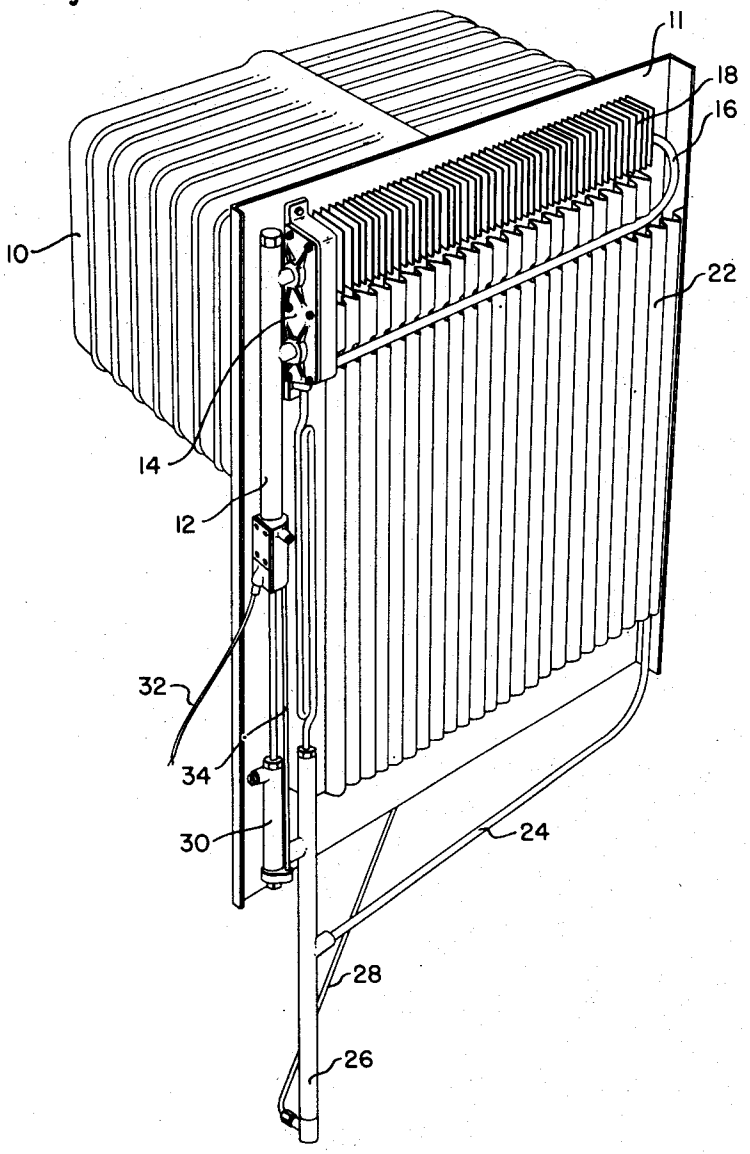
Nov. 10, 1953 E. P. NEUMANN ET AL 2,658,356

