Oct. 4, 1966 W. T. OSBORNE 3,276,226

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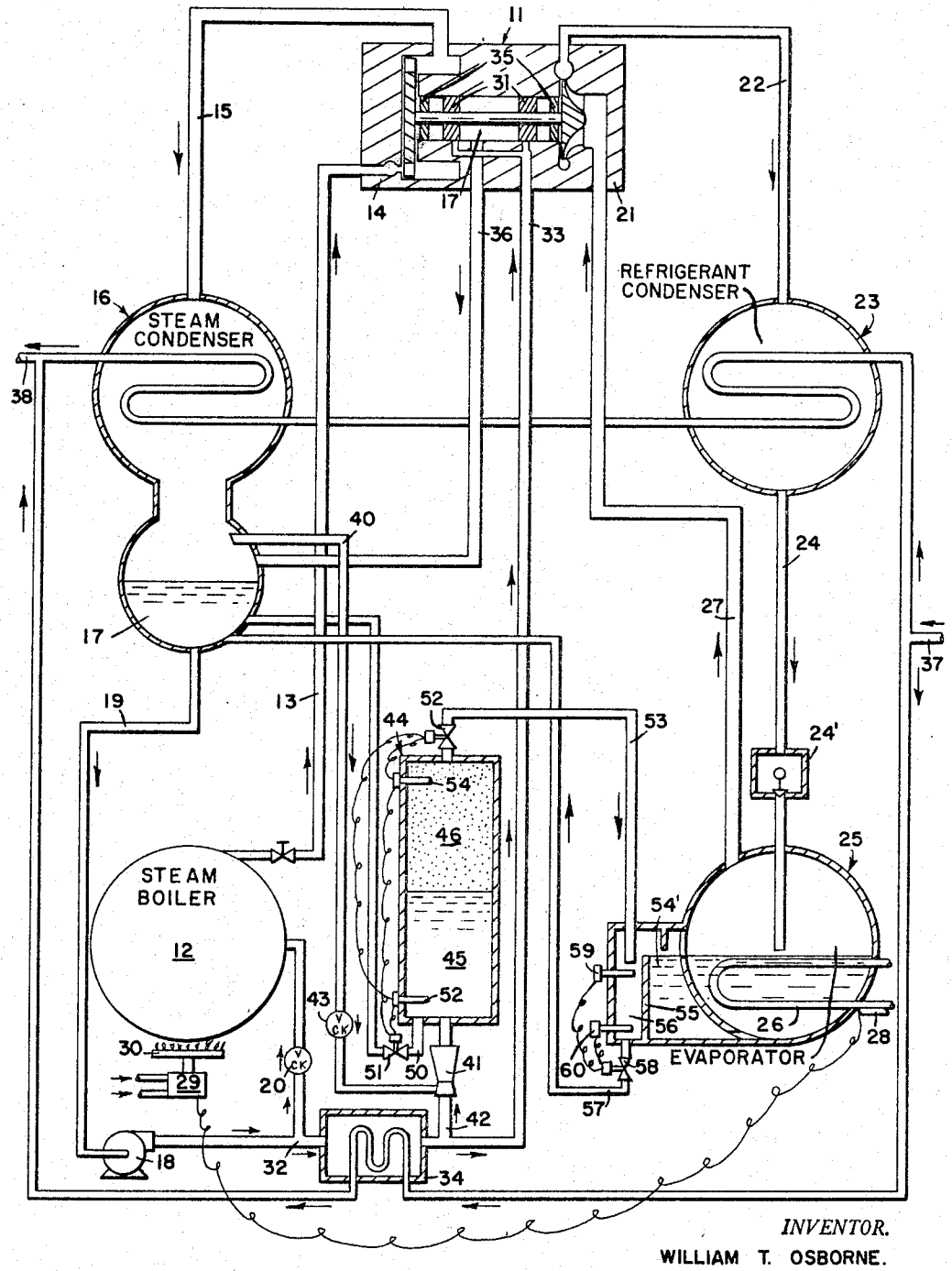
Filed Oct. 8, 1964



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United States Patent Office 3,276,226 Patented Oct. 4, 1966

3,276,226

REFRIGERATION SYSTEM WITH TURBINE DRIVE FOR COMPRESSOR

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Filed Oct. 8, 1964, Ser. No. 402,395
5 Claims. (Cl. 62—474)

This invention relates to purging and balancing fluids in a refrigeration system and, more particularly, to separating fluids mixed during operation of the system and returning separated fluids for reuse in the system.

