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[54] **REFRIGERATION SYSTEMS WITH ELEVATED RECEIVERS**

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[51] Int. Cl. **F25b 39/04**

[58] Field of Search 62/509, 196, 259, 62/DIG. 17, 115

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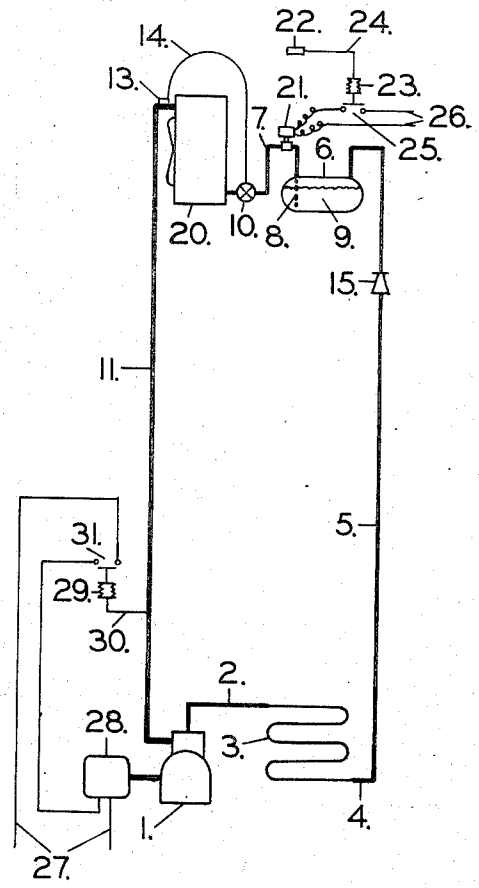
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Assistant Examiner—Peter D. Ferguson

[57] **ABSTRACT**

In air cooled refrigeration systems of the compression type which may operate in low ambients with no or minimum condenser capacity control, it is sometimes required to locate the evaporator high above the condensing unit. Especially under winter conditions, it is likely that liquid refrigerant leaving the condensing unit will suffer sufficient pressure loss by gravity in traversing the vertical upflow riser, that its flash point will be reached. Then the formerly clear liquid column will flash into a mixture of vapor and liquid. Most expansion devices are designed to function correctly with vapor-free liquid entering their orifices.

4 Claims, 3 Drawing Figures



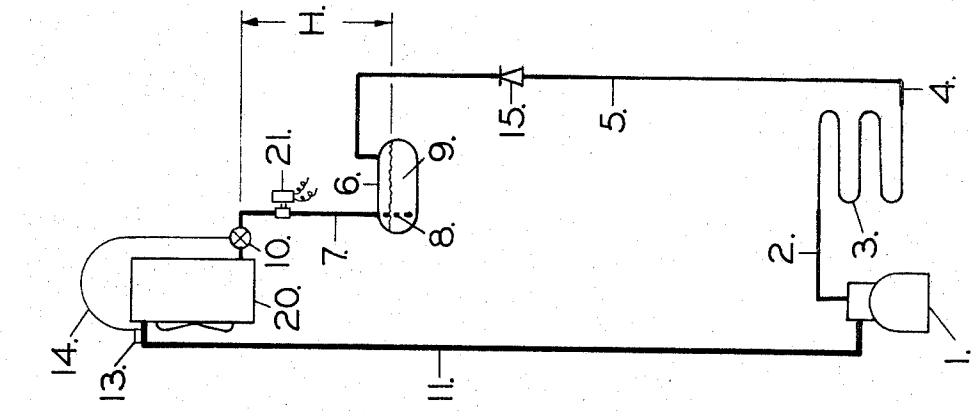


FIG. 3.

