

[54] **METHOD OF CONTROLLING HIGH STAGE AND LOW STAGE COMPRESSORS**

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[58] Field of Search. **62/203, 208, 217, 62/510, 115**

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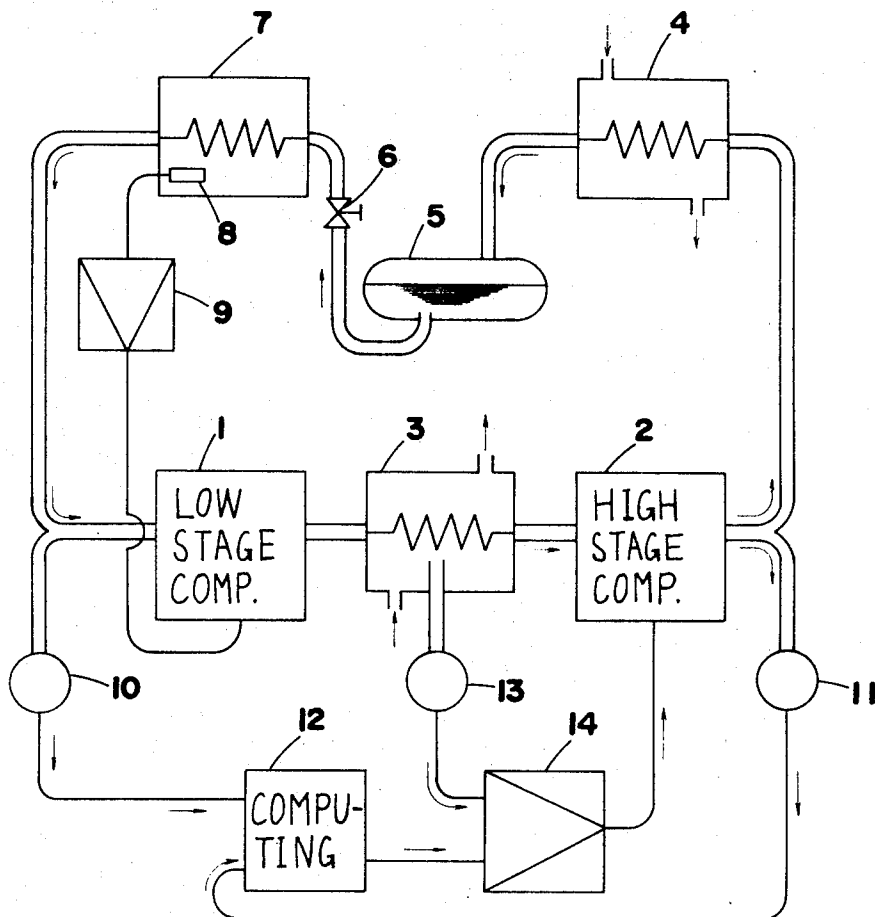
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[57]

ABSTRACT

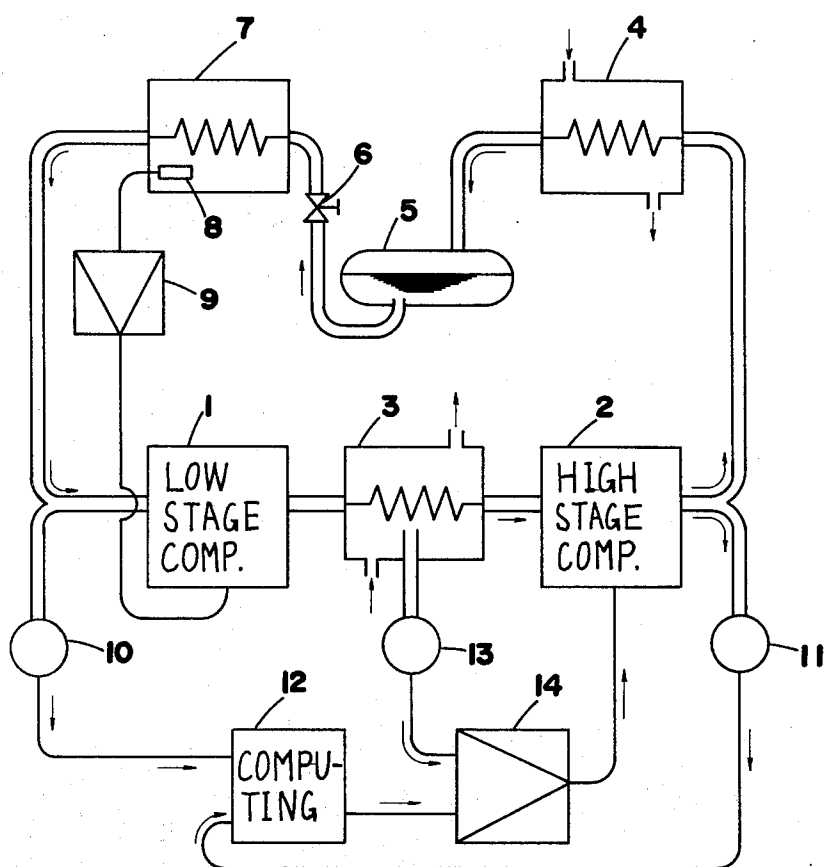
This invention relates to a method of controlling high stage and low stage compressors having non-linear control characteristics. Said method is characterized by comprising the steps of controlling the capacity of the low stage compressor during operation in accordance with a change in the temperature of a load for an evaporator, automatically computing the square root of the product of the pressure at which gas is drawn by suction into the low stage compressor and the pressure at which gas is discharged from the high stage compressor or an approximation thereof by means of an automatic computing unit, comparing the output of the automatic computing unit with the pressure of an intermediate cooler interposed between the low stage compressor and high stage compressor, and subordinatively controlling the ratio of the capacity of the low stage compressor to that of the high stage compressor by the result of the comparison.

