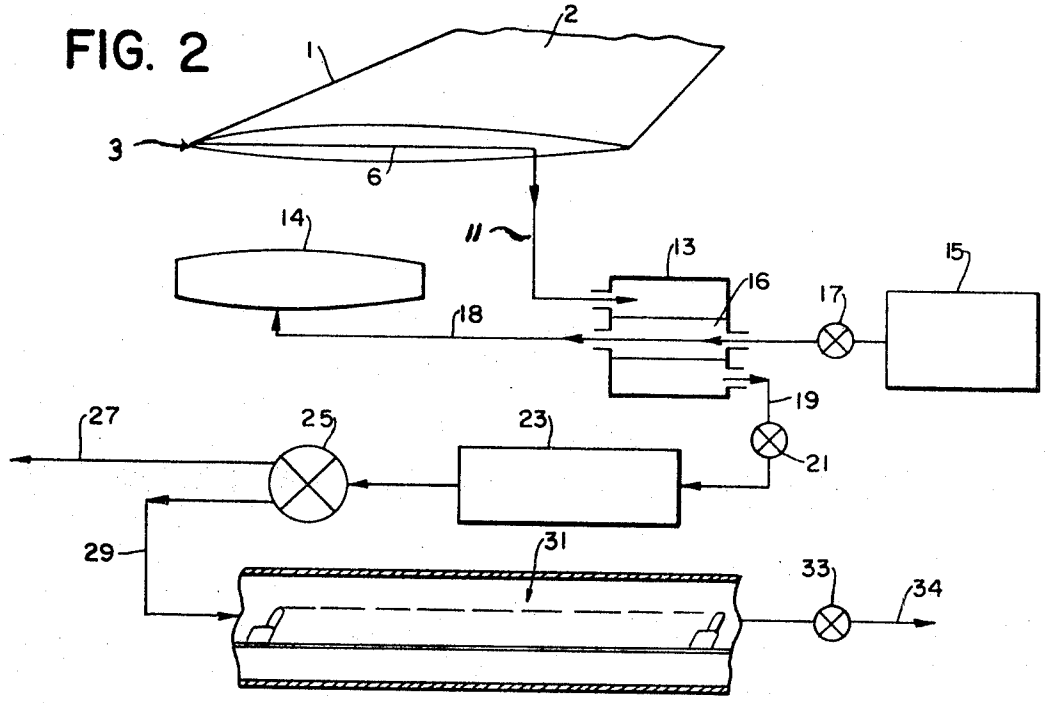


FIG. 2



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FIG. 