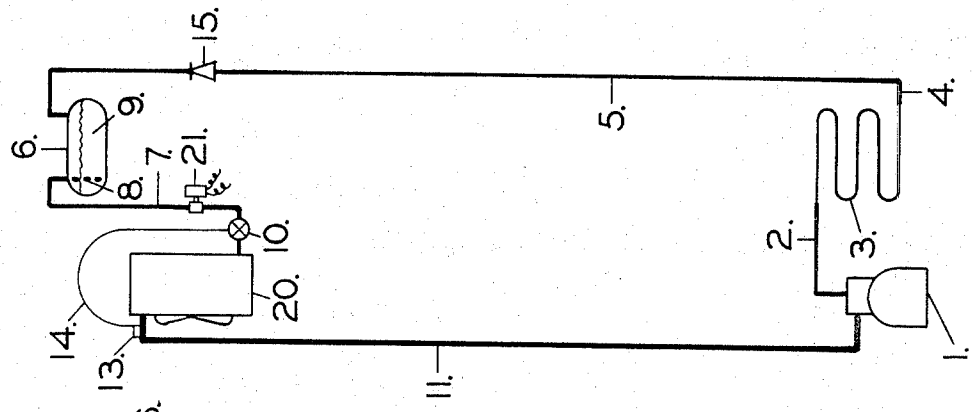


FIG. 2.

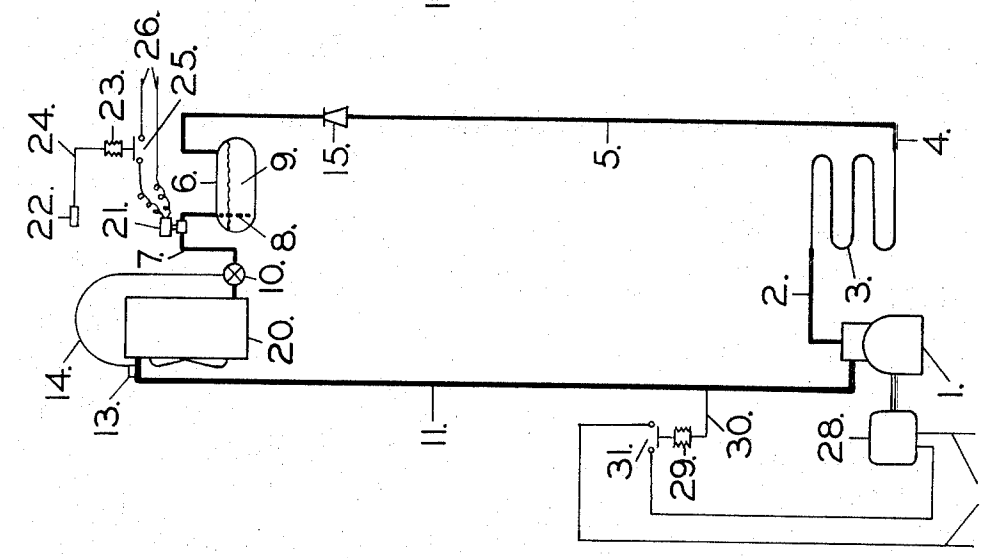


FIG. 1.

REFRIGERATION SYSTEMS WITH ELEVATED RECEIVERS

This invention proposes to cope with the condition of great elevation of the evaporator or expansion device over the condensing unit by elevating the liquid receiver to a position below, even with, or above the expansion device even though this might place the receiver many feet above the condenser.

BACKGROUND

Since 1938 air cooled condensers have been used for refrigeration system condensing in increasing numbers and in increasing sizes.

Initial attempts to apply air cooled condensers outdoors for year round service met with failure. It was thought, at that time, that system failure to function under winter conditions arose because of the reduced head and liquid pressure which produced insufficient pressure differential across the expansion device to cause sufficient flow to occur to satisfy the requirements of the evaporator. When steps were taken to reduce condenser capacity during winter conditions, thereby raising the head pressure, and normal system performance and function resulted, it was considered confirmation of the source of the difficulty. Consequently, a tremendous inventive effort was made throughout the industry to develop controls for air cooled condensers which would work automatically to adjust the pressures in the condenser and the receiver and liquid line to those which would normally exist under summer conditions regardless of the low temperature of the air drawn through the condenser coils.

By the use of these condensing pressure controls which were in reality, condenser capacity controls, it became possible to apply air cooled condensers outdoors for year round use and their application for this purpose became almost universal.

