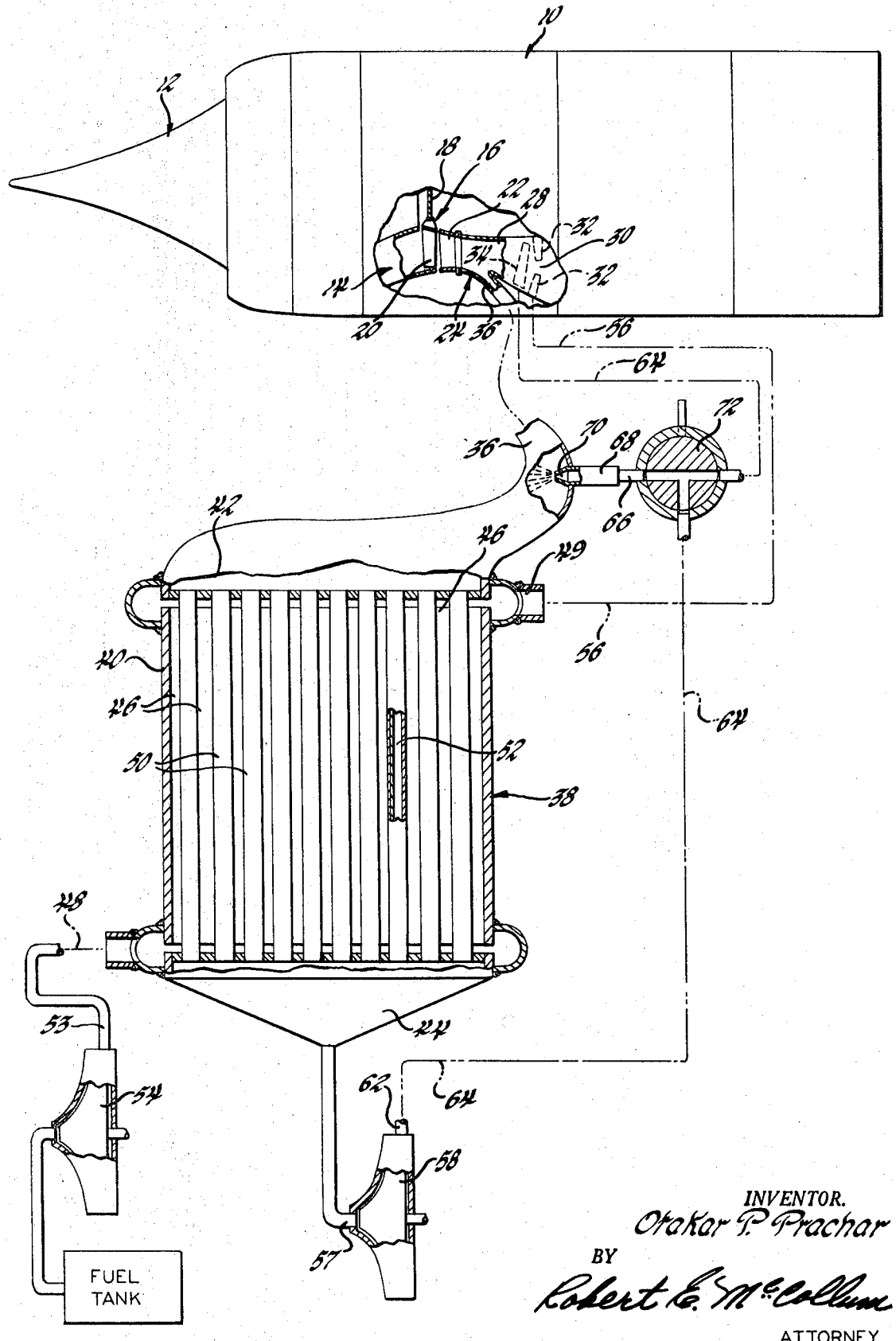
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ENGINE AIR PRECOOLER AND ICE ELIMINATOR

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ENGINE AIR PRECOOLER AND ICE ELIMINATOR

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ABSTRACT OF THE DISCLOSURE

A jet engine using cryogenic fuel produces liquid air by indirect heat exchange between combustion air entering the engine and the fuel. A part of the liquid air is sprayed into the engine air inlet ahead of the heat exchanger to cool the air sufficiently to freeze moisture so that it passes through the heat exchanger as a solid and does not freeze out onto the heat exchanger walls.