JET PUMP REFRIGERATION SYSTEM

Filed July 5, 1951 4 Sheets-Sheet 1

Fig. 1



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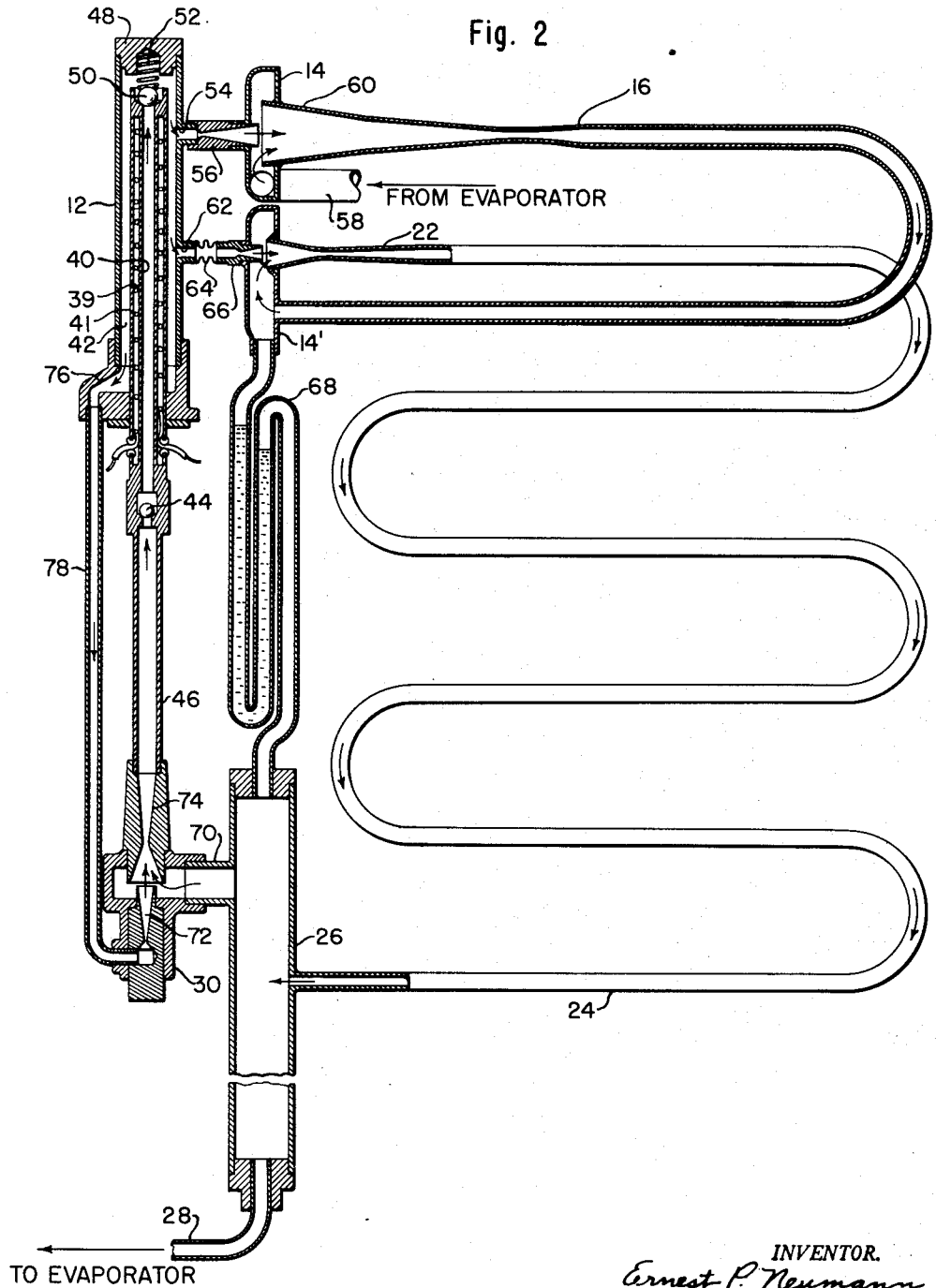
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JET PUMP REFRIGERATION SYSTEM

