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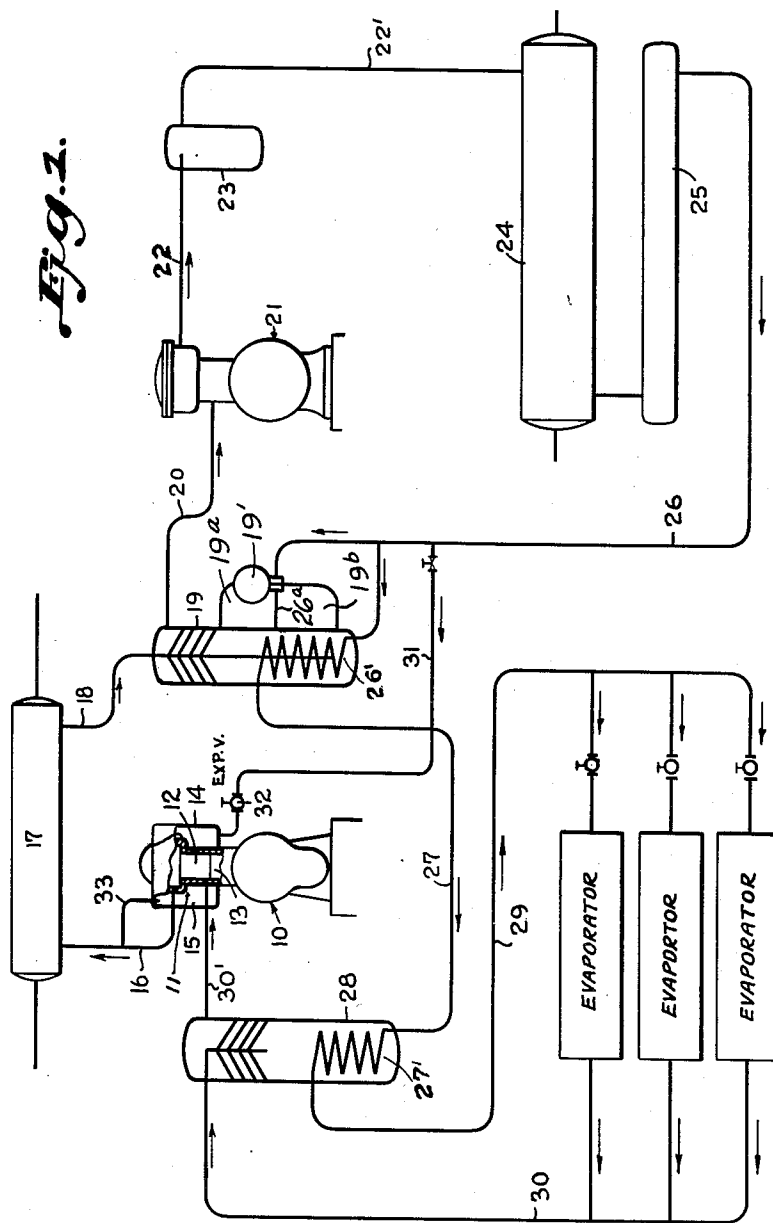
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MULTISTAGE REFRIGERATION SYSTEM