3

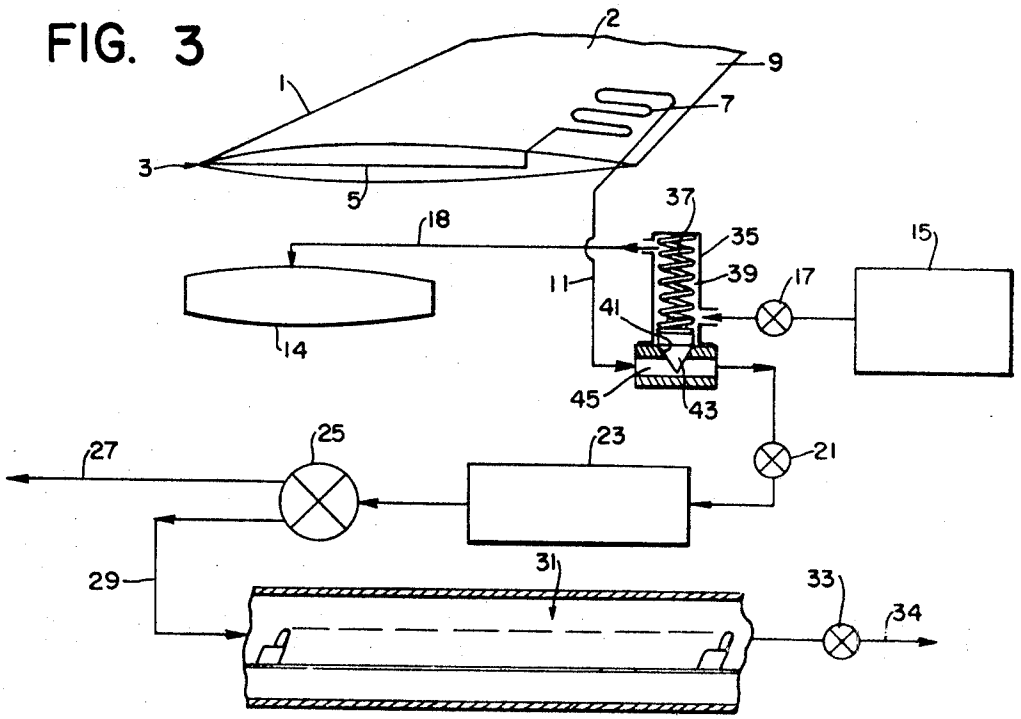
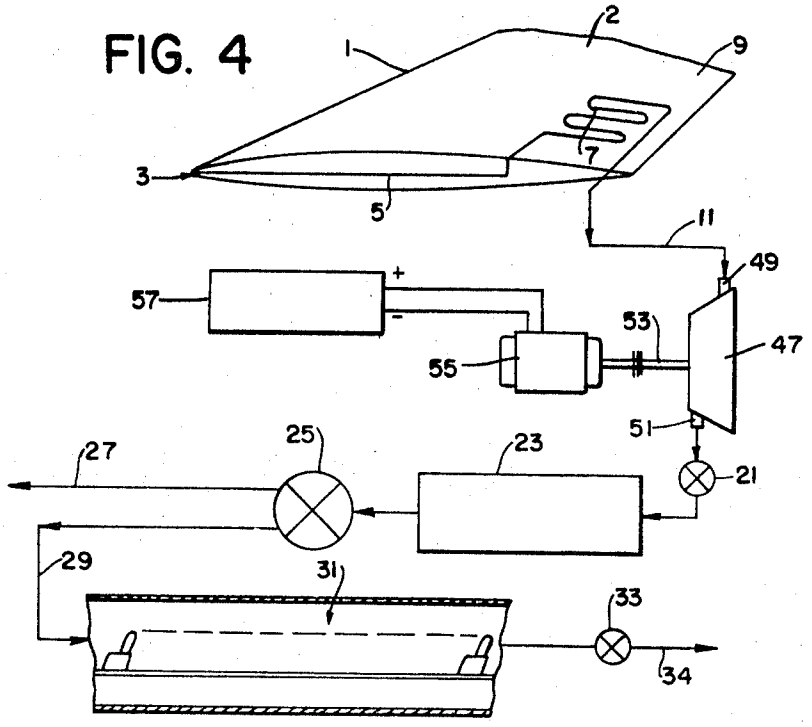


