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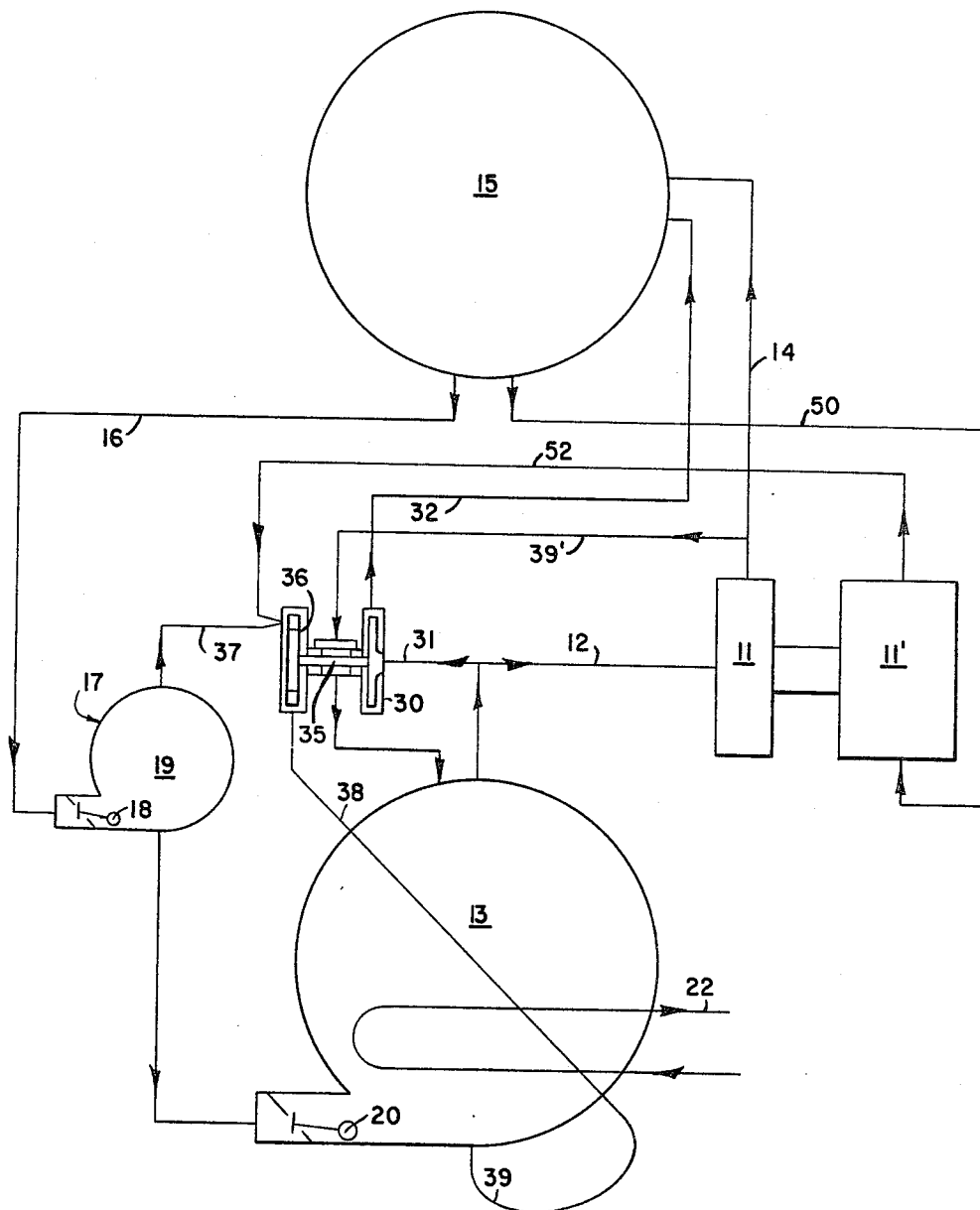
L. H. LEONARD, JR
REFRIGERATION APPARATUS