The invention herein described was made in the course of work under a contract or subcontract thereunder with the Department of Defense.

This application is a continuation of my application Ser. No. 58,283 for Engine Air Precooler, filed Sept. 26, 1960, now abandoned.

This invention relates to a fluid cooler, and more particularly to means for precooling the fluid entering a condenser type heat exchanger.

In high altitude, air breathing type aircraft or missiles having engines burning a liquid a liquid air-cryogenic fuel combination, the liquid air may be provided by a heat exchanger using the ram air as the primary fluid. However, in ascending from ground take-off to design point operation altitudes, the engines must necessarily pass through strata of air containing a fair percentage of moisture in the form of CO_2 or water vapor. The problem, therefore, is to prevent the icing of the heat exchanger by the adherence of solidified vapor particles to the exchanger as the air passes through and is reduced to its liquid state. The ice builds up in layers which eventually block the exchanger and cause failure of the entire engine.

This invention eliminates this icing problem by providing a construction whereby the incoming air to the exchanger is precooled by the liquid air to a temperature low enough to change any moisture contained therein to its solid state in the form of small particles. These particles then pass through the heat exchanger without adhering to its surfaces, and the exchanger is maintained free of ice for as long as is necessary for the craft to obtain cruising altitude, at which point practically no moisture exists.

Therefore, it is an object of this invention to provide a fluid precooler for use in connection with an apparatus reducing a fluid from one temperature phase or state to another lower state, the precooler solidifying any moisture contained within the fluid prior to its entry into the apparatus to prevent icing of the apparatus.

It is a further object of the invention to prevent icing of a heat exchanger by providing means to precool the incoming air by the cryogenic liquid air discharged from the exchanger.

Other objects, features and advantages will become apparent upon reference to the succeeding detailed description of the invention, and to the drawing illustrating the preferred embodiment of the invention.

The drawing schematically illustrates the invention em-

bodied in an air breathing type engine, such as the turbofan **10**. It has a supersonic inlet **12** through which the incoming air passes into a diverging passage **14** leading to a single stage fan **16**. Fan **16**, in this instance, has a single rotor **18** adapted to be suitably driven at all times by a turbine or similar device (not shown). The rotor wheel has a row of circumferentially spaced rotor blades **20** mounted thereon and cooperating with a similar number of spaced stator guide vanes **22**. Vanes **22** are secured to a stator vane assembly **24**, which is fixed to the engine casing by struts or other suitable means (not shown).

The fan **16** discharges the air in a known manner into a diverging annular diffusion passage **28**, which in turn opens up into an afterburner combustion chamber **30**, only the inlet of which is shown. The combustion chamber chamber contains a number of circumferential rows of spaced fuel and liquid air spray bars **32** and **34**, respectively, therein for burning of the mixture in the chamber.

Further details of the engine per se are not given since they are known and are believed to be unnecessary for an understanding of the invention.

In this particular engine, liquid air is combined with a cryogenic fuel in the combustion chamber and the resulting mixture is burned to produce the desired thrust force.

To provide a continuous supply of liquid air to the chamber for burning and whatever other purposes may be desired, a portion of the air discharged from the fan **16** into the diffusion passage is by-passed therefrom through an annular ducting **36** into the inlet of a condenser type heat exchanger **38**. Exchanger **38** is illustrated only schematically and would generally be secured on the outside of the engine.

Exchanger **38** may be of a known cross-flow type having a cylindrical casing **40** with an air inlet **42** at one end and a liquid air conical collector **44** at the other end. The exchanger has a main chamber **46** having a liquid coolant inlet **48** and outlet **49**, and is operably sealed from the air inlet and outlets **42** and **44** to prevent intermixing of the two fluids. Extending lengthwise of the chamber and sealingly projecting through opposite ends of the casing are a number of hollow flat open end air flow tubes **50**. Tubes **50**, which are spaced crosswise of the chamber, have corrugated sheet metal cooling fins **52** therein, and receive the air from inlet **42** into their open ends.