FIG. 4



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FIG. 5

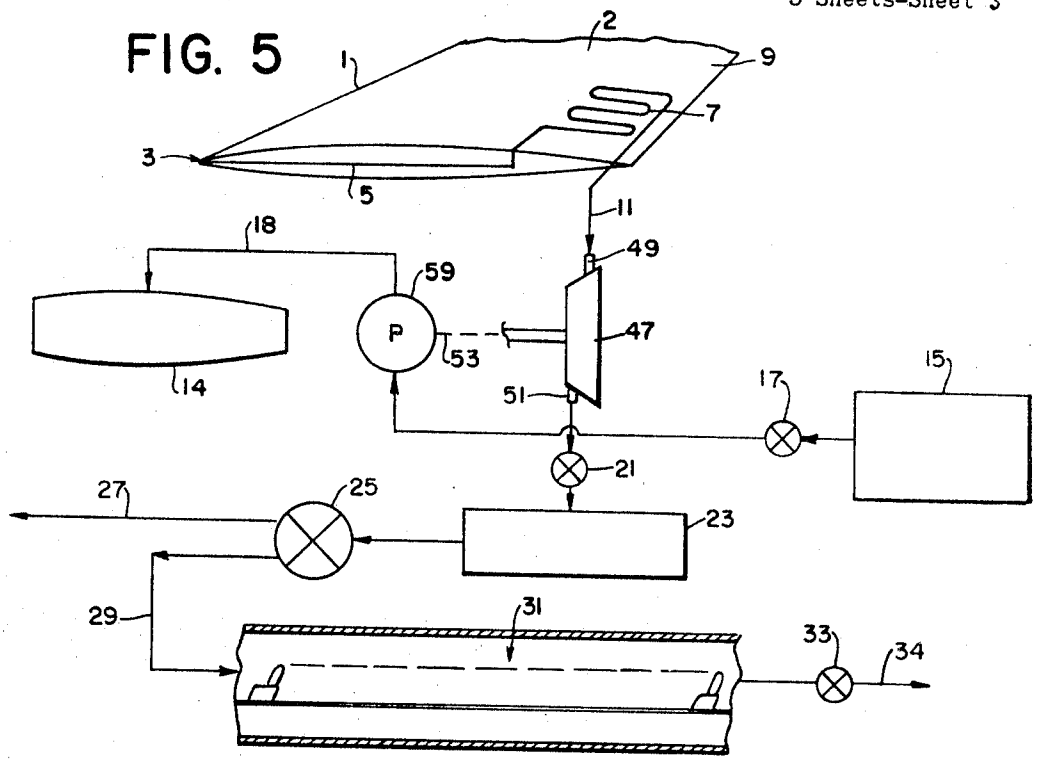
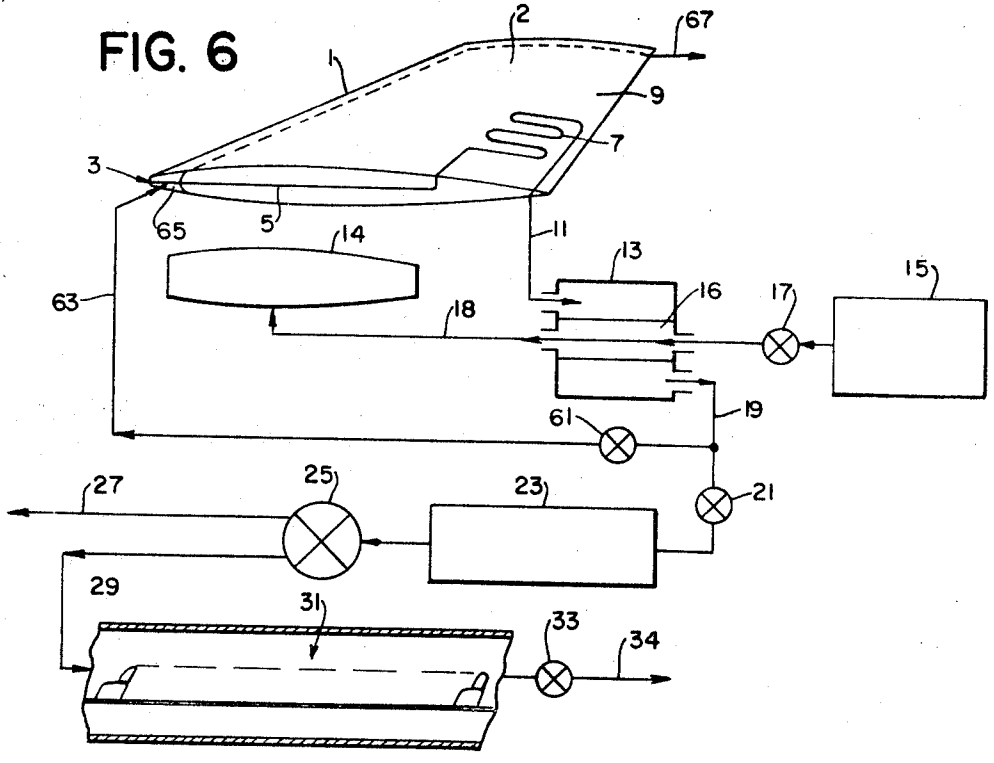


FIG. 6



United States Patent Office

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3,470,703

HYPERSONIC COOLING DEVICE

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Continuation-in-part of application Ser. No. 536,220, Feb. 1, 1966. This application Jan. 16, 1968, Ser. No. 698,277

Int. Cl. F25b *9/00;* B60h *3/04*

U.S. Cl. 62—86 6 Claims

ABSTRACT OF THE DISCLOSURE

Ram air, at high temperature and pressure, is drawn from the leading edges of hypersonic planes during flight, is then cooled and expanded to provide the atmosphere within the cabin and for other purposes within the plane. The invention provides a source of air at useful temperatures and pressures in airplanes operating at hypersonic speeds. Provision is made for modifying the ram intake orifices at the leading edges to follow the zone of greatest compression. From these orifices, ducts lead the ram air to heat abstractors communicating with heat sinks where the excess heat energy is dissipated. The cooled air is then expanded and ducted to areas for use. The treated air may be used for providing breathable atmospheres within the cabin, for controlling temperatures along the leading edges of the plane, and in jets for utilizing the Coanda Effect in pneumatic controls.

CROSS-REFERENCE

This application is a continuation-in-part of my application Ser. No. 536,220, filed Feb. 1, 1966, and herewith abandoned.