3,277,658

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FIG. 2



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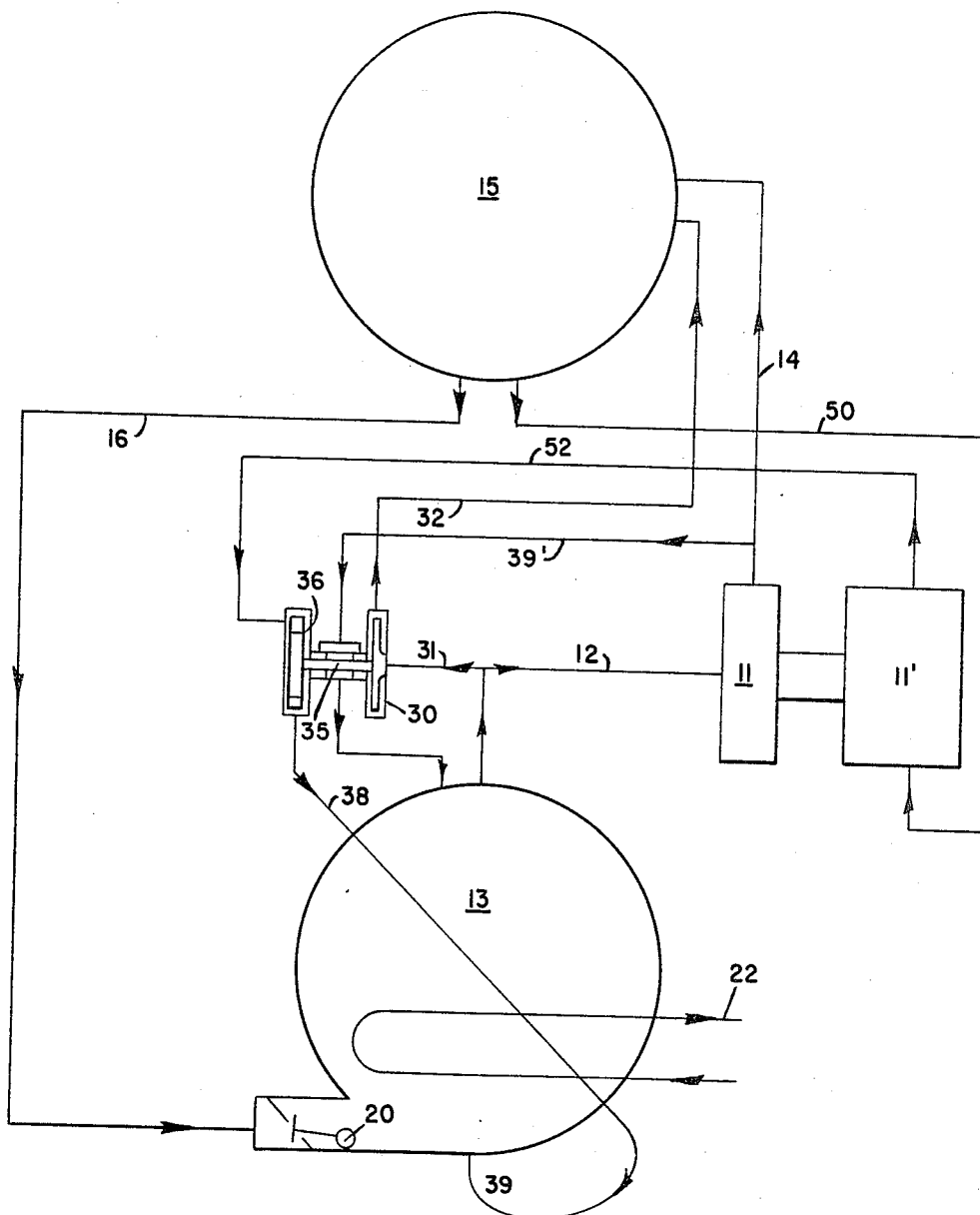
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FIG. 3