More recently, it was discovered that expansion valve feeding problems formerly encountered when air cooled condensers were applied under winter ambients without head pressure controls had primarily been caused by the flashing of liquid in the liquid line enroute to the expansion device. It was further found that the flow capacity of the orifice in the expansion device does not drop as sharply as expected at sharply reduced pressure differentials provided the condition of the liquid at the expansion valve inlet is maintained bubble-free. The reasons for this area : a) that the liquid termperature drops as the head pressure drops. b) as the dropping liquid temperature approaches the evaporating temperature, less and less flash gas is formed as the liquid passes from the high pressure side to the low pressure evaporator side.

When hot liquid is fed to the expansion device, much of the liquid flashes into vapor reducing the temperature of the remainder to the equilibrium evaporating temperature in the evaporator. This large quantity of flash gas, which is created within the orifice itself, acts to restrict the capacity of the orifice. As the temperature of the liquid approaches the evaporating temperature, however, the quantity of flash gas is sharply reduced. With less flash gas formed in the orifice, the orifice, therefore, has greater capacity to pass liquid. The net result of these two conflicting phenomena; that is, reduced pressure differential tending to decrease the capacity of the expansion valve orifice, and reduced liquid temperature forming less flash gas which tends to

increase the capacity of the expansion valve orifice, is that the capacity of the expansion valve orifice remains substantially constant over an extremely wide range of pressure differentials.

This characteristic permits satisfactory functioning of the refrigeration system year-round without any condenser winter control at all or with only a rudimentary control such as an ambient temperature activated fan control so long as the low pressure, cool, liquid refrigerant, reaching the expansion device, is in a bubble-free condition.

It has been observed that the liquid refrigerant normally leaving the condenser and the receiver has about 6° sub-cooling; that is, its actual temperature is about 6° F less than its saturation temperature. This liquid, therefore, will begin to flash into vapor if it is warmed 6°, or will do likewise if the pressure on the liquid is reduced an amount equal to a 6° F drop in saturation temperature, keeping the liquid temperature the same. Therefore, if the receiver is located at about the same level as or higher than the evaporator and if the liquid line does not traverse a warm area, it is very likely that the liquid from the receiver will approach the expansion valve in a bubble-free condition. If on the other hand the expansion device is mounted far above the receiver, then the hydraulic head of the liquid, as it flows from the receiver upward toward the expansion device, will act to lower its pressure sufficiently that bubbles will form.

EXPLANATION OF THE INVENTION

Examination of the published characteristics of any volatile refrigerant shows that the height to which a column of liquid refrigerant with predetermined subcooling can be elevated, depends on its saturated temperature. Saturated temperature is that temperature which on a pressure-temperature chart for the specific refrigerant, corresponds to the measured or actual pressure. This height is given in table I for **R22.**

The table shows that at saturated or condensing temperatures most commonly found under indoor or summer conditions outdoors (80° condensing thru 140° condensing), liquid R22 refrigerant with 6° sub-cooling will tolerate a lift of 20 to 35 feet without flashing.

Under winter outdoor conditions, however, where the saturated condensing temperature may well be 0° and the liquid temperature −6°, the chart shows that liquid lifts of only 2 to 5 feet are tolerable before partial flashing of the liquid to vapor occurs. Consequently, in cases where the expansion valve is elevated more than the limiting amount given in table I, flashing of the liquid will occur.

Tradition in the refrigerating industry has called for the liquid receiver to be located lower than the condenser, with the pipe between the condenser outlet and receiver inlet free draining and preferably sized large enough for sewer type drainage; that is, for the condition of flow where the liquid flowing occupies only a small portion of the bottom segment of the pipe interior and vapor the remainder.

The inventor's analysis of the reasons for flow between the condenser and the receiver disclosed that the condenser could function without loss of capacity with a pressure drop at its outlet whose amount was not greater than that which would cause flashing in the subcooled refrigerant leaving the condenser.

For systems using one of the high pressure refrigerants, such as refrigerant **22**, the tolerable pressure drop at the condenser outlet (table I) during summer conditions, with saturated or condensing temperatures above approximately 80°, is in the range of 14 to 21 PSI (equivalent to 28–42 feet of hydraulic head).