Filed May 5, 1944

2 Sheets-Sheet 1



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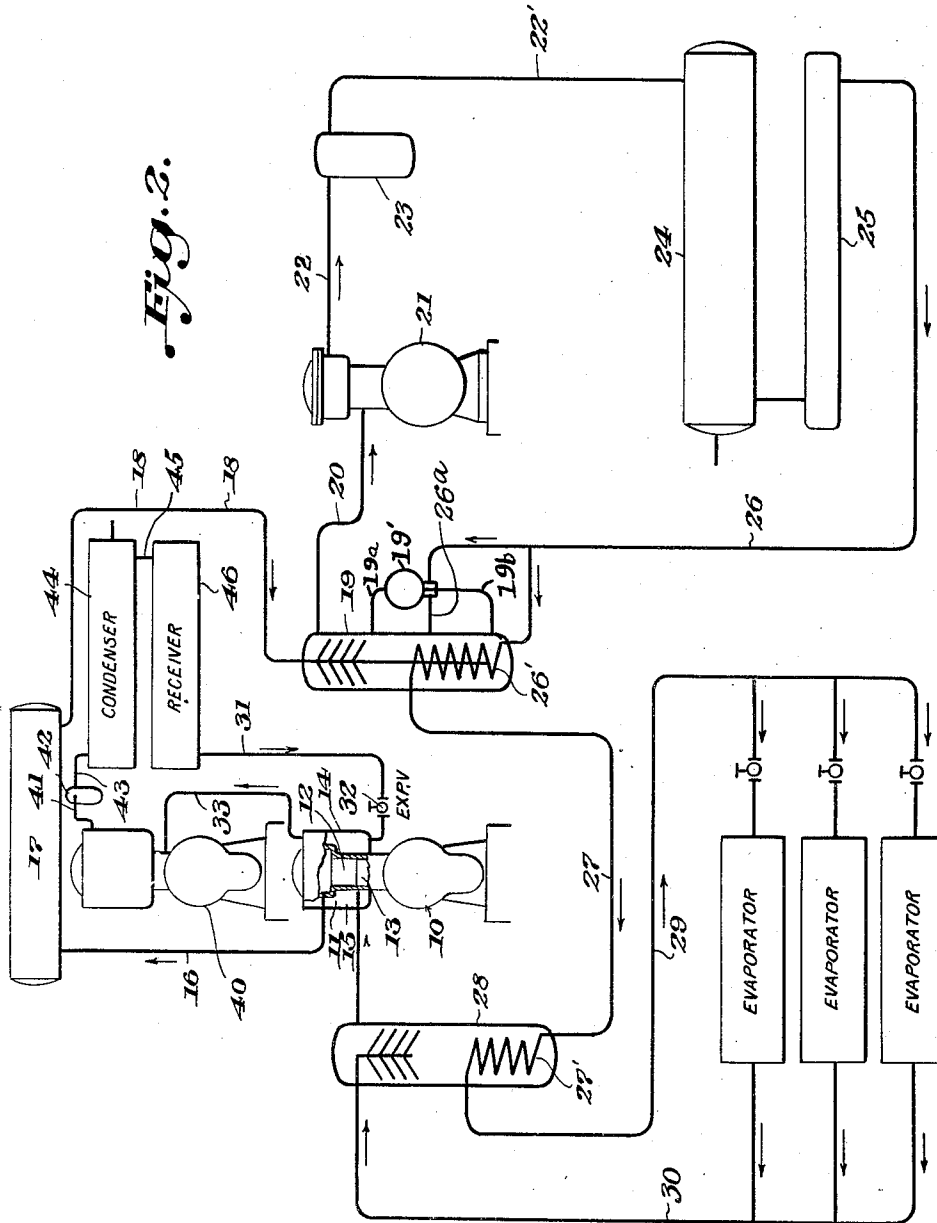
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2 Sheets-Sheet 2



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UNITED STATES PATENT OFFICE

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MULTISTAGE REFRIGERATION SYSTEM

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16 Claims. (Cl. 62—115)

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This invention relates to refrigeration, and particularly to an improved system for obtaining in an efficient manner extremely low temperatures.

This application is a continuation-in-part of my co-pending application Serial No. 423,683, filed December 19, 1941, and now abandoned.

Where temperatures from minus 40° F. to minus 100° F. or lower are involved the pressure range in a system using ammonia as a refrigerant may vary from 1¼ pounds per square inch absolute to 200 pounds per square inch absolute. This wide range causes compression ratios of the compressor that lower the volumetric efficiency, and obviously the over-all efficiency of the refrigeration system. Further, the wide range of compression ratios cause high compression heat, which also must be removed in part to maintain efficiency.

It is further true that the heat of the gas at low pressures is relatively low, and at the same time the specific volume of the gas is extremely high, to the extent that the ability of the gas to absorb heat is insufficient to carry off the heat of the compressor (i. e., friction and compression heat).

In order to overcome these difficulties two or more stages of compression are employed. These stages reduce the compression ratio on any one compressor and permit an improvement in the volumetric efficiency.