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REFRIGERATION APPARATUS

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22 Claims. (Cl. 62—87)

This is a continuation-in-part of application Serial No. 379,446, filed July 1, 1964, now abandoned. This invention relates to a refrigeration system and a method of providing refrigeration and, more particularly, to a method and circuit for improving the efficiency of a refrigeration system. Refrigerant gas, such as economizer flash gas, which in a sense may be considered a loss as far as refrigerating effect is concerned, is utilized to lift refrigerant from a relatively low side to a relatively high side of the system, so that the energy of the gas is utilized to improve the efficiency of the system.

In many refrigeration systems, refrigerant is expanded in an expansion motor prior to passing into an evaporator, and the expansion motor is used to drive a refrigerant compressor or perform other work in the system. While such expedients may provide advantages in a refrigeration system, for the most part they do not utilize energy which would otherwise be a loss in the system, for performing useful work to increase the efficiency of the system.

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

An important object of this invention is to increase the efficiency of a refrigeration system.

Another object is provision of a new and improved refrigeration system and method of providing refrigeration wherein energy which would otherwise be a loss in the system is utilized to perform useful work and thereby increase the efficiency of the system.

Still another object is provision of a new and improved refrigeration system in which refrigerant gas compression means is driven by flash gas in the system for lifting refrigerant from a relatively low side to a relatively high side of the system so that the energy of the flash gas is utilized to improve the efficiency of the system. A related object is provision in a refrigeration system having an economizer, for driving refrigerant gas compression means with economizer flash gas. Another related object is to utilize the expended flash gas for agitating refrigerant in the system.

Another object is to provide a new and improved method of increasing the efficiency of a refrigeration system wherein flash gas in the system is utilized for driving a compressor which lifts refrigerant vapor from a relatively low side to a relatively high side of the system, thereby utilizing the energy of the flash gas to improve the efficiency of the system. A related object is provision for utilizing economizer flash gas to lift the refrigerant from the low side to the high side of the system, and for agitating refrigerant in the system.

A further object of the invention is the provision of utilizing gas formed in a refrigeration machine having a liquid refrigerant cooled motor as the heat from the motor vaporizes the liquid refrigerant coolant for driving a compressor pumping refrigerant to the condenser employed in the machine.

An additional object of the invention is the provision of a novel lubricating arrangement for mechanism functioning as an accessory to a refrigeration machine.

A still further object of the invention is the provision of an auxiliary refrigerant gas pumping means for use with a refrigeration machine wherein lubrication of the auxiliary means may be accomplished by using refrigerant gas from the refrigeration machine.

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The invention is embodied in a small turbocompressor wherein the turbine is driven by refrigerant flash gas in the system, for example economizer flash gas. The gas is discharged from the turbine into an evaporator and may be utilized therein to agitate the refrigerant. The turbocompressor lifts refrigerant from a relatively low pressure side to a relatively high pressure side of the system and, more particularly, from the evaporator to the refrigerant condenser. While the invention is equally applicable to heat pumps, absorption refrigeration systems and other types of refrigeration systems, it is illustrated in a compression type refrigeration system, with the turbocompressor in parallel with the main refrigerant compressor. With this arrangement it has been found that the turbocompressor lifts about 10–12% of the refrigerant from the evaporator to the condenser, thus reducing the required power input to the main compressor and increasing the efficiency of the system.

FIGURE 1 is a schematic diagram of a refrigeration machine illustrating one form of the invention;

FIGURE 2 is a schematic diagram of a refrigeration machine illustrating another form of the invention; and FIGURE 3 is a schematic diagram of a refrigeration machine illustrating a third form of the invention.