However, under winter conditions when the condensing temperature of the refrigerant is low, for instance below +10°, the tolerable pressure drop at the receiver outlet may be only 4 or 5 PSI (table I). Since the components normally supplied in the liquid line from the receiver to expansion device such as service valve, sightglass, dryer, liquid solenoid, and heat exchanger themselves normally impose a pressure drop of 3 to 4 PSI, the pressure-drop remaining, which can be dissipated without flashing through friction or elevation in the liquid line, may only be 1 or 2 PSI. Since the liquid halogenated hydrocarbon refrigerants generally have densities greater than that of water, averaging 1.25 times that of water, the liquid column height which will cause a pressure reduction sufficient to generate flashing in a clear liquid column may be, under winter conditions, only a few feet.

Therefore the limiting elevation H, which the receiver may be below the expansion device is, for a given refrigerant, related almost entirely to the minimum ambient to which the condensing system is to be exposed; the lower the ambient, the smaller the height H (table I).

However, the same laws which govern the liquid column leaving the receiver when it is located immediately adjacent the condenser also govern the liquid leaving the condenser on its way to the elevated receiver; that is, liquid which can tolerate a small elevation without flashing, now flashes when the requirement for traversing a great elevation is imposed. However, flashing, which does occur, generates gas which cannot enter the liquid line at the receiver outlet

TABLE 1

Saturated liquid temperature [a]	Pressure drop allowed to offset 6° subcooling (p.s.i.)	Allowable head loss in liquid line (p.s.i.)	Foot lift tolerable before flashing occurs (H)
120	21.2	16.2	34
80	14.0	10.0	19
40	8.7	4.7	8.5
0	4.1	0	0

[a] Temperature corresponding to actual pressure.
[b] After deducting 4 p.s.i. for pressure drop of drier, solenoid valve, etc

because of the immersion of the receiver dip tube into the pool of liquid refrigerant which normally partially fills receiver. Since the gas formed is not able to pass the reciever, it reacts by forcing liquid refrigerant to backup in the condenser, increasing the degree of subcooling to the extent necessary to allow the required liquid lift to take place without excessive flash gas formation. At high ambients, because the inherent **6°** subcooling allows substantial lift without flashing, relatively little or no excess condenser flooding occurs. At low ambients, the large initial amount of flashing causes sufficient condenser flooding to occur to ensure that the liquid leaving the condenser is sufficiently subcooled to flow to the elevated receiver with no more flash gas formed than occurs when the receiver is at the same level as the condenser.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** shows a refrigeration system with the evaporator and expansion device located over the compressor and condenser where the receiver is elevated to the same level as the expansion device.

FIG. **2** shows a system similar to FIG. **1** except that the receiver is elevated to a level over the expansion device.

FIG. **3** shows a system similar to that of FIG. **1** except that the receiver is elevated over the condenser to a level somewhat below the expansion device.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

This invention requires that the liquid receiver be elevated from its traditional position adjacent or below the condenser to a level above the condenser, possibly somewhat lower than, possibly even with, possibly much higher than the expansion device. The relative elevation of the receiver and expansion device is unimportant so long as the reciver is not so far below the expansion device that flashign occurs at the lowest ambients.

Referring to FIGS. **1** and **2**, compressor **1** receives vapor from suction line **11** and pumps it at higher pressure level to condenser **3** via discharge line **2.** The gas is cooled and condensed to a liquid by a forced air stream generated by a powered fan (not shown). From the condenser outlet the liquid flows via conduit **5** and check valve **15** to liquid reciever **6** which is located well-over the condenser at a position adjacent the expansion device **10.** The expansion device **10** could be any type; such as thermostatic expansion valve, automatic expansion valve, float valve, thermostatically actuated liquid level control valve, orifice, capillary tube, or others.

The expansion device **10** is elevated over the condenser **3** only by the physical requirements imposed by space or structural consideration. For example, in a refrigerator or freezer the roof structure might be inadequately strong to support the weight of both the evaporator, which is normally hung from the box ceiling to allow free use of the box floor and the compressor **1,** condenser **3,** and receiver **9.** The cost of increasing the strength of the roof for the purpose of supporting these additional elements might be prohibitive, encouraging the contractor or design engineer to locate these additional elements at ground level.

As the liquid flows through the expansion device **10,** its pressure drops to the same pressure as the other liquid evaporating in an evaporator **20.** As the liquid refrigerant approaches the end of the conduit exposed to the medium it is intended to cool, it gradually evaporates to dryness. The liquid refrigerant, having evaporated completely to a vapor, is returned through suction line **11** to the compressor **1** for recompression and recycling through the refrigeration cycle just described.