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Fig. 2



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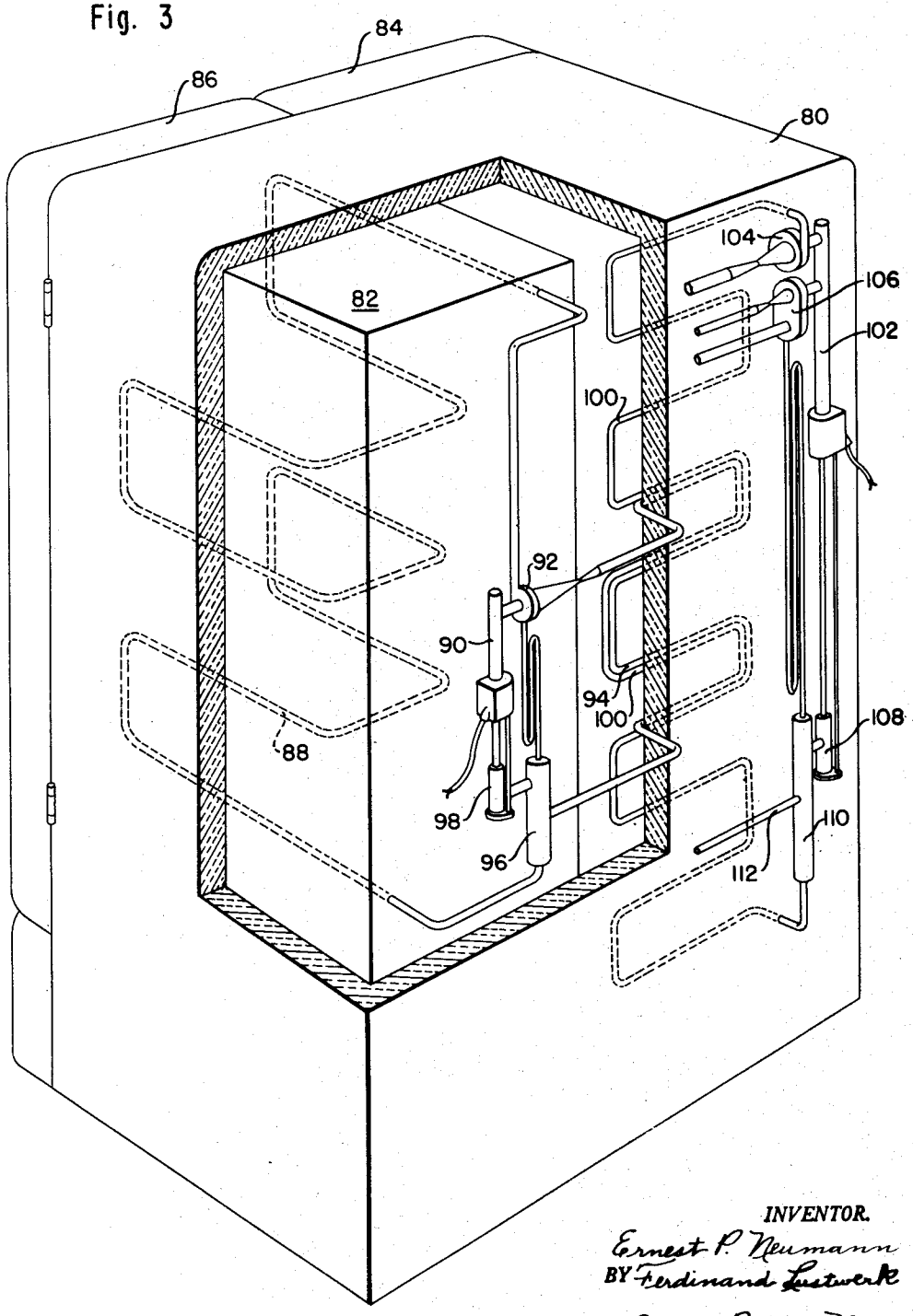
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JET PUMP REFRIGERATION SYSTEM

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Fig. 3



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JET PUMP REFRIGERATION SYSTEM

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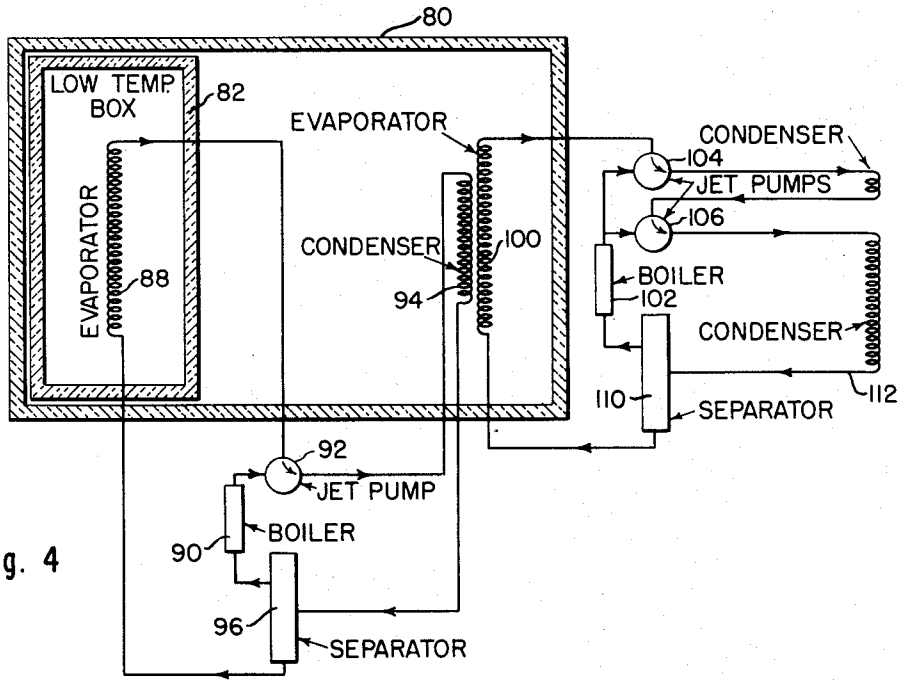