Refrigeration systems employing the economizer principle wherein the liquid refrigerant formed in the condenser is passed to an economizer chamber having communication with an intermediate stage of compressor so as to be at a pressure intermediate the high and low pressure sides of the system are utilized to cool water for use in air conditioning installation for large buildings.

This invention contemplates, in its preferred form, using flash gas, formed as the liquid refrigerant flowing from the condenser enters the economizer chamber, as a power fluid for driving a turbocompressor, the compressor suction of which is connected between the evaporator and the condenser of the refrigeration system for the purpose of delivering a portion of the suction gas generated in the evaporator to the condenser. Turbocompressors of the kind under consideration are often used as superchargers for internal combustion engines.

In the drawing a first or main compressor 11 of any desired type is driven by any suitable means such as an electrical motor or a turbine 11', and receives refrigerant vapor through a main suction line 12 from an evaporator 13 and passes compressed refrigerant through a main discharge line 14 to a refrigerant condenser 15. From the condenser 15 the refrigerant flows through a condensate line 16 to refrigerant flow control means, here in the form of an economizer 17 for sub-cooling the refrigerant. The economizer has a first float valve 18 which receives the condensed refrigerant and passes the refrigerant into an economizer chamber 19 for collecting economizer flash gas and from which the flash cooled refrigerant passes through a second float valve 20 and an evaporator supply line 21 into the evaporator 13 provided with a chilled water line 22 to a load to be cooled. From the evaporator the vaporized refrigerant enters the suction line 12 thus completing the refrigerant circuit.

A refrigerant economizer circuit includes a second or auxiliary refrigerant compressor 30, preferably a centrifugal compressor, which is connected in parallel with the main compressor 11 between the evaporator 13 and the condenser 15. More particularly, an auxiliary suction 31 branches off of the main suction line 12 for passing refrigerant vapor from the evaporator to the auxiliary compressor, and the refrigerant compressed by compressor 30 passes through an auxiliary discharge line 32 into the refrigerant condenser 15.

A suitable prime mover, such as a turbine or expander 36 is drivingly connected, as by a drive shaft 35, with the auxiliary compressor 30. Economizer flash gas passes

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from the economizer chamber 19 through a flash gas line 37 to the turbine 36 for driving the turbine and the compressor 30, and the flash gas discharged from the turbine 36 passes through a flash gas line 38 and into the evaporator 13. The refrigerant flash gas in the economizer chamber 19 is at an intermediate pressure between that of the high pressure side of the system (between the discharge of the main compressor 11 and the float valve 18) and the low pressure side of the system (between the second float valve 20 and the suction of the main compressor 11) so that the flash gas driving the turbine passes from a zone of intermediate pressure within the economizer chamber 19 to a zone of low pressure within the evaporator 13. By passing only gas to the turbine, cavitation of the turbine is effectively prevented.

The turbine discharge line 38 may open into the evaporator 13 through a suitable agitator line 39 disposed within the evaporator for agitating the liquid refrigerant entering through the supply line 21.

The auxiliary compressor 30 and turbine 36 are preferably a compact turbocompressor unit which may be easily installed in existing refrigeration systems. It is merely necessary to suitably mount the turbocompressor and connect the auxiliary refrigerant lines 31 and 32 to the compressor and the flash gas lines 37 and 38 to the turbine and, if desired, the agitating line 39 in the evaporator. Because both the turbine and compressor sides of the turbocompressor are passing the same fluid, that is refrigerant, it is not necessary to provide relatively tight seals between the turbocompressor, and the shaft 35 may be mounted in any suitable type of bearings which are preferably refrigerant lubricated bearings.

To this end line 39' supplies gaseous refrigerant from the refrigeration circuit to the bearings mounting the shaft employed to support the turbine and compressor wheels. The use of gaseous refrigerant as a lubricant is convenient in the arrangement described because discharge gas (the lubricant supply) will be generated before the economizer gas is of sufficient volume to load the bearings of the turbocompressor when operation of the refrigeration machine is initiated. It will also be appreciated that gas lubrication of the turbocompressor increases the efficiency of the machinery for the energy required to overcome the resistance to shaft movement due to the lubrication is minimized. Other forms of lubrication may be employed if desired. For example, liquid refrigerant, water or conventional lubricating oils may be used.