Further details of the exchanger beyond those already described are not given since they are believed to be unnecessary for an understanding of the invention and may be known. Reference may be made, however, to U.S. Pat. No. 2,988,335 of Disinger et al. entitled Heat Exchangers, issued June 13, 1961, showing and describing an exchanger of this type. Suffice it to say, therefore, that the liquid coolant is pumped into the chamber **46** through inlet **48** from the outlet **53** of a centrifugal pump **54**, circulates through the chamber and around the tubes **50** absorbing the heat from the air passing through the tubes, and passes into outlet **49** to the fuel spray bars in the combustion chamber of the engine as indicated schematically by the line **56**. The coolant in this instance is a cryogenic liuid fuel, such as liquid hydrogen, for example, and its use as a coolant prior to its burning in the combustion chamber would not affect its burning qualities, and would save space and result in other economies by eliminating the use of a separate coolant. The cryogenic fuel would have a very low temperature (—400° F., for example), and a high specific heat capacity. The fuel in passing through the exchanger chamber **46** would be vaporized by the absorption of the heat from the air in the tubes, but otherwise unaffected as already stated.

The air passing through tubes **50**, therefore, is cooled to a point when it changes to liquid air and condenses on the fins **52**. The liquid air then flows by gravity out of the ends of the tubes and into the conical collector **44**. Collector **44** is connected to the inlet **57** of a centrifugal pump **58**, which may be driven either by the fan drive shaft (not shown) directly, through reduction gearing by the engine accessory drive shaft (not shown), by a separate electric motor (not shown), or by any other suitable means. Pump **58**, like pump **54**, may be of a known type having a centrifugal impeller delivering the liquid air under pressure into an outlet **62** connected by a conduit **64** (indicated schematically) to the spray bars in the combustion chamber. The pumps are each of a capacity to present the fuel and liquid air to the combustion chamber at the proper pressure in accordance with known design practices for combination and burning in the chamber.

Turning to the invention, as stated previously, any moisture in the form of carbon dioxide, water vapor or the like present in the air entering the exchanger would condense on the fins **52** and solidify thereon in the form of ice as the temperature of the air is reduced below the freezing point of the moisture. This would quickly build up in layers until the entire tube is blocked, preventing the passage of air therethrough. This would quickly cause failure of the engine.

Therefore, to eliminate this problem, a portion of the liqid air from pump **58** passes, as indicated schematically by the branch line **66**, into the inlets of a number of circumferentially spaced spray nozzles **68** (only one shown). Nozzles **68** are each secured to the bypass ducting **36**, and have orifice type spray heads **70**. The spray heads project into the ducting and spray the liquid air across the duct and mix it with all the air passing through the ducting. Immediately, therefore, the temperature of the incoming air is reduced to approximately −50° F. to −100° F. so that the moisture contained therein is immediately frozen and converted to its solid state or phase in the form of fine dust or minute snow particles. These particles will then pass through the exchanger without adhering thereto in the same manner as small dirt particles, since the temperature of the particles is well below their melting point. The small ice particles being in suspension will not block up the inlet to the pump **58**.

While not shown, since it is not necessary, a particle separator could be used if desired on the outlet side of the pump **58** to separate out the ice particles. Also, if desired, an automatically operated twoway shut-off valve **72** may be positioned in the line **64** at the junction with the branch line **66** so that at high altitudes where practically no moisture or water vapor exists, the spraying device may be shut off to conserve liquid air. Furthermore, positive displacement type pumps could be used in place of the centrifugal pumps without invention if a lower volume of pumping would suffice.

The operation of the invention is believed to be clear from a consideration of the drawing and the previous description and, therefore, will not be repeated. Suffice it to say, however, that the pumps would be primed to assure precooling operation immediately upon fire-up of the engine and the passage of air through the exchanger to prevent even a small amount of icing.

From the foregoing, therefore, it will be seen that this invention provides an apparatus for preventing the icing of a heat exchanger by precooling the incoming air to a temperature to solidify any moisture contained therein into minute ice particles which pass through the exchanger without adhering thereto.

While the invention has been illustrated in its preferred embodiment in connection with a heat exchanger in a jet engine, it will be obvious to those skilled in the arts to which this invention pertains that the invention may be used in installations other than that illustrated and many

modifications can be made thereto without departing from the scope of the invention.

I claim:

1. In a method of minimizing coil frosting in reducing the temperature of a flowing gas substantially above freezing to well below freezing while passing it through successive cooling coils; mixing a volume of sufficiently low temperature auxiliary fluid with a main gas volume, which has a temperature above freezing, to produce a temperature of said combined gas and fluid below freezing before passing said main gas volume in heat exchanging relation with a cooling coil having a surface temperature below freezing.

2. A method as recited in claim **1** in which the main gas colume is air in a gaseous phase and the auxiliary fluid is air in a liquid phase.