Where several stages of compression are employed in attaining low temperatures the suction pressure of the lower stage or stages is extremely low. In certain ammonia plants the suction pressure at the lowest stage runs from approximately 10½ pounds absolute down to about 1¼ pounds per square inch absolute, while at the same time the specific volume of the gas is extremely high, ranging from about 25 cubic feet per pound to 183 cubic feet per pound. Also, the heat of the gas is relatively low. Due to its high specific volume, the pounds of gas pumped per cubic foot of piston displacement is relatively small, and that combined with the low specific heat of the gas results in a marked increase in temperature. Therefore the temperature of the suction gas should be kept as low as possible for it to do more useful refrigeration work, and since there is quite a large difference in temperature between the gas entering the compression chamber of the compressor and the temperature of the surrounding cylinder walls, primarily due to the temperature of the medium surrounding the compressor and the frictional heat resulting from

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the operation of the machine, means of reducing the temperature increase of the gas within the cylinder is desirable. An increase in temperature of the gas increases its volume and therefore reduces the pumping capacity of the compressor, and it is therefore desirable to keep this gas at a low temperature. The most commonly accepted methods of cooling compressor cylinders is by radiation of heat to the surrounding atmosphere, or by water-cooling a jacket surrounding the cylinder. Ordinarily ambient or air temperatures in the region of the compressor are very much higher than the suction gas temperatures; and in the case of water, it cannot possibly have a temperature lower than 32° and during warm weather, temperatures of 85° are much more common. Therefore, while such methods of cooling may prevent the cylinder from attaining a dangerous temperature, they are inefficient in preventing excessive heating of the suction gas. Thus, when extremely cold suction gas contacts the relatively hot cylinder wall, there is a relatively great increase in temperature accompanied by a large increase in volume, so that at the end of its suction stroke, the compressor cylinder instead of being filled with cold gas is filled with quite warm gas and the compressor cylinder has therefore not been able to take in as many pounds of refrigerant as it would have if the temperature were lower.

It has heretofore been proposed to utilize a refrigerating medium in cooling compression cylinders of multi-stage compressors by by-passing refrigerant through the cooling jackets of compressor cylinders after the refrigerant traversed the cooling coils or has performed its cooling function in the cooling unit or evaporator, but in such methods the efficiency is low since the gas has already absorbed heat and its cooling or heat exchange ability is greatly reduced. It has also been proposed to cool a compressor cylinder in an ammonia system by the expansion of ammonia gas. For instance, in horizontal double acting machines, it has long been common practice to inject liquid ammonia into the suction gas to keep down the heat effect, but in such case the cooling work is done by the low stage compressor at an added power input, and such liquid ammonia injection is not efficient as a cooling method, particularly in high speed machines.

Although multiple stage refrigeration has given improved results, it is still not completely satisfactory, because it does not give the best possible volumetric efficiency.

It is an object of the present invention to pro-

vide a simple, practical, and economical refrigerating system for obtaining low temperatures and in which the absorption of heat by the suction gas entering the compressor is minimized.

Another object of the invention is to minimize the absorption of heat without increasing the refrigerating load on the compressor to which it is applied.

The invention contemplates temperatures far below freezing, and therefore water is not usable as a refrigerating medium due to the hazard of freezing at operating temperatures, and furthermore owing to the fact that water has higher temperature than is desirable for efficient cooling action. Non-volatile refrigerating mediums, such as brine, with low freezing points may be employed. They are, however, much less desirable than direct expansion mediums, one reason for which is because they require separate, relatively expensive, systems for cooling.

Further, it may be practical to use an entirely separate refrigerating system for cooling the cylinder walls of one or more compressors of a multiple system. While this separate system may be relatively expensive from a first cost viewpoint, it has the advantage of operation at high suction pressures with the resulting low power cost per ton of refrigeration for this independent system. Further, employment of a separate refrigeration system at high suction pressure would improve the capacity of the main plant.

Briefly stated the present invention comprises the provision of a multiple stage refrigeration system for producing low temperatures, such a system including refrigerating means for minimizing the absorption of heat by the suction gas entering the compressor.

The desired result is accomplished in a number of ways, as for example by vaporization of a refrigerating fluid, which fluid is obtained either by diverting the refrigerant liquid before it reaches the evaporator, i. e., from the high pressure side of the system prior to its expansion, or by an independent refrigeration system of any desired type including compression or absorption, which system is utilized for securing the cooling effect. When liquid refrigerant for producing the cooling action is diverted prior to its reaching the evaporator, it is returned into the suction line or suction side of a higher pressure stage compressor of the system.