The economizer circuit is self-balancing since it is driven by flash gas from the economizer 17 and is preferably sized so that the auxiliary compressor 30 passes about 10-12% of the refrigerant lifted from the evaporator to the condenser, the remaining refrigerant being lifted in the normal manner by the main compressor 11.

The capacity of the turbocompressor is governed by the supply of economizer gas generated in the refrigeration circuit. Accordingly, at low lifts the speed and thus the pumping capacity of the turbocompressor is relatively low. At high lifts when additional pumping capacity is desirable, the turbocompressor is operated at higher speeds thus rendering additional capacity to the main compressor. Because of the relationship between the turbocompressor performance and the refrigeration system operating condition as indicated by the economizer gas, the turbocompressor can improve cycle efficiency without special controls such as suction guide vanes, throttling valves or the like.

By providing an auxiliary compressor in parallel with the main compressor 11, rather than in series with the main compressor, the auxiliary compressor 30 may be much smaller and therefore less expensive and may be provided as an accessory on existing systems, and automatically balances to any particular operating condition of the system.

Another advantage obtained with the turbocompressor unit is realized in heat pump applications where an in-

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creased lift is required below the low side and the high side of the system when operating during the heating cycle. The turbocompressor will assist the main compressor so that a smaller and less expensive main compressor may be employed. It might also be desirable to employ additional turbocompressors in a staged manner to achieve even greater economy.

The construction described may be most efficiently employed with refrigerants known as refrigerant C-318 (octafluorocyclobutane) and refrigerant R-114 (tetrafluorodichloroethane) for the reason that these refrigerants possess thermodynamic properties among which is the property of "dry expansion." This property renders the refrigerant more suitable for use in a turbo-expander construction of the kind described.

FIGURE 2 illustrates a second embodiment of the invention and includes the arrangement illustrated in FIGURE 1 in addition to certain other conduits to be later described. Accordingly, the reference numerals and their respective parts are the same in FIGURE 2 as they are in FIGURE 1 with the exception that line 50 connects the condenser 15 with the motor compartment 11'. Conduit 50 is provided for the purpose of transmitting a small volume of condenser liquid to the interior of the motor to cool the heat generating components of the motor. In accomplishing the cooling action, the liquid refrigerant from the condenser is converted to gaseous refrigerant flowing from the motor casing through line 52. There is disclosed in United States Patent 3,146,605, issued September 1, 1964, in the names of Stanley J. Rachfal and Lawrence Macrow, an arrangement for cooling a motor of the kind contemplated here. Reference may be had to the patent for a more complete explanation of this action. The vaporous refrigerant flowing in line 52 is delivered to turbine 36 where it assists the vaporous refrigerant created in the economizer 19 in driving the turbine 36.

In FIGURE 3 another embodiment of the invention is illustrated. In this embodiment, the vaporous refrigerant created as the motor is cooled in the manner described above, serves as the sole driving force for turbine 36. Accordingly, FIGURE 3 does not include the economizer 17. In the form of the invention illustrated in FIGURE 3, liquid refrigerant formed in condenser 15 flows via line 16 directly to expansion member 20 associated with the evaporator 13. Under the circumstances, it will be appreciated that with conduit 50 serving to bleed a portion of the liquid refrigerant from the condenser, vaporous refrigerant will be formed in the motor compartment 11' and will flow via line 52 to the turbine 36 and be introduced therein through conventional nozzle means, not shown, for the purpose of driving the turbine.

