

May 28, 1968

J. E. EMBURY
HEAT EXCHANGER UNIT

3,385,348

Filed June 23, 1964

2 Sheets-Sheet 1

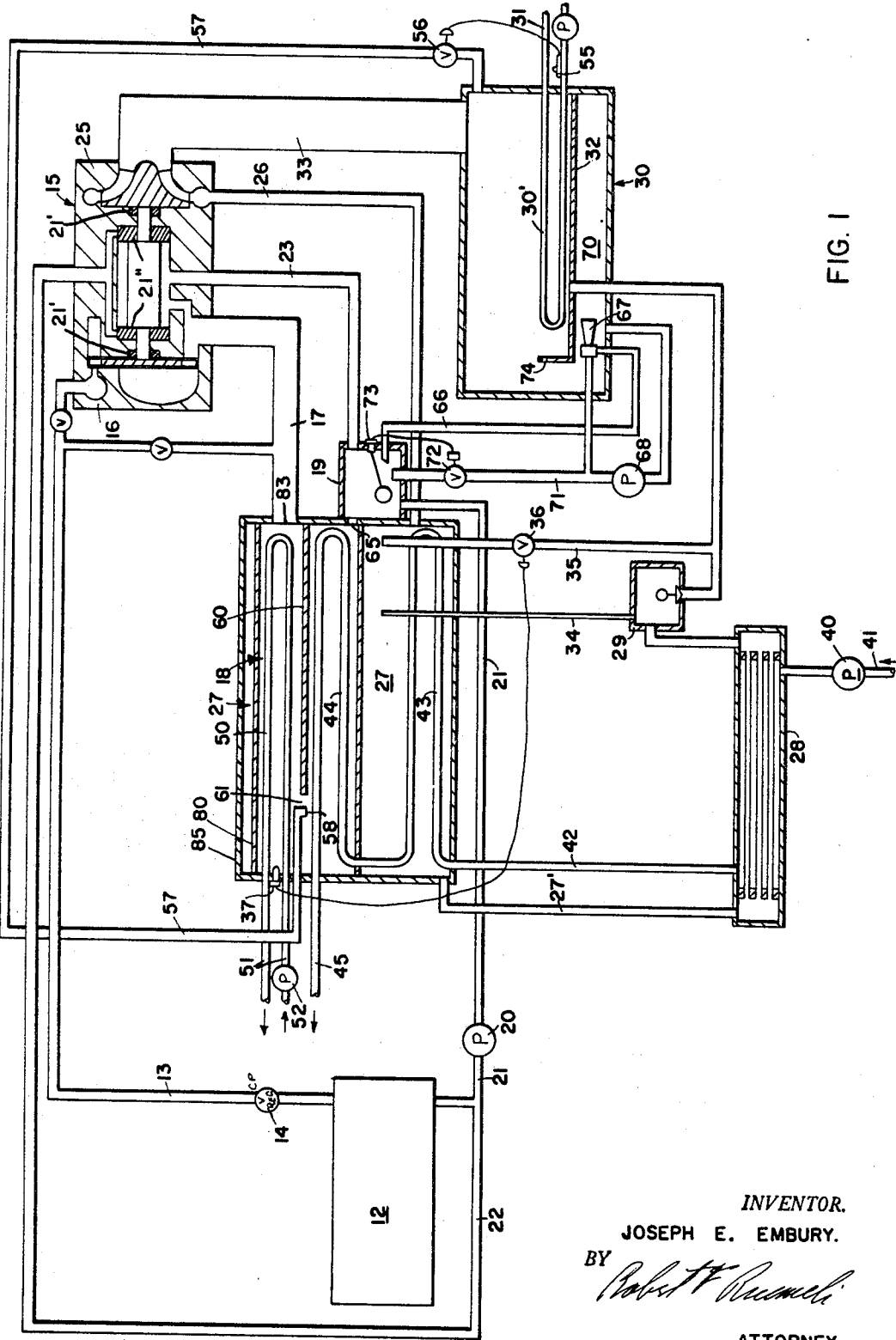


FIG. 1

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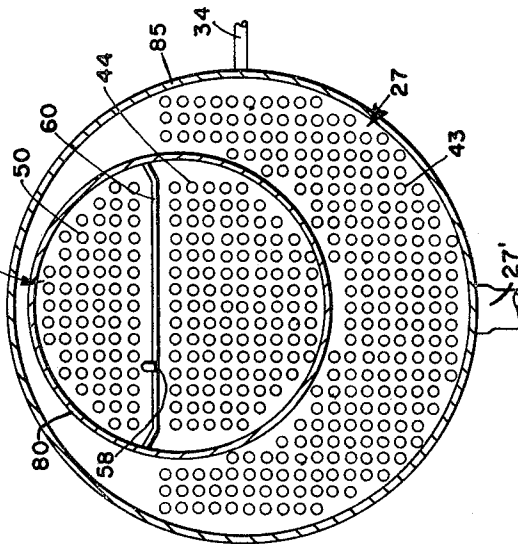
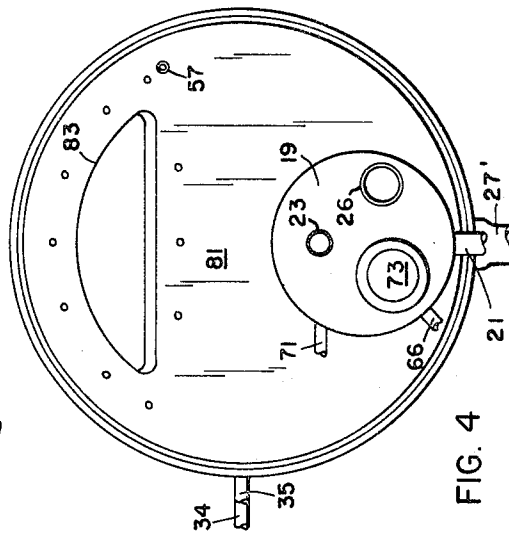
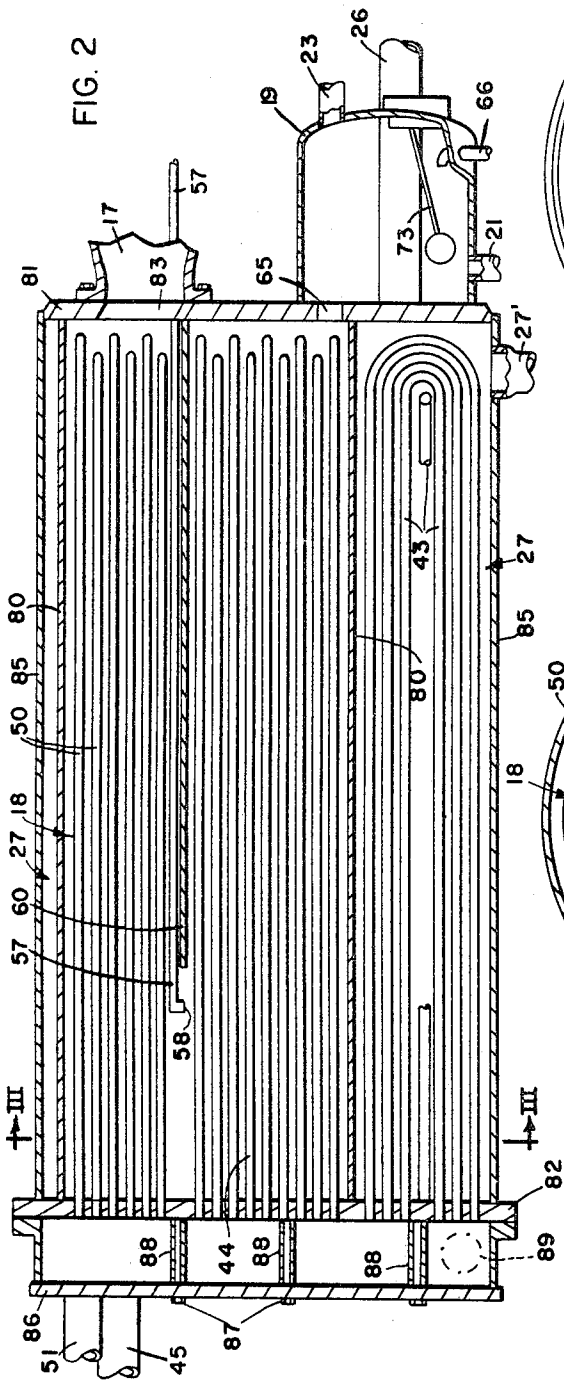
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2 Sheets-Sheet 2



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3,385,348

HEAT EXCHANGER UNIT

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8 Claims. (Cl. 165—1)

ABSTRACT OF THE DISCLOSURE

A refrigeration system condensing unit having a steam condenser normally operable below ambient air pressure surrounded by a refrigerant condenser for confining refrigerant fluid normally at a pressure above ambient air pressure so that ambient air is prevented from entering the condensers through leaks therein. Leaks in the steam condenser draw refrigerant from the refrigerant condenser; leaks in the refrigerant condenser eject refrigerant to ambient atmosphere.