A heating and cooling system is discussed in my prior copending United States patent application for a "Cooler," Serial No. 377,317, and filed June 23, 1964. This system incorporates a steam driven turbocompressor, and the cooling capacity of the system is regulated responsive to the output of the turbocompressor which is regulated by blanketing a portion of a steam condenser with noncondensible (refrigerant) vapor to vary the discharge pressure of the turbine side of the turbocompressor. Any leakage of steam or refrigerant within the turbocompressor is passed to the steam condenser and along with any other refrigerant entering the steam condenser is mixed with water vapor therein, and a purge system passes the vapors from the steam condenser to a cooler. The mixed fluids are separated in the cooler and the refrigerant is passed through the refrigerant side of the system and the power fluid is returned to the power side of the system, for reuse in the system. Steam condensate is returned from the steam condenser to a steam generator by means of a steam condensate pump, and a separate water supply pump is used for operating the purge system and for passing the water power fluid from the cooler back to the steam power side of the system. Excessive water vapor in the cooler may reduce the efficiency of the cooler somewhat because it places an artificial load on the compressor. Furthermore, a plurality of water pumps is required, thus increasing the cost and complexity of the system.

It is a primary object of this invention to provide a new and improved refrigeration system and a method of providing refrigeration.

Another object is to provide a new and improved purging and balancing arrangement in a refrigeration system and a method of purging and balancing a refrigeration system.

Another object is provision in a refrigeration system of new and improved means and method for separating mixed fluids in the system and returning at least one of the separated fluids for reuse in the system.

These and other objects of the invention will be apparent from the following description and the accompanying drawing which is a flow diagram of a refrigeration system illustrating an embodiment of apparatus incorporating features of the invention.

The illustrated refrigeration system is preferably hermetic for effectively containing fluids in the system and preventing ambient air from entering the system. The system may be considered as having a power side including a circuit for circulation of a power fluid, a refrigerant side including a circuit for the flow of a refrigerant fluid under the influence of drive means driven by the power fluid, with suitable means for regulating the capacity of the refrigeration system.

The invention will be described with reference to a preferred power fluid, which is water, and a preferred refrigerant which is octafluorocyclobutane, commonly referred to as C318 and having a chemical formula C_4F_8. These fluids are particularly preferred because of their relative immiscibility and because they are inherently

highly stable and do not tend to decompose or chemically react with each other or other materials in the system, or cause or promote corrosion or undesirable by-products. Also, this refrigerant is a relatively noncondensible vapor at the temperatures and pressures at which the power fluid (water) condenses, as well as at the usual ambient atmospheric conditions of temperature and pressure. However, other power fluids and refrigerants having the required chemical and physical properties may be utilized within the scope of this invention.

As is more fully described in the aforementioned patent application, the drawing illustrates a refrigeration system incorporating a turbocompressor **11**. A power side of the refrigeration system includes a steam generator **12** which passes steam through a steam supply line **13** to a turbine section **14** of the turbocompressor **11** for driving the turbocompressor. From the turbine **14** the steam passes through a steam discharge line **15** to a steam condenser **16** from which the resultant condensate flows into a steam condensate chamber **17** defining a second zone. From the condensate chamber **17** a steam condensate or water pump **18** in a steam condensate line **19** returns the condensate through a check valve **20** to the steam generator **12** for recirculation through the power side of the system. A refrigerant side of the system includes a refrigerant compressor section **21** of the turbocompressor **11**. The compressor **21** is driven by the turbine **14** for passing high pressure refrigerant vapor through a high pressure line **22** to a refrigerant condenser **23** from which the refrigerant condensate passes through a refrigerant condensate line **24** and flow metering device **24'** and into a suitable cooler or evaporator **25** defining a first zone and having a chilled water line including a chilled water bundle **26** flooded in liquid refrigerant in the cooler for cooling chilled water circulated to a load having a cooling requirement. From the cooler **25**, refrigerant vapor returns to the compressor through a suction line **27** for recirculation through the refrigerant side of the system. Means for controlling the cooling capacity of the system may be of any desired type, and in the aforementioned patent application capacity control is provided by controlled blanketing of a condensing portion of the steam condenser with a noncondensible (refrigerant) vapor to reduce the condensing capacity of the steam condenser below its maximum condensing capacity, thereby regulating the turbine steam discharge pressure while preferably substantially constant pressure steam is supplied to the turbine in order to regulate the compressor refrigerant output. Alternatively, the system capacity may be regulated as by inlet guide vanes on the compressor, or as shown in the drawing, by regulating the heat input to the steam generator **12**, for example, as by a suitable sensor **28** on the chilled water line **26** which actuates a regulator **29** to control the quantity of fuel and air delivered to a steam generator burner **30**.