Fig. 4

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UNITED STATES PATENT OFFICE

2,658,356

JET PUMP REFRIGERATION SYSTEM

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10 Claims. (Cl. 62—117.35)

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This invention relates to refrigeration apparatus and in particular to systems wherein a refrigerant is moved through its cycle by a pressurized motive fluid.

In one aspect the invention comprises the combination of an evaporator and a condenser together with an improved heat pump including a novel boiler and injector assembly.

In another aspect the invention comprises a plurality of jet pump refrigeration systems so coupled as to render it possible to dispose a low-temperature compartment at any desired zone within a refrigerated box.

An important object of the invention is to reduce the cost and simplify the task of constructing an efficient refrigerator.

Another object of the invention is to devise a two compartment refrigerator including compartments refrigerated to different temperature levels and arranged in any one of various relative positions.

Still another object of the invention is to provide a small compact jet pump refrigeration unit capable of use as a single system or of being coupled with a multiplicity of similar units to provide flexible, efficient refrigeration at a number of temperature levels.

An important feature of the invention resides in a novel boiler fed by a jet injector operated by vapor from the boiler and in turn feeding one or more jet pumps employed to compress refrigerant gas coming from the evaporator.

The second important feature of the invention relates to the provision of means effective to cause proper starting of the jet injector for the boiler feed comprising the combination of an entrance passage to the boiler controlled by a check valve in combination with a tubular chamber between the boiler passage and the jet injector within which the initial charge of vapor from the injector is compressed until the pressure in the chamber is sufficient to unseat the check valve and thereby start the pressurized feeding of liquid into the boiler.

Another feature of the invention resides in a system of pressure-operated check valves employed to prevent premature release of vapor from the boiler to the injector and jet pumps.

Another feature of the invention resides in means rendering the system operable with a motive fluid of either greater or lesser specific gravity than the refrigerant fluid.

Still another feature of the invention comprises a combination of motive and refrigerant fluids presenting significant improvement in efficiency of operation of the system.

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These and other objects and features of the invention will be more readily understood and appreciated from the following detailed description of preferred embodiments thereof selected for purposes of illustration and shown in the accompanying drawings, in which:

Fig. 1 is a view in perspective of a refrigerator constructed in accordance with the invention,

Fig. 2 is a diagrammatic view partly in cross-section through the boiler, injector, and pet pump assembly,

Fig. 3 is a diagrammatic view in perspective of an alternative embodiment of the invention, and

Fig. 4 is a diagram schematically illustrating a double unit system.

In advance of a discussion of the details of the embodiments herein shown it will be helpful first to consider the general organization of the system, as best shown in Fig. 1. There is provided a conventional evaporator 10 of standard construction secured to a panel 11 to the back of which is secured a boiler 12 of elongated tubular form. The boiler 12 serves a pair of jet pumps contained in a housing 14 and connected in series by a pipe 16 having cooling fins 18 secured thereto. Refrigerant gas from the evaporator is pumped and compressed by the jet pumps working in tandem, the effluent therefrom being thereafter passed through a condenser 22 in which it yields heat and liquefies.

From the condenser 22 the liquid refrigerant, together with the motive fluid injected from the boiler 12, passes through a tube 24 and into a gravity separating chamber 26. As shown the connections are established for operation with a heavier refrigerant and a lighter motive fluid. Hence the former collects at the bottom of the separator 26 and is drawn off through a pipe 28 and returned to the evaporator through a conventional expansion valve (not shown).

The lighter motive fluid fills the upper portion of the separator and is drawn off through an injector contained in a housing 30 and thereby pumped back to the boiler 12. The injector in the housing 30 is powered by vapor exhausted from the boiler 12 and conducted to the injector through an external tube 34. Heat for the boiler is in the form of Nichrome windings served by a supply line 32.