This invention relates generally to a heat exchanger and to a method of heat exchange and, more particularly, to a condensing unit in a refrigeration system, and to a method of condensing fluids, as steam and refrigerant, in such a system. The invention encompasses a condensing unit including a steam condenser enveloped by a refrigerant condenser, thus effectively preventing leakage of ambient air into the condensing unit and insulating the steam condenser.

Leakage of air into most refrigeration systems is generally undesirable in that such leakage often causes serious corrosion problems and reduces the efficiency of the system. In steam driven compressors this can be particularly troublesome in that efficient operation of the steam side of the system usually requires that a steam condenser operate below ambient atmospheric pressure so that any leaks in the steam condenser result in air flowing into the condenser. Furthermore, it is often practical to use a steam condenser for providing heat to a load to be heated. Such usage makes it desirable that the steam condenser be insulated in order to avoid heat loss, and even without serving a load to be heated it may be desirable to insulate the steam condenser in order to avoid excessive heating of the area about the steam condenser and to facilitate controlling the steam condensing rate. For example, in three-pipe air conditioning installations, both cooling and heating water are piped throughout the installation so that air circulating within the various areas can be regulated independently to a desired temperature.

The refrigeration system disclosed in this application is more fully described in a copending United States patent application of Louis H. Leonard for a "Heating and Cooling System," Ser. No. 377,258, filed June 23, 1964, now Patent Number 3,303,872. This system is particularly well suited to service in conjunction with a three-pipe air conditioning installation, in that the heating capacity of the steam condenser varies inversely of the cooling capacity of the system, and this is particularly desirable in three-pipe systems since, when the cooling demand is relatively high the heating demand is relatively low, and when the heating demand is high the cooling demand is relatively low. In the present system, the steam condenser is enveloped within the refrigerant condenser, thus insulating the steam condenser from ambient air and effectively preventing the entry of ambient air through leaks in the condensing unit.

It is a primary object of this invention to provide a new

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and improved heat exchanger and method of heat exchange and, more particularly, a steam and refrigerant condensing unit particularly suited for use in a refrigeration system.

Another object is to provide a new and improved compact condenser assembly, particularly suited for use in a refrigeration system for heating and cooling, thus saving space.

A still further object is provision of a new and improved heat exchanger assembly embodied in a refrigerant and steam condensing unit, and a method for effectively insulating a steam condenser and preventing leakage of air into the unit. A related object is provision of such a unit and method for encasing a steam condenser with refrigerant. Another related object is provision for withdrawing refrigerant from the steam condenser.

A still further object is provision of a new and improved refrigeration system condensing unit and method of operation in which leakage of ambient air into the system is effectively prevented during operation and at shutdown of the system. A related object is provision of such a system which is pressurized at shutdown.

These and other objects of the invention will be apparent from the following description and the accompanying drawings, in which:

FIGURE 1 is a flow diagram of a refrigeration system adapted for use to either heat or cool or to heat and cool a heat exchange medium and including the condensing unit of this invention.

FIGURE 2 is a longitudinal side view partly in section of the condensing unit and associated apparatus with parts broken away for clearer illustration;

FIGURE 3 is a vertical sectional view taken generally along the line III—III in FIGURE 2; and

FIGURE 4 is an end view from the right of the unit shown in FIGURE 2, with a part removed for clearer illustration.

Referring to the drawings, the condensing unit is illustrated in FIGURE 1 in a refrigeration system for providing simultaneous heating and cooling. A power side of the system includes a steam generator 12, for example a boiler, which discharges steam into a steam line 13 including a constant pressure steam regulating valve 14 for providing constant pressure steam to a turbocompressor 15 and, more particularly, to a turbine 16 thereof. The turbine 16 discharge saturated steam through a steam discharge line 17 opening into a steam condenser 18 including a steam condensate chamber 19 at one end from which the steam condensate is returned by means of a steam condensate pump 20 through a steam condensate return line 21 to the steam generator 12. The turbocompressor 15 is preferably provided with seals, as 21' and water lubricated bearings, as 21". Steam condensate is provided through a lubricant water line 22, by means of the steam condensate pump 20, for lubricating the bearings. Any leakage of steam or refrigerant, and the lubricating water, is removed from the turbocompressor 15 through a drain line 23 opening into the steam condensate chamber 19 of the steam condenser, as is more fully described in the previously mentioned Leonard application.