3. In a method of minimizing frosting of a cooling coil having a surface temperature below freezing:

(a) reduciing the temperature of a flowing gas from above freezing to below freezing by mixing a volume of sufficiently low temperature auxiliary fluid with a main gas volume, which has a temperature above freezing, to produce a temperature of the combined gas and fluid below freezing;

(b) and then passing said combined gas and fluid in heat exchanging relation through said coil.

4. A method as recited in claim **3** in which the main gas volume is air in a gaseous phase and the auxiliary fluid is air in a liquid phase.

5. The combination with an air-breathing jet propulsion engine having an air inlet, a fan supplied through the inlet, and combustion apparatus supplied with compressed air through the fan of a comburent supply system comprising, in combination, a source of cryogenic fuel, means for bleeding air from the engine fan outlet, a duct conveying the air from the bleeding means, means for diffusing and evaporating liquid air directly into the bled air in the duct in sufficient quantity to lower the temperature below the freezing point of water and thus solidify water in the air and cause it to be carried through the duct in suspension as a solid in the air, an indirect heat exchanger supplied by the duct including means for further cooling and liquefying the air by heat exchange with fuel from the said source, means conducting the fuel heated by the said heat exchanger to the engine combustion apparatus, means supplying the liquid air from the heat exchanger to the engine combustion apparatus, and means for diverting a portion of the liquid air to the said diffusing means.

6. The combination with an air-breathing jet propulsion engine having an air inlet, a fan supplied through the inlet, and combustion apparatus supplied with compressed air through the fan of a comburent supply system comprising, in combination, a source of cryogenic fuel, means for bleeding air from the engine fan outlet, a duct conveying the air from the bleeding means, means for diffusing and evaporating liquid air directly into the bled air in the duct in sufficient quantity to lower the temperature below the freezing point of moisture in the air and thus solidify the moisture and cause it to be carried through the duct in suspension as a solid in the air, an indirect heat exchanger supplied by the duct including means for further cooling and liquefying the air by heat exchange with fuel from the said source, means conducting the fuel heated by the said heat exchanger to the engine combustion apparatus, means supplying the liquid air from the heat exchanger to the engine combustion apparatus, and means for diverting a portion of the liquid air to the said diffusing means.

7. A combustion system for a gas generator comprising a source of first gaseous ingredient, a cryogenic fluid fuel, said first ingredient containing moisture, a heat exchanger, means for passing said first gaseous ingredient through said heat exchanger, means for passing said fuel through said heat exchanger in heat exchange relation with said first ingredient for liquefying the latter, means for elimi-

nating ice accumulation in the system including means for circulating a portion of the liquefied first ingredient for injection into the gaseous ingredient upstream of said heat exchanger for freezing the moisture therein prior to passage through said heat exchanger whereby the frozen moisture passes as an ice cloud through said exchanger, and combustion chamber means downstream of said heat exchanger for combining said first ingredient with said fuel.

8. In an air-breathing power plant having a compressor and a turbine connected to drive the compressor, a cryogenic fuel supply, means for diverting a portion of the air discharged by said compressor, a heat exchanger, means for passing said diverted air directly through said heat exchanger, means for passing fuel from said supply through said heat exchanger to liquefy said diverted air, means for connecting the liquid air and the fuel exhausted from said heat exchanger to said power plant for burning therein, means for eliminating the accumulation of ice in said diverting means and said heat exchanger comprising means conducting a portion of the liquid air to said diverting means, and means for injecting said last-mentioned liquid air into the airstream in said diverting means to freeze any moisture in the air which moisture passes in the form of an ice cloud through said exchanger.

9. The combination with an air-breathing jet propulsion engine having an air inlet, a fan supplied through the inlet, and combustion apparatus supplied with compressed air through the fan of a comburent supply system comprising, in combination, a source of cryogenic fuel, means for bleeding air from the engine fan outlet, a duct conveying the air from the bleeding means, means for diffusing and evaporating liquid air directly into the bled air in the duct in sufficient quantity to lower the temperature below the freezing point of moisture in the air and thus solidify the moisture and cause it to be carried through the duct in suspension as a solid in the air, an indirect heat exchanger supplied by the duct including means for further cooling and liquefying the air by heat exchange with fuel from the said source, means conducting the fuel heated by the said heat exchanger to the engine combustion apparatus, means supplying the liquid air from the heat exchanger to the engine combustion apparatus, and means for diverting a portion of the liquid air to the said diffusing means.

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