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

I claim:

1. A method of improving the efficiency of a refrigeration system including first and second refrigerant compressors in parallel with each other between relatively high and low pressure sides of the system, and a prime mover drivingly connected with the second compressor, comprising the steps of, operating the first compressor to pass refrigerant from said low side to said high side, expanding refrigerant passing from said high side to said low side, thereby creating flash gas and cooling the refrigerant passing to said low side to improve the efficiency of the system, passing the flash gas to the prime mover for driving the second compressor, passing refrigerant vapor around the first compressor from said low side to the second compressor to compress the vapor, and passing the compressed vapor from the second compressor to said high side, thereby utilizing the energy of the flash gas to improve the efficiency of the system.

2. A method of improving the efficiency of a refrigeration system including first and second refrigerant com-

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pressors in parallel with each other between relatively high and low pressure sides of the system, and a prime mover drivingly connected with the second compressor, comprising the steps of, operating the first compressor to pass refrigerant from said low side to said high side, passing flash gas in the system to the prime mover for driving the second compressor, passing refrigerant vapor around the first compressor from said low side to the second compressor to compress the vapor, and passing the compressed vapor from the second compressor to said high side, thereby utilizing the energy of the flash gas to improve the efficiency of the system.

3. A method of improving the efficiency of a refrigeration system including first and second refrigerant compressors between relatively high and low sides of the system, and a prime mover drivingly connected with the second compressor, comprising the steps of, operating the first compressor to pass refrigerant from said low side to said high side, passing flash gas to the prime mover for driving the second compressor, passing refrigerant vapor from said low side to the second compressor to compress the vapor, and passing the compressed vapor from the second compressor to said high side, thereby utilizing the energy of the flash gas to improve the efficiency of the system.

4. A method of improving the efficiency of a refrigeration system, comprising the steps of, lifting refrigerant vapor from a relatively low pressure side to a relatively high pressure side of the system, expanding refrigerant passing from the high pressure side to the low pressure side, thereby creating flash gas, and utilizing the flash gas from the system to provide energy for so lifting the vapor, thereby utilizing the energy of the flash gas to improve the efficiency of the system.

5. The method of utilizing energy available in refrigerant flowing in a refrigeration circuit to perform useful work which comprises the steps of condensing refrigerant vapor to provide liquid refrigerant at a relatively high pressure, forwarding the condensed liquid refrigerant to a zone of pressure intermediate the high pressure zone and the low pressure zone to vaporize a part of the liquid refrigerant and employing the vaporized refrigerant as a power source to drive machinery associated with the circuit.

6. A method of improving the efficiency of a refrigeration system, comprising the steps of, lifting refrigerant vapor through separate first and second parallel paths from a relatively low pressure side to a relatively high pressure side of the system, expanding refrigerant passing from the high pressure side to the low pressure side, thereby creating flash gas, and utilizing the flash gas from the system to provide energy for so lifting the vapor through the second path, thereby utilizing the energy of the flash gas to improve the efficiency of the system.

7. The method of claim 6 wherein the second circuit lifts about ten to twelve percent of the total vapor lifted by both circuits.

8. A method of improving the efficiency of a refrigeration system including a compressor between relatively high and low pressure sides of the system, and a prime mover drivingly connected with the compressor, comprising the steps of expanding refrigerant passing from the high pressure side to the low pressure side, thereby creating flash gas, passing the flash gas formed in the system to the prime mover for driving the compressor, passing refrigerant vapor from said low side to the compressor to compress the vapor, and passing the compressed vapor from the compressor to said high side, thereby utilizing the energy of the flash gas to improve the efficiency of the system.

9. A method of improving the efficiency of a refrigeration system including first and second refrigerant compressors in parallel with each other between relatively high and low sides of the system, an economizer, and a prime mover drivingly connected with the second com-

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pressor, comprising the steps of, passing economizer gas from the economizer to the prime mover and returning the gas to said low side for driving the second compressor, passing refrigerant vapor around the first compressor from said low side to the second compressor to compress the vapor, and passing the compressed vapor from the second compressor to said high side, thereby utilizing the energy of the economizer gas to improve the efficiency of the system.