A refrigerant side of the refrigeration system includes a compressor 25 of the turbocompressor 15. The compressor 25 passes compressed refrigerant through a refrigerant line 26 to a refrigerant condenser section 27 of the improved heat exchanger forming the subject of this invention, from which the condensed refrigerant passes

through a refrigerant condensate line 27' to a refrigerant subcooler 28 and then an expansion valve 29 and into a cooler 30 in which a tube bundle 30' of a chilled water line 31 is flooded with boiling refrigerant in a refrigerant pan 32. As the refrigerant vaporizes from the pan 32 it cools the chilled water tube bundle 30' of the chilled water line 31 and passes through a refrigerant chamber to a suction line 33 back to the compressor 25. In keeping with accepted practice, an equalizer line 34 may be provided between the refrigerant condenser 27 and the chamber housing expansion valve 29, and a hot gas bypass line 35 may be provided, as between the refrigerant condenser and the refrigerant line between the expansion valve 29 and the cooler 30. A hot gas bypass valve 36 in the line 35 is controlled in any suitable manner as by a pressure sensor 37 in the steam condenser 18.

Cooling tower condensing water is circulated by a tower water pump 40 in a tower water supply line 41 which opens into the refrigerant subcooler 28 and then passes through a line 42 into the heat exchanger in the form of a tube bundle 43 in the refrigerant condenser section 27 from which the tower water passes into a first steam condensing portion in the form of a tube bundle 44 in a lower portion of the steam condenser section 18, from which the tower water is returned to the tower through a return line 45.

The steam condenser section 18 may provide heat for a load to be heated, and herein an upper portion of the steam condenser 18 contains a second steam condensing portion in the form of a tube bundle 50 for condensing steam and to be heated thereby for supplying heat through a hot water line 51 including a hot water pump 52.

The heating and cooling capacities of the system are regulated responsive to leaving chilled water temperature when operation under heating and cooling cycle condition. A temperature sensor 55 on a leaving branch of the chilled water line 31 operates a modulating refrigerant valve 56 in a refrigerant line 57 connecting the refrigerant chamber of the cooler 30 with the steam condenser 18. More particularly, the refrigerant line 57 opens into the steam condenser through a refrigerant port 58 between the first and second condensing tube bundles 44 and 50. A baffle 60 extends longitudinally through the steam condenser 18 between the tube bundles 44 and 50 to prevent the passage of fluids between upper and lower portions of the steam condenser except in an area of limited communication 61 at the refrigerant port 58. The discharge steam from the turbine 16 enters the steam condenser in the portion above the baffle 60 and at an end of the steam condenser opposite the refrigerant port 58 and the area of limited communication 61 between the upper and lower portions of the condenser. The entering steam sweeps across the second tube bundle 50 and through the area of limited communication 61 and past the refrigerant port 58 thus sweeping the refrigerant into the lower portion of the steam condenser. This refrigerant blankets the first condensing tube bundle 44 and, more particularly, envelops each tube of the tube bundle to reduce the tube bundle's condensing capacity. The refrigerant vapor is withdrawn through a port 65 into the steam condensate chamber 19 from which it is withdrawn by a purge including a purge line 66 opening into the throat of a jet pump 67 in the cooler 30. The jet pump is operated by impeller water from a water supply pump 68.

The condensing rate of the steam condenser 18 is controlled by the quantity of refrigerant effectively blanketing the first tube bundle 44. As the cooling requirement increases the temperature sensor 55 on the leaving branch of the chilled water line 31 operates the valve 56 in a closing direction to reduce the amount of refrigerant admitted to the steam condenser, thereby reducing the blanketing of the first tube bundle 44 to increase the condensing rate and thereby reduce the steam condenser pressure. Thus, the turbine discharge or back pressure

is reduced, permitting the turbocompressor to operate at a higher power output and generally higher speed, so that the compressor 25 passes a greater volume of refrigerant to the cooler 30, thus increasing the cooling capacity of the system. The heating capacity of the system varies inversely as the cooling capacity, so that as the cooling capacity rises, the heating capacity drops. More particularly, as the blanketing of the first tube bundle 44 is reduced to increase the cooling capacity, the steam condenser pressure drops and therefore the temperature of saturated steam in the condenser also drops so that the second tube bundle 50 operates at a lower temperature reducing the heating capacity of the system. In a converse manner, as the cooling capacity is reduced the heating capacity increases, both responsive to an increase in steam condenser pressure.