In operation the liquid refrigerant passes into the evaporator where it is expanded and heated. From the evaporator the gaseous refrigerant is drawn by the upper jet pump in the housing 14 into the tube 16 where it is given preliminary compression and wherein part of its heat is ex-

tracted and radiated to the atmosphere by the cooling fins 18. The partially compressed refrigerant then passes through the tube 16 into the second jet pump into the housing 14 where it is further compressed and then discharged into the condenser 22 where additional heat is given up and wherein the gaseous refrigerant condenses to the liquid state and then passes into the tubular separating chamber 26 where it settles to the bottom readily to pass again through the refrigerating cycle. On the other hand, the motive fluid is withdrawn from the top of the separating chamber 26 by the jet pump in the housing 30, by means of which the liquid is injected into the boiler 12 and therein heated until it vaporizes and leaves the top of the boiler under pressure to serve as the motive fluid for the two stage jet pump. Also a portion of the vapor from the boiler passes through the tube 34 and serves as the motive fluid to operate the injector in the pump 39 and thus to feed the boiler 12.

With the foregoing general remarks in mind the details of the boiler and jet pump assembly can more easily be understood. As best shown in Fig. 2 the boiler comprises an outer tube or shell 12 within which and concentrically arranged is a tube 40 around which is wrapped a spiral of Nichrome wire 39, the latter being protected in turn by a casing 41. There is thus formed an elongated annular chamber 42 lying between the casing 41 and the shell 12. At the bottom of the tube 40 there is disposed a ball check valve 44 serving to prevent the draining of liquid from the bottom of the boiler. At the top of the tube 40 there is a second ball check valve 50 working against a spring 52 set in a socket formed in a plug 48 serving to close the top of the shell 12. Adjacent the upper end of the boiler shell 12 is an outlet 54 which is coupled to an injector nozzle 56 having its inner passage so shaped that vapor leaving the boiler shell 12 first encounters a converging wall portion in which the pressure of the vapor is raised and then a diverging or diffuser portion which discharges into the housing 14. Refrigerant gas is admitted into the housing 14 through a pipe 58 connected into the exhaust end of the evaporator. One end of the tube 16 is enlarged as shown at 60 and projected within the housing 14 opposite the injector nozzle 56.

The rush of vapor through the nozzle 56 and into the tube 60 carries with it refrigerant gas entering the housing 14 through the pipe 58 and the refrigerant gas thus entrained is compressed to a preliminary extent in the tube 16; another result, of course, is to create suction in the line 58 leading from the evaporator. Disposed below the outlet 54 is a second outlet 62 receiving one end of a bellows connection 64 which is coupled at its outer end to the housing 14 and to a second and smaller jet nozzle 66. The condenser tube 22 has an enlarged head projected into the housing 14 (or 14' as shown in Fig. 2) opposite the diffuser end of the nozzle 66, the result being that partially compressed refrigerant together with motive fluid introduced into the tube 16 is discharged into the housing 14' and then entrained in the rush of vapor through the nozzle 66 and dispatched through the condenser tube 22 where the refrigerant is further compressed to an extent where the refrigerant will condense to a liquid as it passes through the condenser 22. As a matter of fact, most of the motive fluid will be condensed by the time it reaches the bottom of the housing 14', and I provide a trapped drain 68 leading from the bottom of the housing 14' to the top of the separator 26, the drain 68 having a U-shaped loop portion effective to provide a head of pressure sufficient to prevent liquid in the separator from blowing back into the housing 14' through the drain 68.

Adjacent the upper end of the separator there is provided an outlet pipe 70 leading to a housing 30 in which is contained a jet nozzle 72 disposed opposite an injector nozzle 74 leading to a vertical pipe 46 which is connected into the bottom of the tube 40 below the ball check valve 44. Adjacent the bottom of the boiler shell 12 there is provided an annular housing enclosing a conduit 76 leading to a tube 78 which in turn terminates in the nozzle 72.