The turbocompressor **11** is preferably provided with water lubricated bearings **31**, and a water supply line **32** branches off of the steam condensate line **19** downstream of the water pump **18** for supplying lubricant water through a lubricant water line **33** to the turbocompressor **11**. The water supply line **32** is provided with a heat exchanger **34** for cooling the water passing therethrough. Lubricant water, and any leakage of steam or refrigerant which may pass suitable seal means **35** in the turbocompressor **11**, passes through a drain line **36** and into the steam condensate chamber **17**. The condensers **16** and **23** and the heat exchanger **34** are preferably provided with cooling tower water through a suitable tower water circuit, which as illustrated, includes a tower water inlet line **37** from a suitable cooling tower (not shown) and a tower water return line **38** back to the tower.

Any refrigerant or other noncondensible vapor such

as air in the power side of the system passes into the steam condenser **16** from which it is withdrawn by a purge system. The purge system includes a purge line **40** opening into the steam condensate chamber **17** for withdrawing the noncondensible vapor and any water vapor carried therewith and passing these mixed vapors to a jet pump **41** which receives cooled impelling water through an impeller water line **42** branching off of the water supply line **32** downstream of the cooling heat exchanger **34**. The purge line **40** has a check valve **43** to prevent reverse flow into the steam condenser **16**. The jet pump **41** discharges the mixture of impeller water and the noncondensibles into a separator chamber or vessel defining a third zone at a lower elevation than the steam condensate chamber **17** to provide a static head therebetween. A suitably low temperature is provided the impeller water by means of the heat exchanger **34** so that water vapor in the purge line **40** condenses and along with the impeller water collects in a body of water **45** in a lower portion of the separator chamber as the noncondensibles **46** discharged from the jet pump **41** rise to the top of the separator chamber **44** and are trapped therein. The operating pressures and temperature ranges in the separator chamber **44** are such that the refrigerant remains in vapor form along with other noncondensibles such as air introduced into the separator chamber, thus separating the water power fluid and the noncondensibles **46** in the upper portion of the separator chamber.

During a purging cycle, water from the body of water **45** returns to the steam condensate chamber **17** through a first water return line **50** and a normally open solenoid valve **51** in the line **50**. As purging continues, the noncondensibles continue to collect in the chamber **44** and the water volume in the chamber **44** is slowly displaced. When sufficient non-condensibles **46** have collected to displace the water level down to a first electrically actuated probe sensor **52**, the solenoid valve **51** is actuated to closed position. A normally closed second solenoid actuated valve **52** in a refrigerant return line **53** between the upper portion of the separator chamber **44** and the cooler **25** is simultaneously opened to commence an exhausting cycle. As water and noncondensible continue to pass into the separator chamber **44** the level of the water in the separator chamber rises and the noncondensibles flow into the cooler. After about thirty seconds, the water in the separator chamber engages a second electrically actuated probe sensor **54** near the top of the separator chamber to again open the solenoid valve **51** and close the solenoid valve **52**. The residual noncondensibles **46** in the separator chamber **44** will expand slightly causing the water level to drop slightly when the valve **51** opens and the valve **52** closes and because of the static head between the steam condenser chamber **17** and the separator chamber **44** the pressure in the separator chamber is now only slightly greater than the pressure in the steam condensate chamber **17**. Water from body of water **45** flows from the separator chamber to the steam condensate chamber until again after collecting sufficient noncondensibles the water level in the separator chamber **44** drops below the first probe sensor **52** whereupon the cycle is repeated.

During cooling operation, the cooler **25** is normally at about 5 p.s.i.g., and the steam condenser **16** is normally at about 27" Hg vacuum.