Where brines or other means are employed they may be cooled in any desired manner, as for example by an independent refrigeration system with any desired arrangement for absorbing heat from the cylinder of the compressor.

Where an independent refrigeration system is employed the refrigerant from the independent system may be expanded around the cylinder walls and then returned to the independent system, the refrigerant being handled in this system in the manner well known in the art.

The invention has been used in multi-stage hook-ups for ammonia plants, and may be said therefore to be particularly advantageous in an ammonia system, although other refrigerants may be employed.

Apparatus in accordance with the present invention is illustrated in the accompanying drawings, wherein:

Figure 1 is a diagrammatic view of a multiple stage compression refrigeration system employing ammonia as a refrigerating medium, and with the lower stage compressor cooled by refrigerant diverted from the system;

Fig. 2 is a similar view with the lower stage compressor cooled by a separate refrigeration system.

Referring to the drawings in detail, there is shown a multiple stage refrigeration system which may consist of a larger number of stages, although only two stages are shown. Additional stages, of course, would be in accordance with the demands of the system installed, and the invention is not limited to any particular number of stages, but where the expression "multi-stage" is used it is intended to refer to 2, 3, 4 or more stages.

Also, parts such as coolers, separators, condensers, etc., are shown which could be replaced by parts having equivalent functions or may be eliminated in certain systems, such parts being included more to make the system complete rather than as having any practical bearing on the invention.

A low pressure machine or compressor is generally indicated at 10 and is provided with a cylinder 11 defining a compression chamber 12 in which a piston 13 is mounted to reciprocate to compress refrigerant in a well-known manner. A jacket 14 surrounds the wall 11 of the cylinder and defines a cooling space or chamber 15.

Gas compressed in the chamber 12 passes therefrom through pipe line or conduit 16 to intercooler 17 and then through line 18 to a gas and liquid cooler 19, from which it passes through line 20 to the compression chamber of a high pressure machine or compressor 21. After being compressed by the high pressure machine, the gas passes into pipe line 22, which forms part of the high pressure side of the system, thence into oil separator 23 and line 22' to condenser 24, the condensed and liquified refrigerant passing into receiver 25. Liquid refrigerant (in this case ammonia) passes from receiver 25 into line 26, through coils 26' in gas and liquid cooler 19 and on through line 27 to and through coils 27' in accumulator 28, and thence through line 29 having expansion valves therein to the evaporator or evaporators. In the evaporators, expanded refrigerant absorbs heat from the surrounding atmosphere or material to produce cold in a well-known manner, after which it passes through conduit 30 to accumulator 28 and line 30' into the compression or piston chamber 12 of the low pressure machine 10.

The gas and liquid cooler 19 has a predetermined amount of liquid refrigerant maintained therein by means of a float valve unit 19' which communicates with the cooler at points above and below the liquid level to be maintained by means of pipes 19a and 19b, said valve controlling flow of refrigerant to the cooler through an extension 26a of the line 26. Gas from the line 18 bubbles up through the liquid refrigerant, producing an interchange of heat and resulting in a better balanced system.

That part of the system between the compression chamber 12 of the low pressure machine and the compression chamber of the high pressure machine constitutes the discharge from the low pressure machine or the suction area of the high pressure machine.

Means are provided whereby a certain quantity of liquid refrigerant may be diverted from the high pressure side of the system to the cooling chamber 15 defined by the jacket 14, the liquid refrigerant being expanded as it enters the chamber 15, at which point it functions to cool cylinder 11. From the chamber 15 the gas is

passed to the discharge of the low pressure machine or the suction of the high pressure machine it being apparent that the gas may be returned at any point to that part of the system described in the preceding paragraph. Accordingly, a conduit 31 is tapped into the line 26 at its inlet end and at its discharge end enters the cooling chamber 15. This line is provided with an expansion valve 32 which may be controlled manually or automatically. From the chamber 15, the refrigerant passes through conduit 33 into line 16 leading from the compression chamber of the low pressure machine.

By this means, a predetermined amount of liquid refrigerant may be taken from the high pressure side of the multi-stage system, expanded and passed into and through the cooling chamber 15 to effect cooling of the cylinder walls. This maintains the cylinder of the low pressure machine at a temperature sufficiently low to obtain a relatively high degree of efficiency. Actual experience has demonstrated that the temperature of the gas taken into the compression chamber of the low pressure machine does not go as high as where conventional methods of cooling are employed.