There are additional factors connected with the operation of the system which require consideration. In order that satisfactory operation may be achieved the nozzle 72 and at least the lower portion of the injector nozzle 74 must be immersed in liquid when the apparatus is started. This is achieved by placing the outlet 70 and the nozzles 72 and 74 substantially below the top of the separator 26, it being understood that both fluids used in the system are liquids at the normal ranges of room temperatures. It is also important that there be liquid in the boiler at the time it is started. This condition is satisfied by the presence of the two ball check valves 44 and 50. The ball check 44 prevents the drainage of liquid from the bottom of the boiler back through the supply tube 46. The function of the ball check 50 is to prevent the escape of vapor from the boiler until a predetermined degree of pressure has been obtained. That is to say, when the current is supplied to the Nichrome windings the liquid in the boiler vaporizes, and the boiler pressure rises until it is sufficient to overcome the compression of the spring 52. Prior to that time no vapor leaves the tube 40. Consequently the injector nozzle 72 is not operating; nor are the jet pumps 56 and 66 operating. However, when the ball check 50 rises due to the pressure in the boiler, the vapor then exhausts through the outlets 64 and 62 to operate the jet pumps 56 and 66 and thereby to start the operation of the refrigeration system. Simultaneously vapor exhausts through the conduit 76 and the tube 78 to the injector nozzle 72 and the motive fluid is then pumped through the tube 46 and into the boiler tube 40 past the ball check 44. If the nozzles 72 and 74 were not immersed in liquid, the rush of fluid through the nozzle 72 would not be affected to draw motive fluid from the separator 26 and discharge it into the boiler. If there were no liquid in the boiler tube 40 at the start, there would be nothing to start the operation of the nozzles 72, 56 and 66.

It is extremely important to note that the tube 46 interposed between the ball check valve 44 at the entrance to the boiler and the injector nozzle 74 serves as a novel compression chamber effective to cause the injector to start feeding the liquid into the boiler without the interposition of auxiliary means to provide starting pressure. If the injector nozzle 74 were coupled directly to the boiler beneath the ball check 44, the initial charge of vapor passing through the nozzle 72 would spend itself vainly against the ball check valve 44 and the access of pressure would blow laterally back through the tube 70 toward the separator 26. However, with the construc-

tion shown in Fig. 2 the momentum of the vapor passing through the nozzles 72 and 74 causes the stream of vapor to enter the tube 46 rather than dissipate laterally. During this process some of the vapor is condensed in the nozzles and in the tube 46, but the residual vapor is compressed within the tube 46 and as the operation progresses there is eventually built in the tube 46 a pressure head sufficient to unseat the ball check valve 44 and start the feed of liquid into the bottom of the boiler tube 40. It will be remembered that upon starting the apparatus there is a quantity of liquid trapped within the boiler tube 40. It is important to note that the tube 46 be sufficiently small so that there will be sufficient pressure built up therein to unseat the ball 44 prior to the time when the initial charge of liquid in the boiler tube 40 is completely vaporized and exhausted. Consequently the size of the tube 46 should be sufficiently large to permit the compression of the vapors therein and yet not so large as to fail to start the feeding of liquid to the boiler before the initial volume of liquid therein has been completely vaporized. The size of the tube 46, with the foregoing considerations in mind, is not too critical and may vary from 10% to 20%. Of course, its actual size will depend upon the relative sizes of the other elements of the system.

Another factor to be considered is the desirability of condensing the greater part of the motive fluid in the pipe 16 so that it can drain into the tube 68 and thus reduce the amount of work which has to be done by the second jet pump 66. As shown in Fig. 2 the system is connected for operation utilizing a refrigerant fluid which is greater specific gravity than the motive fluid. Consequently the refrigerant line to the evaporator is taken from the bottom of the separator 26, while the motive fluid supply outlet 70 is connected adjacent the upper end thereof. However, it is equally feasible to employ a motive fluid which is heavier than the refrigerant fluid. It is merely necessary to reverse the connections so that the refrigerant supply pipe 28 is connected adjacent the upper end of the separator and the supply to the nozzles 72 and 74 is connected adjacent the lower end thereof.

Several factors govern the choice of the motive and refrigerant liquids to be used in the system herein disclosed. For example, they must differ in specific gravity in order to permit separation either in a centrifugal separator or in the simple gravity separator shown in the drawings. Obviously they must be liquids which do not react chemically with each other and which are relatively non-corrosive. I have found, for example, that tetrachlorethylene (C_2Cl_4) may advantageously be used as the motive fluid in combination with methanol (CH_4O) as the refrigerant liquid.

With respect to the design of the nozzles preference may be had, in general, to a paper on the subject by applicant together with J. H. Keenan "An Investigation of Ejector Design by Analysis and Experiment" published in the Journal of Applied Mechanics for September 1950.