FIELD OF INVENTION

This invention relates to a method and means for providing cool air for air vehicles and more particularly to a method and associated devices for modifying the ram air from along the leading edges of hypersonic vehicles to pressures and temperatures that are useful within the vehicles.

PRIOR ART

In airplanes and similar vehicles flying at hypersonic speeds, it has been found that at the leading edges, the rarefield air through which the plane is flying is compressed and heated by the ramming effect against these edges of the vehicles. Temperatures at these leading edges range generally from about 600° Fahrenheit to 800° Fahrenheit and have corresponding pressures from 115 to 200 p.s.i. Areas away from these leading edges are 200° to 300° Fahrenheit cooler. This high-temperature compressed air that forms in thin layers at the leading edges of the plane poses many problems. It is the source of the shock wave that develops instantaneous heat and pressure. It also causes heating and erosion of the leading edges at which it is generated. Such heating and erosive conditions require the use of special and costly alloys to minimize these conditions.

The prior art has had little concern with the utilization of hypersonic ram air. Beyond early feasibility tests on ram-jet aircraft where the ram air was utilized as the source of oxidizer for ram-jet thrust engines, there has been little utilization of this medium.

Hyposonic ram air has always been used for cabin atmospheres and for the engines. The art contains various descriptions of compressors, heaters and humidifiers, superchargers and conditioners for modifying and utilizing hypersonic air. This air was introduced into the plane at intakes either situated at the boundary layers and

along the leading edges of the wings or at special intake ducts for the superchargers. This air at hyposonic speeds is cooled and is at rarefied pressure depending on the altitude. It therefore has to be compressed and heated before use. Examples of devices to achieve the heating and compression of hyposonic ram air includes the supercharger systems of Douglas, Stewart, Warner, and Boeing which are discussed in U.S. Patents 2,391,838, 2,441,279 and 2,767,561 respectively where the compressors or turbines compress the air and heat exchangers warm the air for use within the cabin.

It has also been proposed to tap the air leaving the turbine compressor of turbosuperchargers used for supplying air to the engines. This hyposonic compressed air has to be cooled as is shown in U.S. Patent 2,851,863.

With the advent of supersonic planes, attempts have been made to cool the leading edges of the wings of these planes by the transfer of heat from the leading edges to the fuel utilized in the plane. U. S. Patents 2,930,553 and 2,958,482 describe methods for the transfer of the heat to precooled fuels and/or oxidizers. U.S. Patent 3,158,197 describes a method for the transfer of intermittent heat from air to be introduced into the cabin. This is a special procedure for air which may be heated by intermittent causes such as during landing operations. The heat taken from this air is transferred to quantities of reserve fuel. The heat storage capacity of such reserve fuels is recognized as being limited, and this system is proposed where heating is encountered for only short periods as during descent and landing operations.

OBJECTS AND STATEMENT OF INVENTION

It is an object of this invention to modify ram air from the leading edges of hypersonic planes in such manner as to serve useful functions within the plane.

It is a further object of this invention to provide a means and method for abstracting excess heat content from ram air directed from the leading edges of the hypersonic planes and releasing said heat into suitable heat sinks.

It is a further object to introduce portions of the ram air into the plane and to reduce its temperature and pressure sufficiently so that it may also serve such useful purposes as a cooling medium for overheated surfaces or for pneumatic jets useful in controlling devices operating by the Coanda Effect.

These and other objects are achieved by my invention which provides for the ducting of portions of the hypersonic ram air from the leading edges of the planes, through orifices situated along these edges, ducting this air within the plane to heat abstractors communicating with heat sinks where it is cooled and then expanding this air to useful pressures.

According to one aspect of this invention the cooled air may be directly expanded to provide an atmosphere which can be used as breathable air within the passenger sections and crew portions of the plane.

According to another aspect of this invention, the cooled ram air may be utilized to cool critical areas of the plane where some measure of controlling excessive temperatures is needed.

According to a further aspect of this invention the cooled ram air may be utilized as the fluids controlling and operating apparatus on the aircraft including Coanda Effect pneumatically-operated devices within the plane.

The terms "heat abstractor" and "heat sink" as used herein refer to materials, devices and arrangements for the utilization, disposal and conversion of the excess heat content from the rammed air. Heat abstractors within the scope of this invention include heat operated devices wherein the heat content of the rammed air is transferred

to another medium as by conduction or radiation or is converted to other forms of energy through the intervention of energy transducers such as turbines, spring-loaded check-valves, thermoelectric devices, etc.