While by cooling the cylinder in this manner some extra power is required for driving the higher stage compressor, this is more than offset by the increase in pumping efficiency.

As previously indicated instead of diverting refrigerant from the system an independent refrigeration system may be employed, as shown in Fig. 2 of the drawing. The line 31 has been carried directly to the receiver of a conventional refrigeration system, and the line 33 to the suction side of the system. This system as shown comprises a compressor 40 in which refrigerant is compressed and supplied through a pipe 41, an oil separator 42, and a pipe 43 to a condenser 44, from which refrigerant flows through pipe 45 to a receiver 46. From the receiver 46 liquid refrigerant is supplied through the pipe 31 to an expansion valve 32 and to the cylinder wall of the compressor where it changes its state from a liquid to a vapor, absorbing heat from the cylinder wall. The vapor thus formed is withdrawn through the pipe 33 and returned to the compressor 40, thus cyclically refrigeration in this auxiliary system is employed for cooling the cylinder wall of the compressor.

It will be understood that certain minor changes in construction and design may be adopted without departing from the spirit or scope of the invention as defined by the appended claims.

What is claimed is:

1. In the operation of a multi-stage refrigeration system employing a low stage compressor and a high stage compressor, the method which includes the steps of diverting refrigerant from the system beyond the high stage compressor and circulating it in expanded form around the cylinder walls of the low pressure compressor to effect cooling of the latter, and returning the refrigerant to the system at a point between the low and high stage compressors.

2. In the operation of a multi-stage refrigeration system employing a low stage compressor and a high stage compressor, the method which includes the steps of circulating a stream of liquid refrigerant from the high pressure side of the system around the cylinder walls of the low pressure compressor, expanding said stream prior to contact with said walls, and returning the re-

frigerant to the system between the low and high stage machines.

3. In the operation of a multi-stage refrigeration system employing a low pressure compressor and a high pressure compressor, the method which includes the steps of by-passing refrigerant from the high pressure side of the system to a point between the low and high pressure machines through a cooling chamber for the low pressure machine, and expanding the refrigerant as it enters said chamber.

4. In the operation of a multi-stage refrigeration system employing a low pressure compressor and a high pressure compressor, the method which includes the steps of diverting a portion of the stream of liquid refrigerant from the high pressure side of the system and passing the diverted stream in expanded and gaseous form within cooling adjacency to the cylinder walls of the low pressure machine, and after it has effected its cooling function, merging the gas with the main stream of refrigerant at a point where it will be subjected to the action of the high pressure compressor.

5. In the operation of a multi-stage refrigeration system, the method which consists in subjecting refrigerant from an evaporator to the action of a low pressure compressor and then to a higher stage compressor, diverting a portion of liquid refrigerant from the system after it has been subjected to the action of the higher stage machine and condensed into liquid form and by-passing the diverted stream through a chamber surrounding the cylinder walls of the low pressure machine to a point in the system between the low pressure and high pressure machines, and expanding the liquid refrigerant as it passes into said chamber.

6. In a refrigeration system, a low stage compressor, a high stage compressor and a cooling unit or evaporator with interconnecting conduits, said low stage compressor being provided with cylinder walls having a cooling jacket surrounding the same and defining a cooling chamber, a conduit connected into the system between the high stage compressor and evaporator and leading to said cooling chamber and another conduit leading from said cooling chamber to the system between the discharge of the low stage compressor and the intake of the high stage compressor, and whereby a portion of the stream of refrigerant may be by-passed from the high pressure side of the system through said cooling chamber and then returned to the system without passing through the cooling unit, and means for expanding refrigerant prior to entering said cooling chamber.

7. In a refrigeration system, an evaporator or cooling unit, means for attaining extremely low temperatures adjacent said unit including a low stage compressor for compressing the gas from said unit and a high stage compressor for further compressing the gas from said low stage compressor, said low stage compressor having cylinder walls and a jacket surrounding said walls providing a cooling chamber, means for diverting a portion of the liquid refrigerant from the stream passing from the high stage compressor to the evaporator and circulating the refrigerant so diverted through said cooling chamber and thence to the system between the low and high stage compressor, and means for expanding the refrigerant prior to passing into said cooling chamber.