One important advantage resulting from the use of the invention is the fact that it becomes possible to construct the refrigerating box having compartments maintained at different temperature levels, without regard to the relative positions of the two compartments. In the conventional refrigerator design it has always been regarded necessary that the freezing or low temperature compartment be disposed adjacent the upper end

of the box. This is true because in the past such boxes have been served by a single evaporator. Consequently if the evaporator were placed adjacent the bottom of the refrigerated box, there would be no circulation and the upper portion thereof would always be at an unduly high temperature. While it would be theoretically possible to provide two complete mechanical refrigerating systems and thereby achieve freedom of placement for the low temperature compartment, the expense of equipment required would render it uneconomic in almost every case. However, one important feature of our invention is the fact that a complete system involves relatively small and inexpensive equipment or that two complete systems can be applied to one refrigerated box without involving uneconomic capital expense. In Figs. 3 and 4 there is illustrated an embodiment of a double unit comprising another embodiment of the invention.

As shown in Fig. 3 there is provided a large box having an insulated wall 80 within which there is a second and smaller insulated box 82. At the front of the box there is a door 84 giving access to the main box and a door 86 giving access to the small box 82. Within the smaller box or compartment 82 there is disposed a conventional evaporator 88 which is served by a jet pump system secured to the outer surface of the rear wall of the main box 80. This system includes a boiler 90 feeding a single stage jet pump 92 connected to a tubular condenser 94 which drains into a separator 96 in turn connected to an injector 98. The parts of the system have not been described in detail because they are in all respects precisely similar to the corresponding elements shown and described in conjunction with Fig. 2, the sole exception being that a single jet pump is served by the boiler instead of the duplex arrangement appearing in Fig. 2.

The condenser 94 is in metal to metal contact with a portion of a tubular evaporator 100 mounted within the main box 80 and served by a two stage jet pump system including a boiler 102, a first jet pump 104 and a second jet pump 106. As before, there is provided a separator 110 which feeds a jet pump injector 108. To avoid confusion on the drawing the condenser serving this second duplex system has been omitted, although the connections for it are indicated. The line 112, for example, brings the condenser into the separator 110. This duplex jet pump system may conveniently be precisely similar to the construction shown in Fig. 2.

The first jet pump system represented by the jet 92 serves to extract heat from the inner smaller compartment 82, while heat is transferred from its condenser 94 to a portion of the large evaporator 100 which in turn is served by the jet pump system represented by the jets 104 and 106. Thus the second system not only serves to pump heat from the condenser of the first single stage unit, but also extracts heat from the interior of the main box. Although the specific temperatures maintained in the two compartments will be a matter of design and adjustment, it is quite possible, by way of example, to maintain the smaller compartment 82 at a temperature of, say, minus 10° F. while the interior of the main box 80 is maintained at a temperature of perhaps 40° F.

It will be noted that the low temperature compartment 82 is in side by side relation with the remaining space within the main box 80, as opposed to the conventional arrangement in which

the low temperature compartment must of necessity be arranged at the top of the main unit, as in conventional household refrigerators having a compartment for storing frozen foods or making ice cubes. The particular arrangement shown in Fig. 3 is illustrative of the fact that a duplex system constructed in accordance with our invention is flexible with respect to the relative positions of the low temperature compartment and the main box. For example, the low temperature compartment would be placed at the bottom of the main box, at the rear thereof, or in any other desired location. The jet pump systems shown herein are relatively cheap so that a unit having two or more jet pump systems serving various compartments may be constructed at a cost quite competitive with conventional mechanical systems.

While the invention has been herein described in conjunction with a household refrigerator, it may also conveniently be embodied wherever it is desired to extract heat from a given space and may therefore be usefully employed in conjunction with the air conditioning of railway cars and the like. Those skilled in the art will readily appreciate that the embodiment herein shown may be modified considerably to fit particular needs.

Having now described a preferred embodiment of the invention, what we claim as new and desire to secure by Letters Patent of the United States is:

1. In a refrigeration system including an evaporator and a condenser, the combination of a shell casing, walls forming a chamber within and spaced from said casing, means for heating said chamber, walls forming a passage from said chamber to the space between the casing and the chamber, a spring-loaded valve normally closing said passage, a pair of jet pumps connected to said casing, a jet injector connected to said casing and to said chamber, a conduit connecting said jet pumps in series, said jet pumps being connected between the evaporator and the condenser, and means for supplying fluid to said injector.