The term "heat sink" as used herein includes the external environment of the plane to which the excess abstracted heat content is transferred by radiation and/or conduction; the internal environment of the plane where the abstracted heat is converted to mechanical and electrical energy and utilized within the plane; and the on-board fuel proceeding from the fuel tanks to the engines where it is consumed, which is preheated by the abstracted heat via heat exchangers or via utilization as a cooling agent for the heated springs of check-valves. In other words, the heat content of the rammed air is exchanged or converted and thereby extracted from the rammed air stream which has its temperature consequently lowered.

An additional lowering of the temperature of the rammed air is available upon expansion of this air through an orifice by virtue of the Joule-Thompson Effect, since the rammed air is not a perfect gas. A lowering of the temperature of the rammed air in the order of about 20–40° Fahrenheit is available at the conditions of expansion between the rammed air at the intake orifice and the desired cabin pressures.

DRAWING

For a fuller understanding of the method, procedures and apparatus by which the objects of this invention are achieved, reference should be made to the following description taken in connection with the accompanying drawing in which:

FIG. 1 is a schematic drawing illustrating the cooling arrangement for aircraft cabin air according to this invention wherein a portion of the excess heat content of the ram is abstracted and radiated to the external environment as a heat sink at the trailing surfaces of the wing and additional excess heat content is abstracted and imparted to the fuel as a further heat sink.

FIG. 2 is a schematic drawing illustrating another device according to this invention wherein the excess heat content is abstracted from the ram air and imparted to the fuel used in the plane propulsion system.

FIG. 3 is a schematic drawing illustrating another arrangement according to this invention wherein the excess heat content is abstracted from the ram air by a spring-loaded expansion check-valve which is cooled by the fuel being fed to the propulsion system.

FIG. 4 is a schematic drawing of another arrangement according to this invention wherein the excess heat content is abstracted from the ram air by conversion to mechanical energy in a turbine which is connected to electrical current generators.

FIG. 5 is still a further schematic drawing of an arrangement according to this invention where the excess heat content is converted by turbine means to mechanical energy and is used to drive the fuel-feeding pump for the aircraft.

FIG. 6 is a schematic drawing of another arrangement according to this invention wherein a portion of the cooled air is ducted behind the leading edges of the plane to cool those areas which are subjected to intense heating by the ram effect.

Referring to the drawing in which like numerals identify certain parts, FIG. 1 illustrates the wing **2** of the hypersonic plane having along its leading edge **1** orifices **3** for admitting the ram air into duct **5** which extends from orifice **3** to abstractor coils **7** located at non-leading surfaces **9** of the wing **2**. Abstractor coils **7** are designed to transfer heat abstracted from the ram air by radiation and conduction to the outer environment through which the plane is flying. Duct **11** leads the ram air from radiant abstractor **7** to heat exchanger **13**. Fuel for jet engine **14** flows from tank **15** through valve **17** to fuel chamber **16** in heat exchanger **13**. From chamber **16** the fuel then proceeds via pipe **18** to the jet engine **14**. The ram air from heat exchanger **13** is led via duct **19** and control valve **21** to water separator **23** and thence to expansion valve **25**. In expansion valve **25**, which may be a series of valves, the ram air is expanded to various pressures as desired for specific utilization. The bulk of the air from expansion valve **25** is directed via duct **29** to the aircraft cabin **31** for utilization. The exhaust from cabin **31** is vented to the outside **34** via control valve **33**. Some of the air at the cabin pressure or any other pressure set in expansion valve **25** may be led to pneumatic instruments via air line **27**.

Referring now to FIG. 2, the arrangement is similar to that of FIG. 1, but the orifice **3** communicates directly with heat exchanger **13** without recourse to the abstractor **7** of FIG. 1.

In the embodiment shown in FIG. 3, orifice **3** communicates via duct **5** with abstractor **7** as in FIG. 1 and thence connected via duct **11** to a spring-loaded expansion check-valve unit **35** consisting of spring **37**, cooling jacket **39**, valve seat **41**, and valve chamber **45** containing valve **43**. The cooling jacket is supplied with the cool fuel from tank **15** via control valve **17**. The fuel leaving jacket **39** is led to jet engine **14** for consumption.

In the embodiment shown in FIG. 4, abstractor **7** is connected via duct **11** to turbine **47**. Duct **11** is connected to turbine-intake **49** where the ram air is fed into the turbine **47** and exhausted from there via turbine-exhaust **51** leading to control valve **21**. Shaft **53** of turbine **47** is connected to electrical generator **55** for generating current as required by electrical load **57** of the plane.