Means for separating refrigerant and water or steam power fluid mixed in the refrigeration system is provided as is more fully described in the previously mentioned Leonard application and in a copending United States patent application of William T. Osborne for a "Cooler," Ser. No. 377,317, filed June 23, 1964, now Patent No. 3,279,210. Herein the cooler 30 includes a water sump 70 which contains the jet pump 67. The sump is maintained at about 10° F. above the refrigerant chamber temperature so that refrigerant in the sump is a vapor and passes into the refrigerant chamber. The water in the sump is recirculated by the water supply pump 68 which further provides make-up water for the steam generator 12 through a make-up water line 71 to the steam condensate chamber 19. A make-up water valve 72 in the line 71 is controlled by a float actuated sensor 73 in the steam condensate chamber 19. It should further be noted that the purge line 66 opens into the steam condensate chamber 19 at a level to remove excessive condensate from the chamber and pass it into the sump 70.

Any water in the cooler refrigerant chamber floats atop the refrigerant in the pan 32 and the chilled water tube bundle is spaced a substantial distance from the left-hand wall of the pan 32 so that a relatively quiet pool of liquid refrigerant forms at this wall and the water floats atop this refrigerant and passes through a suitable weir or port 74 in the wall, to the sump 70.

Referring to FIGURES 2-4 the steam condenser 18 and the refrigerant condenser 27 form a condensing unit. Herein an inner steam condenser shell 80 (FIGURE 3) extends between and is suitably welded to an end plate 81 at one end and to a header plate 82 at an opposite end. The baffle 60 is welded at opposite longitudinal edges to the shell 80 and at an end to the end plate 81. The end plate 81 (FIGURE 4) has a steam inlet port 83 above the baffle 60, and the port 65 into the steam condensate chamber 19 at the lowest portion of the steam condenser about even with the bottom of the shell 80. An outer, refrigerant shell 85 is spaced from and envelops the inner shell 80 and has opposite ends welded to the end plate 81 and the header plate 82. The refrigerant condensing tube bundle 43 is between the inner shell 80 and the outer shell 85. All tube bundles are herein in the form of U-tubes having their free ends suitably mounted in and opening through the header plate 82. A header chamber shell 86 is suitably secured across the header plate 82, as by bolts 87, to form a header, and has suitably placed partitions 88 for passing tower water through an inlet 89 from the water line 42, through the refrigerant condensing bundle 43 and then through the first steam condensing bundle 44, and then returning the tower water through the return line 45, and for circulating the water in the second steam condenser tube bundle 50 into and out of the lines 51.

As is generally understood in the art, the steam condenser 18 operates below atmospheric pressure and the refrigerant condenser 27 operates above atmospheric pressure. Thus, by enveloping the steam condenser 18 in refrigerant vapor within the refrigerant condenser 27,

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leaks in the steam condenser draw in refrigerant vapor and leaks in the refrigerant condenser 27 eject refrigerant vapor to the ambient air. At shutdown the steam condenser may be pressurized with refrigerant to effectively prevent the entry of air into the system. Also, the refrigerant condenser and the refrigerant enveloping the steam condenser 18 serve to insulate the steam condenser so that it more efficiently provides heat through the lines 51 to the load to be heated.

Leonard Patent No. 3,304,997, granted Feb. 21, 1967, discloses a steam operated refrigeration system in which the condensing capacity of a steam condenser is varied by selectively regulating the quantity of refrigerant vapor in the steam condenser to blanket the condensing portion of the condenser.

While the 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 method of condensing steam and refrigerant in a refrigeration system and controlling the steam condensing capacity of a steam condenser comprising the steps of continuously passing steam into the steam condenser, condensing the steam in the steam condenser, withdrawing steam condensate from the steam condenser, continuously passing refrigerant vapor about the steam condenser to envelope the steam condenser with said refrigerant vapor thereby insulating the steam condenser and causing leaks in the steam condenser to admit refrigerant rather than ambient air, confining the refrigerant vapor about the steam condenser, condensing the confined refrigerant vapor, withdrawing the refrigerant condensate, passing refrigerant into said steam condenser to provide a noncondensable vapor therein, blanketing a condensing portion of the steam condenser with said refrigerant vapor to suppress the steam condensing capacity thereof, withdrawing refrigerant vapor from said steam condenser, and regulating the quantity of refrigerant vapor effective to blanket said condensing portion thereby varying the steam condensing capacity of the steam condenser.