10. A method of improving the efficiency of a refrigeration system including main and second refrigerant compressors in parallel with each other for passing refrigerant from an evaporator to a refrigerant condenser, an economizer cooling liquid refrigerant passing from the condenser to the evaporator while creating economizer flash gas, and a turbine drivingly connected with the second compressor, comprising the steps of, operating the main compressor to pass refrigerant from the evaporator to the condenser, passing the economizer gas to the prime mover and returning the gas to the evaporator for driving the second compressor, passing refrigerant vapor around the main compressor from the evaporator to the second compressor to compress the vapor, and passing the compressed vapor from the second compressor to the condenser, thereby utilizing the energy of the economizer gas to improve the efficiency of the system.

11. The method of claim 10 and the additional step of agitating refrigerant in the evaporator with the economizer gas from the turbine.

12. A refrigeration system comprising, a refrigerant compressor for lifting refrigerant from a relatively low pressure side to a relatively high pressure side of the system, and means for driving the compressor with flash gas in the system, whereby the energy of the flash gas is utilized to improve the efficiency of the system.

13. A refrigeration system comprising, first and second refrigerant compressors for lifting refrigerant from a relatively low pressure side to a relatively high pressure side of the system, means for operating said first compressor, and means for driving the second compressor with flash gas in the system, whereby the energy of the flash gas is utilized to improve the efficiency of the system.

14. A refrigeration system comprising, a first refrigerant compressor, a turbocompressor including a turbine and a second refrigerant compressor, means connecting said compressors in parallel for lifting refrigerant from a relatively low side to a relatively high side of the system, an economizer, and means for passing economizer gas to said turbine for driving said turbocompressor, whereby the energy of the economizer gas is utilized to improve the efficiency of the system.

15. The system of claim 14 wherein said first compressor has a substantially larger capacity than said second compressor.

16. The system of claim 15 wherein said second compressor lifts about ten to twelve percent of the total vapor lifted by both compressors.

17. A refrigeration system comprising, a main refrigerant compressor for passing a refrigerant from an evaporator to a condenser, means for operating said main refrigerant compressor, a turbocompressor including a centrifugal refrigerant compressor in parallel with said main compressor, means for passing flash gas in the system to said turbine to operate the turbocompressor, and means for discharging said flash gas into said evaporator and agitating the refrigerant in said evaporator, whereby the energy of the flash gas is utilized to improve the efficiency of the system.

18. The invention described in claim 17 including a motor for driving the main refrigerant compressor and means for supplying liquid refrigerant to cool the motor, the flash gas forming as a result thereof.

19. The invention described in claim 18 including an economizer interposed in said system, means for passing flash gas from said economizer to assist the flash gas

formed in the motor compartment in driving the turbine.

20. A refrigeration system comprising a main refrigerant compressor for withdrawing refrigerant from the low pressure side of the system and delivering it to the high pressure side of the system, turbocompressor means connected in parallel with said main refrigerant compressor for withdrawing refrigerant from the low pressure side of the system and delivering it to the high pressure side of the system, an economizer wherein refrigerant gas is formed as liquid refrigerant passes into a zone of relatively low pressure, and means for passing said gas to said turbocompressor for driving the turbocompressor.

21. The refrigeration system described in claim 20 wherein said last-mentioned means includes a housing for a motor for driving said main compressor means for supplying liquid refrigerant as a coolant for said motor, the refrigerant changing to gas as it absorbs heat from the motor, and means for directing the gas so formed to said turbine.

22. The refrigeration system described in claim 20 in-

cluding a motor for driving the main compressor, said motor being cooled by liquid refrigerant as the refrigerant is converted to a vapor means for supplying said vapor to the turbine as another source of flash gas for driving the turbine.

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LLOYD L. KING, *Primary Examiner*.