FIG. 5 shows a system similar to that of FIG. 4, but the turbine **47** via shaft **53** drives pump **59** which pumps the fuel from fuel tank **15** via control valve **17** and pipe **18** to jet engine **14**.

FIG. 6 shows a further embodiment of the system of FIG. 1 wherein the cooled rammed gas leaving heated exchanger **13** via duct **19** is partially bled via a control valve **61** to duct **63** communicating with the leading edge cooling chamber **65** for cooling the leading edge **1**.

EMBODIMENTS

In the embodiment of FIG. 1 the ram air, which upon impact with the leading edges of the plane is heated and compressed above 600° Fahrenheit and 100 lbs. per square inch pressure, is introduced into the plane through one or more orifices **3** situated along the leading edge **1** of the plane. These orifices are preferably along the leading edge of the wing **2**, but may be situated at any other leading surfaces of the plane where ram compression occurs.

From orifice **3** the ram air is led via duct **5** to abstractor coils **7** which are radiating and conducting heat exchange surfaces. Abstractor coils **7** are located along non-leading external surfaces of the plane which are exposed to the outer atmosphere. It has been noted that during hypersonic flight such surfaces are at least 200° Fahrenheit cooler than the leading edges. A portion of the heat content of the ram air is radiated to the outer environment by the exposed surfaces of abstractor **7**. A good portion may also be conductively transferred from the surface of abstractor **7** to the thin atmosphere through which the plane is flying. A considerable lowering of the temperature of the ram air takes place at abstractor **7** element.

From radiant abstractor **7**, duct **11** leads the partially cooled ram air to a second abstractor element, heat exchanger **13** where another portion of the heat content of the ram air is given up to the fuel used for propelling the plane. The fuel is stored on board the plane in tank **15** from which flow is controlled by valve **17**. The relatively cool fuel enters fuel chamber **16** of heat exchanger **13** where it is in conduction exchange relationship with the ram air entering from duct **11**. The residual excess heat content of the ram air is transferred in heat exchanger **13** to the fuel which is being pumped via pipe **18**

to the jet engine **14** where it is consumed. The excess heat transferred from the ram air to the fuel merely increases the efficiency of the jet engine.

The cooled ram air from heat exchanger **13** is controllably fed via duct **19** and valve **21** to water separator **23** where any excess moisture is removed. The dried and cooled ram air is then expanded either into the cabin via at least one expansion valve **25** which reduces the pressure to a pressure desirable for the cabin or through a series of expansion valves **25** where some of the cooled ram air is maintained at higher than breathing pressures for utilitarian purposes within the plane, and the rest reduced to cabin pressures for use therein. In general the pressures for the cabin are approximately those encountered at altitudes in the range 5 to 10,000 feet. Such cabin pressures are sufficiently comfortable for the passengers and yet do not require excess structural reinforcement of the plane.

The portions of the partially expanded air to be utilized other than for breathing may serve as pneumatic actuation fluids for such purposes as displacement of fuel, operation of instruments and for actuation and prime movement in devices utilizing the Coanda Effect.

The bulk of the air is, of course, utilized for breathing purposes within the cabin. It has been found that it is best to introduce this breathing air into the cabin at temperatures in the range 55° to 60° Fahrenheit. The body temperatures and the respiratory processes of the passengers will tend to stabilize the cabin temperature within the acceptable range of 70° to 80° Fahrenheit.

A degree of fine control of the cooling of the ram air is available at expansion valve **25** by taking advantage of the Joule-Thompson Effect. Control of the rate of expansion permits flexibility of utilizing the cooling effect available over a range of about 20° Fahrenheit. Controls at valve **25** permit utilizing this effect as a final adjustment of the cabin atmosphere for passenger comfort.

The air from the cabin is subsequently bled to the external environment in order to provide a constant source of fresh air by displacement. Control of the rate of displacement of the cabin air is obtained by valve **33**. It is also possible to use some of the cooled utilized air on its way to the exhaust as a cooling medium or for actuation of instrumentation.

The embodiment of FIG. 2 is similar to that of FIG. 1 but eliminates the abstractor **7** along the trailing edges as shown in FIG. 1. The ram air from the orifices **3** is introduced via ducts **6** and **11** directly into the heat exchanger **13** where its excess heat content is abstracted, transferred and eliminated from the plane via the burning of the fuel. It is, of course, possible to put a by-pass valve between ducts **5** and **11** of FIG. 1, and if conditions so-warrant, abstractor **7** may be removed from the ram air ducting circuit in that embodiment.