Refrigerant passing from the refrigerant condenser **23** through the refrigerant condensate line **24** and into the cooler **25** may carry some water with it, and such water will normally float atop the heavier liquid refrigerant in the cooler and collect in a relatively tranquil area **54'** from which it flows across a suitable weir **55**, or the like, and into a pool or sump of water **56**, as is more fully described in the aforementioned copending patent application. Similarly, any water vapor carried with the refrigerant vapor through the refrigerant vapor line **53** may condense and settle on the body of boiling refrigerant from which it similarly passes into the pool of water **56**.

In order to return water from this pool to the steam condenser **16**, a second water return line **57** connects the cooler **25** and the steam condensate chamber **17** and is provided with a normally closed third solenoid actuated shut-off valve **58** which is opened when the water level of the pool engages an upper electrically actuated probe sensor **59** and is closed when the water level drops below a lower electrically actuated probe sensor **60**. The differential in pressure between the cooler **25** and steam condenser **16** forces the water into the steam condenser.

The system is particularly suited for high pressure machines having a steam operating pressure in the range of 75 p.s.i.g. or greater since such a system requires a high head pump **18** to handle the steam condensate and therefore a greater pressure is available to operate the jet pump **41** for withdrawing the noncondensibles from the steam condenser **16** and providing sufficient force to purge the steam condenser during the start-up of the system when the pressures throughout the system may be very high, for example, 50 p.s.i.g.. The system is applicable for use with many types of capacity control systems for example, a blanketing control system, burner throttling control, inlet guide vane control or a combination thereof for maximum operating efficiency. The pumping functions are combined in one basic pump, that is the water pump **18** which provides lubricant water to the turbocompressor bearings **31**, steam condensate to the steam generator **12**, and impeller water to the jet pump **41** for operating the purge system, thus reducing the initial and maintenance costs of the system. Furthermore, by providing steam condensate to the jet pump **41**, the impeller water is almost entirely refrigerant free to avoid flashing and the jet pump may be relatively small since its efficiency is greatly increased, and less lift is required from the steam condenser **16** to the separator chamber **44** than to the cooler **25** which is at a higher pressure. Also, very little water is introduced into the cooler **25**, thus providing better cooler boiling coefficients, and effectively eliminating artificial compressor loading from water vapor on the refrigerant side of the system while permitting simplified and more flexible cooler construction. The system is applicable for use with direct expansion coolers.

While a preferred embodiment of the invention has been described and illustrated, it will be understood that the invention is not limited thereto since it may be otherwise embodied within the scope of the following claims.

I claim:

1. A refrigeration system comprising a power side operable for circulating steam power fluid and including a steam condenser at a relatively low pressure and in circuit with a steam generator, and means including a steam condensate pump for passing steam condensate from said condenser to said generator, a refrigerant side operable responsive to operation of said power side for circulating a refrigerant fluid having a lower boiling point than water and including a compressor, a refrigerant condenser and a cooler at a higher pressure than said steam condenser, the compressor, the refrigerant condenser and the cooler being placed in circuit for the passage therethrough of said refrigerant fluid to provide cooling during cooling operation of the system, said compressor being actuated by said power side and in communication therewith so that a mixture of power fluid and noncondensible fluid including at least refrigerant fluid are in said steam condenser, means for separating the mixed fluids and returning at least one of the separated fluids for reuse in the system and including a closed vessel, purge means including a jet pump connected to said vessel for discharging into said vessel and to said steam condensate pump for receiving impeller water therefrom, means including a purge line between said steam condenser and said jet pump for the passage of noncondensible vapor and any water vapor carried thereby from said steam condenser to said vessel, means for providing a temperature in said vessel to condense the water vapor

passed to said vessel, whereby the noncondensible vapor collects above a body of water in said vessel, a water line having a normally open first valve between said vessel and said steam condenser for passing the water from said vessel to said steam condenser, and a refrigerant vapor line having a normally closed second valve between said vessel and said cooler for passing the refrigerant vapor from said vessel to said cooler when said second valve is open.

2. A refrigeration system, comprising a refrigerant side operable for providing cooling including a compressor, a condenser and a cooler, the cooler forming a first zone for receiving refrigerant fluid, a power side for circulating a power fluid to operate said compressor and having a second zone for containing mixed power and refrigerant fluids, and means for separating the mixed fluids and passing the separated fluids for reuse on their respective sides of the system including a third zone providing means for separating the mixed fluids, means for passing the mixed fluids from said second zone to said third zone to separate the mixed fluids, means for normally passing the separated power fluid to said power side until a low liquid level is reached in said third zone, and means for then passing the separated refrigerant vapor from said third zone to said first zone until a high liquid level is reached in said third zone.