2. In a refrigeration system including an evaporator and a condenser, the combination of a boiler having an inlet for liquid and an exhaust passage for vapor, a jet pump connected between said evaporator and condenser and receiving motive fluid from said exhaust passage, a pressure-responsive check valve controlling said inlet, walls forming a chamber connected at one end to said inlet, a jet pump injector connected to said chamber, a connection from said exhaust passage to said injector, and a source of liquid also connected to said injector, whereby said jet pump injector pumps liquid through said chamber and valve into said boiler.

3. Apparatus of the class described, comprising a boiler having an inlet for liquid and an exhaust passage for vapor, pressure responsive check valves controlling said inlet and said outlet, walls forming a chamber connected at one end to said inlet, a jet pump injector connected to said chamber, a connection from said exhaust passage to said injector, and a source of liquid also connected to said injector.

4. Apparatus of the class described, comprising a boiler having an inlet for liquid and an exhaust passage for vapor, pressure responsive check valves controlling the inlet and the exhaust passage, a pair of jet pumps connected in parallel to said exhaust passage, a condenser connected to said jet pumps, a tank connected to said condenser, an injector connected to said exhaust passage and to said tank, and walls forming a chamber connected at one end to said boiler inlet and at the other end to said injector.

5. Apparatus of the class described, comprising a boiler having an inlet for liquid and an exhaust passage for vapor, pressure responsive check valves controlling the inlet and the exhaust passage, a pair of jet pumps connected in parallel to said exhaust passage, a condenser connected to said jet pumps, a tank connected to said condenser, a trapped drain connecting said tank to one of said jet pumps, an injector connected to said exhaust passage and to said tank, and walls forming a chamber connected at one end to said boiler inlet and at the other end to said injector.

6. In a refrigeration system including an evaporator and a condenser, the combination of a pair of jet pumps connected in series between the evaporator and the condenser, a boiler connected to said jet pumps to supply motive fluid thereto, a tank connected to said condenser, an injector connected to receive motive fluid from said boiler, walls forming a compression chamber connected to the discharge end of said injector and to said boiler, a pressure responsive check valve controlling the connection from said chamber to said boiler, and a supply connection from the tank to the injector.

7. A refrigerator comprising a relatively large insulated box, a relatively small insulated box disposed within the larger box, evaporators disposed in both boxes, a first condenser disposed in heat exchange relation with the evaporator in the larger box, a boiler and jet pump assembly unit amounted exteriorly of both boxes and serving to cycle refrigerant through the small box evaporator and the condenser within the larger box, a condenser mounted exteriorly of both boxes, and a second boiler and jet pump assembly mounted exteriorly of both boxes to cycle refrigerant through the evaporator in the larger box and the exteriorly mounted condenser.

8. In a refrigeration system including an evaporator and a condenser, the combination of a shell casing, walls forming a chamber within and spaced from said casing, means for heating said chamber, walls forming a passage from said chamber to the space between the casing and the chamber, a spring-loaded valve normally closing said passage, a jet pump connected to said casing, a jet injector connected to said casing and to said chamber, a conduit connecting said jet pump in series between the evaporator and the condenser, and means for supplying fluid to said injector.

9. Apparatus of the class described, comprising a boiler having an inlet for liquid and an exhaust passage for vapor, pressure responsive check valves controlling the inlet and the exhaust passage, a jet pump connected to said exhaust passage, a condenser connected to said jet pump, a tank connected to said condenser, an injector connected to said exhaust passage and to said tank, and walls forming a chamber connected at one end to said boiler inlet and at the other end to said injector.

10. A refrigerator including a pair of insulated compartments, a first evaporator disposed in the first compartment, a first condenser connected to said first evaporator and disposed in the second compartment, a second evaporator disposed in the second compartment and in heat

exchange relation with the first condenser, a second condenser connected to the second evaporator and disposed outside both compartments, a first boiler and jet pump disposed outside said compartments and connected to cycle refrigerant through the first evaporator and first condenser, and a second boiler and jet pump connected to cycle refrigerant through said second evaporator and condenser.

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