The embodiment of FIG. 3 substitutes a heat transducer in the form of a spring-loaded expansion check-valve unit **35** for the heat exchanger **13** shown in the embodiment of FIG. 1. The energy expended by the ram air entering the check-valve unit **35** via duct **11** is expended against spring **37** contained in cooling jacket **39**. This energy is abstracted from the ram air and is converted to heat within the body of the spring **37**.

Fuel from tank **15** is introduced into cooling jacket **39**, cools spring **37**, abstracts the heat therefrom and transfers it to the fuel stream on its way to jet engine **14** where it is consumed and utilized for whatever thrust value it may impart by virtue of the elevated temperature of the fuel. The cooled ram air leaving the expansion check-valve unit **35** is then treated in the succeeding stages as described in the embodiment of FIG. 1. The transducer, i.e. spring-loaded expansion check-valve **37** achieves the same result as heat exchanger **13**. It abstracts the excess heat content from the ram air and transfers it to the fuel stream.

In the embodiment of FIG. 4 the ram air leaving heat abstractor **7** via duct **11** is introduced into turbine **47** where it is expanded and its excess heat content is converted to rotary energy. The exhaust, cooled ram air at a lower pressure, leaves turbine **47** via turbine-exhaust port **51** and is then conveyed and treated throughout the rest of the system in the same manner as shown in the embodiment of FIG. 1.

The rotary energy, generated by the heat content abstracted from the ram air stream by turbine **47**, is conveyed by shaft **53** to electrical generator **55** where it is converted to electrical energy. The electrical energy may then be utilized in the plane for such prosaic purposes as light, heating and for instrumentation actuation. It may also be utilized to generate the current for actuating electrical fields in magnetohydrodynamic propulsion accessory devices for the jet engines.

The embodiment of FIG. 5 is similar to that of FIG. 4 in that the heat is abstracted from the ram air by means of a turbine **47**, but in this embodiment the mechanical energy imparted to turbine shaft **53** is used to operate pump **59** used for pumping fuel to the jet engines **14**.

It is further contemplated that within the scope of this invention is the combination of the systems of the embodiments of FIGS. 1, 3 and 5. The excess content of the ram air may be extracted in several stages including the radiating heat abstractor **7**, heat exchanger **13**, expansion valve unit **37**, as well as turbines **47**, which may all achieve the abstraction of the excess heat in a series of consecutive stages. In other words, after cooling via radiating abstractor **7** and heat exchanger **13**, the ram air may give up some additional energy by driving turbine **47** to pump fuel via pump **59** from tank **15** through heat exchanger **13** to jet engine **14**.

FIG. 6 is a further embodiment of this invention wherein a portion of the ram air, which has had its excess heat content abstracted by either radiator **7**, heat exchanger **13**, expansion check-valve **35**, turbine **47** or combinations thereof and is consequently cooled, is diverted and injected to chamber **65** adjacent to the leading edges of the plane. The cool ram air circulating therethrough acts as a cooling medium for reducing the temperature of these leading edges to a degree where cheaper and/or stronger structural materials may be safely utilized.

These cooling chambers for the leading edges are provided with exhausts **67** at the distal tips for venting the utilized ram air to the atmosphere.

The ram air is admitted into the plane by orifices situated at the leading edges. Optimally these may be a series of small openings of size adequate to admit the quantity of rammed air needed for the specific functions accorded to it by this invention. However, it is also possible to use a single larger orifice to achieve the same intake volume. The purpose of these orifices are to tap, bleed or scoop into the plane the compressed ram air. Any orifice or opening along the leading edge that is facing directly toward the direction of flight will admit this ram, compressed air. However, during maneuvering of the plane it is possible that the center of maximum compression may move slightly away from the leading edges. For such an eventuality a certain number of the orifices may be provided with articulation means so that they may follow the areas of maximum compression. The articulation of these specialized orifices may be accomplished by control means within the plane actuated by the same controls which cause the maneuvering of the plane and shifting of the source of maximum compression.