During the operating cycle, the check valve **15** performs no function, allowing liquid refrigerant to flow through it as if it were not present. When the control for compressor **1,** which typically is a thermostat sensing the temperature of the cooled space, turns the compressor off, both the refrigerant in condenser **3** and in receiver **6** are approximately the same temperature.

However, the condenser 3, with its large surface area, has a tendency to cool more rapidly than the receiver and conditions thereby, are set up for refrigerant liquid 9, residing in the receiver, to migrate backward through conduit 5 to the condenser 3 where condensation would occur. In this way over a period of non-operation of compressor 1, all the refrigerant in the receiver could migrate to the condenser leaving the receiver 6 empty. If, at this condition, the control for the compressor 1 initiated its activity, there would be no liquid refrigerant in the receiver available to feed the expansion device 10 with the result that vapor only, or at best a mixture of liquid and vapor, might be fed from the receiver through dip tube 8 and liquid line 7 to expansion device 10 causing malfunctions such as short cycling, lack of refrigeration, and low back pressure.

The presence of check valve 15 in line 5, however, prevents any migration of refrigerant liquid 9, residing in receiver 6 at the end of the operating cycle, to the condenser 3 since the function of check valve 15 is to prevent flow in conduit 5 in a direction opposite to that which occurs during the normal refrigeration cycle.

To further confine the liquid refrigerant 9 in receiver 6 during the off cycle, a solenoid valve 21, installed in liquid line 7, may be employed. A thermostat, employing switch 25 activated by bellows 23, joined to bulb 22 by capillary tube 24, or any other activating device such as a level control, timer, or humidistat may be used to open and close switch 25. When switch 25 is closed, power supply 26 energizes the coil of solenoid 21, opening the valve and allowing liquid refrigerant to flow from receiver 6 to expansion device 10. As liquid flows into evaporator 20, it evaporates there, raising the presssure in the evaporator and suction line 11, affecting prssure switch 29, which in turn closes its contacts 31, causing compressor motor 28 to begin operation, driving the compressor 1. When the control which closed contacts 25 is satisfied and opens these contacts, liquid solenoid 21 closes, stopping flow of refrigerant from receiver 6 to expansion device 10 and evaporator 20. The compressor continues operating until the pressure in the evaporator and the suction line 11 has been reduced to the cutout point of pressure switch 29, at which time the pressure switch breaks the contacts 31, stopping compressor motor 28 and with it the operation of the compressor 1.

Although the examples of pressure, temperature, and elevation have been given for refrigerant 22 only, all volatile liquids and, therefore, all volatile refrigerants such as refrigerants 12 (dichlorodifluoromethane), 22 (chlorodifluoromethane), 115 (chloropentafluoroethane), or 502 (azeotrope of 115 and 22) exhibit the same relative changes in characteristics with saturated temperature. The invention disclosed in the claims, therefore, applies to refrigeration systems without regard to the refrigerant type used.

I claim:

1. In an air-cooled refrigeration system comprising conduitconnected compressor, condenser means, receiver means, evaporator, and an expansion device located over the condenser means, the improvement which comprises said receiver means being located at an elevation substantially higher than said condenser means whereby upon a decrease in ambient temperature at said condenser means, with resulting decrease in head pressure, said expansion device is continuously supplied with substantially bubble-free refrigerant liquid during operation of said system.

2. A refrigeration system as in claim 1 which includes a check valve in the conduit connecting the condenser and the receiver oriented to allow flow from the condenser to the receiver and prevent reverse flow.

3. A refrigeration system as in claim 2 which includes a solenoid valve in the conduit connecting the receiver with the expansion device.

4. The method of ensuring, during operating cycles, a supply of bubble-free liquid refrigerant to the expansion device of an air-cooled compression-type refrigeration system comprising conduit-connected compressor; condenser and receiver intended for year-round outdoor use; an expansion device elevated over the condenser, and evaporator, said method comprising the step of elevating the receiver over the condenser to a level near that of the expansion device and permitting substantially free variation of head pressure with ambient temperature at the condenser.

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