3. A refrigeration system comprising a turbocompressor, a power side for circulating steam power fluid and including a steam condenser at a relatively low pressure and a steam generator in circuit for operating said turbocompressor, and means including a steam condensate pump for passing steam condensate from said condenser to said generator, a refrigerant side responsive to operation of said turbocompressor for circulating a refrigerant fluid heavier than and having a lower boiling point than water and including the compressor of the turbocompressor, a refrigerant condenser and a cooler at a substantially higher pressure than said steam condenser, the compressor, the refrigerant condenser and the cooler being placed in circuit for the passage therethrough of said refrigerant fluid to provide cooling during cooling operation of the system, the compressor being actuated by the turbine of the turbocompressor and in communication therewith so that a mixture of power fluid and noncondensible fluid including at least refrigerant fluid are in said steam condenser, means for separating the mixed fluids and returning at least one of the separated fluids for reuse in the system including a closed vessel at a lower elevation than said steam condenser, purge means including a jet pump connected to said vessel for discharging into said vessel and to said steam condensate pump for receiving impeller water therefrom, means including a purge line between said steam condenser and said jet pump, means for passing noncondensible vapor and any water vapor carried thereby from said steam condenser to said vessel, means for providing a temperature to condense the water vapor passed to said vessel whereby the noncondensible vapor collects above a body of water in said vessel, a water line having a normally open first valve between said vessel and said steam condenser for passing water from said vessel to said steam condenser when said valve is open, a refrigerant vapor line having a normally closed second valve between said vessel and said cooler for passing the refrigerant vapor from said vessel to said cooler when said second valve is open, and valve operating means for opening said first valve and closing said second valve at a high water level in said vessel and closing said first valve and opening said second valve at a water level below said high level.

4. A refrigeration system comprising a turbocompressor having water lubricated bearings, a power side for circulating steam power fluid and including a steam condenser at a relatively low pressure and a steam generator in circuit for operating said turbocompressor, and means including a steam condensate pump for passing steam condensate from said condenser to said generator and to said bearings to lubricate the bearings, a refrigerant side for circulating a refrigerant fluid heavier than and having a lower boiling point than water and including the compressor of the turbocompressor, a condenser and a cooler at a substantially higher pressure than said steam condenser and in circuit for the passage therethrough of said refrigerant fluid to provide cooling during cooling operation of the system, the compressor being actuated by the turbine of the turbocompressor and in communication therewith so that a mixture of power fluid and noncondensible fluid including at least refrigerant vapor are in said steam condenser, means for passing to said steam condenser the lubricating water from said bearings and any leakage of steam or refrigerant within said turbocompressor, means for removing said noncondensibles from said steam condenser and separating the mixed noncondensible and power fluids and returning the separated refrigerant and power fluids for reuse on their respective sides of the system including a closed vessel, purge means including a jet pump connected to the vessel for discharging into said vessel and to said steam condensate pump for receiving impeller water therefrom, a purge line between said steam condenser and said jet pump for passing the noncondensible vapor and any water vapor carried therewith from said steam condenser to said vessel and including a check valve for effectively preventing reverse flow into said steam condenser, means for cooling the impeller water to condense the water vapor whereby the noncondensible vapor collects above a body of water in said vessel, a water line having a normally open first shut-off valve between said vessel and said steam condenser for passing water from said vessel to said steam condenser responsive to the pressure difference therebetween when said first valve is open, a refrigerant vapor line having a normally closed second shut-off valve between said vessel and said cooler for passing the refrigerant vapor from said vessel into said cooler when said second valve is open, and means for closing said first valve and opening said second valve at low water level in said vessel and opening said first valve and closing said second valve at high water level in said vessel.

5. A system according to claim 4 including means for collecting water in said cooler in a pool of water, a second water line having a normally closed third shut-off valve between said cooler and said steam condenser for passing water from said pool to said steam condenser when said third valve is open, and means for opening said third valve responsive to a high level of said pool to pass the water to said steam condenser and for closing said third valve when the water level drops below said high level.

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