During the periods when the vehicle is flying at subsonic speeds there is no hot compressed ram air available and a substitute for use in the systems and apparatus of this invention must be made available in order to provide a constant source of atmosphere within the cabin. A suitable substitute may be the air compressed by the propulsion engine during its compression phase, prior to the injection of fuel for combustion in the power phase of the propulsion train. In aircraft engines such compressed air can be

bled from the axial compressors (not shown) of the engines into ducts 5 leading the heat abstractors and the rest of the systems of this invention. Such a bleeding of compressed air into the ducts of this invention will therefore provide to these systems the capability of continuously supplying useful atmospheres within the cabins and throughout the plane during all phases of flight, at all flying speeds and on the ground when the engines of the plane are operating.

It is understood that this invention, while directed particularly to the various described transducer means for abstracting energy from the rammed air stream, is not limited to such described means, but any transducers capable of removing heat from the ram air stream and converting it to other forms of energy which may then be disposed within or without the plane are in the scope of this invention. Similarly the heat sinks to which this energy is disposed of may be any energy receptive, materials, arrangements or devices capable of accepting the energy removed from the ram air stream by the heat abstractors disposing or utilizing this energy within or without the plane.

With respect to the embodiments of this invention as illustrated and described, it is to be understood that each of the individual embodiments is a preferred one, since each has its own advantages for the specific purpose for which it is intended. Further, where specific terminology is utilized or specific devices are mentioned, it is understood that the invention is not restricted to such terms or devices, but that all useful equivalents of such terms and devices suitable for the purpose of this invention are intended or included thereby.

I claim:

1. The method of utilizing highly heated and compressed ram air for on board cooling of cabin spaces in aircraft travelling at hypersonic speeds which comprises collecting highly heated and compressed ram air at leading edge locations of the aircraft, effecting a partial cooling of said highly heated and compressed ram air by conveying it through a heat abstractor coil located at a non-leading external surface of said aircraft thereby to radiate and conduct heat from said ram air to the outer environment in which the aircraft is travelling, then effecting a further cooling of said partially cooled air by conveying it through on board heat abstracting and transducing means to cool said ram air to a desired temperature for use in said cabin spaces, thereafter expanding said cooled ram air to reduce its pressure to a desired level for use in said cabin spaces, and thereafter introducing said cooled and expanded ram air into said cabin spaces.

2. The method of claim 1 wherein the further cooling of said partially cooled air is effected by conveying it in heat exchange relationship with the fuel being fed to the aircraft propulsion engines.

3. The method according to claim 1 wherein the further cooling of said partially cooled air is effected by expanding it through an on board turbine device to convert heat therein to mechanical energy.

4. A system for utilizing highly heated and compressed ram air for on board cooling of cabin spaces in aircraft travelling at hypersonic speeds which comprises ram air intake means at leading edge locations of said aircraft, a heat abstractor coil located at a non-leading external surface of said aircraft, first duct means in which ram air can be conveyed from said intake means through said heat abstractor coil, said heat abstractor coil being effective to remove heat from said ram air and radiate and conduct said heat to the outer environment in which the aircraft is travelling, on board heat abstracting and transducing means, duct means in which ram air can be conveyed from said heat abstractor coil to and through said heat abstracting and transducing means for further removing heat from said ram air, expansion valve means for expanding air exiting said heat abstracting and transducing means to reduce the pressure thereof to a desired level and means for conveying said cooled and expanded ram air to said cabin spaces.

5. The system of claim 4, wherein the heat abstracting and transducing means comprises a heat exchanger through which the ram air passes in heat exchange relationship with the fuel being supplied to the aircraft propulsion engines.

6. The system of claim 4 further comprising means defining a chamber within said aircraft extending adjacent said leading edge surfaces, and duct means connecting said chamber with the downstream side of said expansion valve means whereby a portion of the cooling air exiting said expansion valve means can be delivered to said chamber for cooling said leading edge surface.

References Cited

UNITED STATES PATENTS

2,391,838	12/1945	Kleinhans	62—241
2,412,110	12/1946	Williams	62—241
2,441,279	5/1948	McCollum	62—401
2,453,923	11/1948	Mayo	62—87
2,618,470	11/1952	Brown	62—402
2,851,863	9/1958	Theed	62—402
2,930,553	3/1960	Greenough	62—241
2,944,409	7/1960	Chausson	62—402
2,958,482	11/1960	Summers	62—241
3,158,197	11/1964	Blezard	62—241

OTHER REFERENCES

"Thermodynamics," J. E. Enswiler, second ed., 1927, pp. 124, 125, 126, 157, 158 and 159. Published by McGraw-Hill Book Co., New York, N.Y.

WILLIAM J. WYE, Primary Examiner

U.S. Cl. X.R.

62—61, 87, 241, 402