8. In a refrigeration system, an evaporator or

cooling unit and means for attaining extremely low temperatures adjacent said unit including a low stage compressor for compressing refrigerant gas from said evaporator and a high stage compressor for compressing refrigerant from said first stage compressor, a condenser and receiver, a conduit for conducting refrigerant from said receiver to said evaporator, said low stage compressor having cylinder walls defining a compression chamber and a jacket surrounding said walls and defining a cooling chamber, a by-pass conduit arranged to divert part of the refrigerant from said first-named conduit and conduct it to said cooling chamber, said by-pass conduit having an expansion valve therein and whereby refrigerant applied to said cooling chamber is expanded to effect cooling of the cylinder walls, and means for returning refrigerant from said cooling chamber to the system at a point between said low stage and high stage compressors.

9. In a refrigeration plant utilizing ammonia as a refrigerant, an evaporator and means for attaining extremely low temperatures adjacent to said evaporator including a low stage compressor for compressing refrigerant gas from said evaporator and a high stage compressor for compressing refrigerant from said first stage compressor, a receiver for refrigerant compressed by said high stage compressor, means for conducting refrigerant from said receiver to said evaporator, and means for by-passing a portion of the refrigerant from said receiver to the discharge side of the low pressure compressor and applying the by-passed refrigerant in expanded form to effect cooling of mechanism of the low stage compressor.

10. In a multi-stage refrigeration system, an evaporator, a low stage compressor for compressing refrigerant gas from said evaporator and a high stage compressor for compressing refrigerant from the low stage compressor, said latter compressor having a compression cylinder and a cooling chamber to facilitate cooling of the walls of said cylinder, a receiver for refrigerant compressed by said high stage compressor, means for conducting refrigerant from said receiver to said evaporator, and means for by-passing a portion of the refrigerant from said receiver through said cooling chamber to the discharge side of the low pressure compressor to effect cooling of the cylinder walls of the low stage compressor.

11. A low-temperature refrigeration system, comprising an evaporator, a condenser and a plurality of compressors interconnected to provide a multiple-stage refrigeration system, means for supplying an auxiliary cooling medium having a freezing temperature lower than the freezing temperature of water to the lowest-stage compressor for lowering the temperature of the suction gas entering the compressor to increase the volumetric efficiency thereof.

12. A low-temperature refrigeration system, comprising an evaporator, a condenser and a plurality of compressors interconnected to provide a multiple-stage refrigeration system, means for supplying an auxiliary cooling medium having a freezing temperature lower than the freezing temperature of water to a lower stage com-

pressor for lowering the temperature of the suction gas entering the compressor to increase the volumetric efficiency thereof.

13. In the art of low temperature refrigeration employing a plurality of stages of compression, that improvement which comprises compressing the refrigerant in several stages, condensing the compressed refrigerant, vaporizing the refrigerant, returning the vaporized refrigerant to the lowest stage compressor, and supplying an auxiliary cooling medium having a freezing temperature below that of water to said first stage compressor thereby lowering the temperature of the suction gas entering the compressor and increasing the volumetric efficiency of said compressor.

14. In the art of low temperature refrigeration employing a refrigeration system having a plurality of stages of compression that improvement which comprises compressing the refrigerant in several stages, condensing and expanding the refrigerant, and returning the expanded refrigerant to the lowest stage compressor, and supplying an auxiliary cooling medium having a freezing temperature below that of water to a lower stage compressor, thereby lowering the temperature of the suction gas entering the compressor, and increasing the volumetric efficiency of said compressor.

15. In the operation of a refrigeration system having a plurality of stages of compression, that improvement which comprises compressing the refrigerant in two or more stages, condensing and expanding the refrigerant, passing the expanded refrigerant through heat absorption means, returning the refrigerant to a lower stage compressor, and diverting refrigerant from the high side of the system to the discharge of the lower stage compressor through a cooling chamber of said lower stage compressor and expanding the refrigerant entering said chamber.

16. In the operation of a refrigeration system having a plurality of stages of compression, the method which includes the step of diverting refrigerant from the high side of the system through a cooling chamber in heat exchange with a lower stage compressor and exhausting to a point between said lower and a higher stage compressor.

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