2. A condensing unit comprising a first condenser, means to cool said first condenser and means to operate said first condenser below ambient air pressure, and a second condenser, means for confining in said second condenser a fluid normally at a pressure above the ambient air pressure, said second condenser enveloping said first condenser whereby ambient air is effectively prevented from entering said first condenser.

3. A refrigeration system condensing unit comprising a steam condenser normally operable below ambient air pressure, and a refrigerant condenser for confining refrigerant fluid normally at a pressure above the ambient air pressure, said refrigerant condenser developing said steam condenser whereby ambient air is effectively prevented from entering said condensers through leaks therein and leaks in said steam condenser draw refrigerant fluid from said refrigerant condenser and leaks in said refrigerant condenser eject refrigerant fluid.

4. A condensing unit according to claim 3 in which means are provided for purging refrigerant fluid from said steam condenser.

5. A refrigeration system condensing unit comprising a steam condenser normally operable below the ambient air pressure and including means to be heated by steam received in the condenser, a refrigerant condenser for confining refrigerant fluid normally at a pressure above the ambient air pressure, said refrigerant condenser enveloping said steam condenser whereby ambient air is effectively prevented from entering said condensers through leaks therein and leaks in said steam condenser permit refrigerant fluid from said refrigerant condenser to pass into said steam condenser and leaks in said refrig-

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erant condenser permit refrigerant fluid to pass to the ambient air, and said steam condenser being insulated from said ambient atmosphere to provide more efficient heating of said means, and means for withdrawing refrigerant fluid from said steam condenser.

6. A refrigeration system steam and refrigerant condensing assembly comprising a steam condenser normally below ambient atmospheric pressure including an inner shell having opposite ends, an end plate secured across one of said ends, a header secured across the other of said ends, a steam condensing tube bundle within said inner shell and opening into said header, a refrigerant condenser normally above atmospheric ambient pressure comprising an outer shell enveloping said inner shell and having opposite ends, one outer shell end being secured to said end plate and the other to said header, a refrigerant condensing tube bundle between said inner and outer shells and opening into said header, said header having means for passing condensing water through said bundles whereby during normal operation of said system ambient air is effectively prevented from entering said condensing assembly.

7. A refrigerant system steam and refrigerant condensing assembly, comprising a steam condenser normally below ambient atmospheric pressure including an inner shell having opposite ends, an end plate secured across one of said ends, a header secured across the other of said ends, a steam condensing tube bundle within the said inner shell and opening in said header, a refrigerant condenser normally above atmospheric ambient pressure including an outer shell enveloping said inner shell and having opposite ends, one outer shell end being secured to said end plate and the other to said header, a refrigerant condensing tube bundle between said inner and outer shells and opening into said header, said header having means for progressively passing condensing water through said bundles, the refrigerant bundle first, means for passing steam into said steam condenser, means for passing refrigerant into said refrigerant condenser means for removing steam condensate from said steam condenser, and means for removing refrigerant from said refrigerant condenser, whereby during normal operation of said system ambient air is effectively prevented from entering said condensing assembly.

8. A refrigeration system steam and refrigerant condensing assembly comprising a steam condenser normally below ambient atmospheric pressure including an inner shell having opposite ends, an end plate secured across one of said ends, a header secured across the other of said ends, first and second steam condensing tube bundles within said inner shell and opening into said header, a refrigerant condenser normally above ambient atmospheric pressure including an outer shell spaced from and enveloping said inner shell, and having opposite ends, one outer shell end being secured to said end plate and the other to said header, a refrigerant condensing tube bundle between said inner and outer shells and opening into said header, said header having means for progressively passing condensing water through the refrigerant bundle and the first steam condensing bundle, the refrigerant bundle first, and for passing a medium through said second tube bundle for providing heat to a load to be heated, means for passing steam into said steam condenser, means for passing refrigerant vapor into said refrigerant condenser, means for removing steam condensate from said steam condenser, means for removing refrigerant condensate from said refrigerant condenser, means for introducing refrigerant into blanketing association with the first steam condenser bundle to control the condensing rate of the steam condenser, and means for purging refrigerant from said steam condenser whereby the refrigerant condenser insulates the steam condenser and ambient air is effectively prevented from entering leaks in said shells, leaks in said inner shell admit refrig-

erant vapor into the steam condenser and leaks in said
outer shell premit refrigerant to pass to the ambient air.

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