3 Claims, 1 Drawing Figure



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METHOD OF CONTROLLING HIGH STAGE AND LOW STAGE COMPRESSORS

This invention relates to a method of controlling high stage and low stage compressors having non-linear control characteristics.

Heretofore, a so-called two stage compressor comprising a plurality of compressor units having non-linear control characteristics interconnected for continuous operation has been operated automatically by programming such that the capacities of the high stage compressor unit and low stage compressor unit are maintained in a predetermined ratio during operation. Particularly in a two stage compressor for a refrigerator of the multiple cylinder type having step-wise control characteristics, the ratio of the capacity of the low stage compressor unit to that of the high stage compressor unit can readily be determined based on displacement of the pistons. In other words, such two stage compressor can be operated in a manner such that the capacities of the high stage compressor unit and low stage compressor unit are in a predetermined ratio if the number of pistons at work in the high stage compressor unit and low stage compressor unit are in the predetermined ratio.

In the case of a turbo-compressor or screw compressor having non-linear control characteristics, the capacity of the refrigerator is a function of not only the degree of opening of the capacity control vane but also the pressure at which gas is drawn by suction into the compressor and the pressure at which it is discharged therefrom. Such compressor thus has a disadvantage that the two stage compressor thereof is hard to operate at an expected intermediate pressure if the operation is performed in accordance with a program prepared based solely on the degree of opening of the vane under a condition specified beforehand.

This invention obviates the aforementioned disadvantage of the prior art. Accordingly, the invention has as its object the provision of a method of controlling high stage and low stage compressors having non-linear control characteristics whereby the capacities of the high stage compressor and low stage compressor can be automatically controlled during operation by a change in the temperature or pressure of a load, and the square root of the product of the pressure at which gas is discharged from the high stage compressor and the pressure at which gas is drawn by suction into the low stage compressor or an approximation thereof is computed by an automatic computing unit and compared with the intermediate pressure so as to thereby continuously control the ratio of the capacities of the low stage compressor to that of the high stage compressor.

Other and additional objects as well as features and advantages of the invention will become evident from the description set forth hereinafter when considered in conjunction with a drawing which is a schematic view of high stage and low stage compressor adapted to carry the method according to this invention into practice.

In the drawing, 1 is a low stage compressor and 2 is a high stage compressor of a turbo-compressor or screw compressor having non-linear control characteristics. An intermediate cooler 3 is interposed between the two compressors 1 and 2. High stage compressor 2 is connected at its discharge side to a refrigerant condenser 4 and a liquid-state refrigerant sump 5, the latter

being connected at its bottom to an evaporator 7 through a throttle valve 6.

Evaporator 7 is connected to low stage compressor 1 so that the refrigerant changed back to a gaseous state as the result of a heat exchange taking place between the liquid-state refrigerant and a heat load for evaporator 7 is drawn by suction into low stage compressor 1 through its suction side, thereby completing the refrigeration cycle.

Inserted in evaporator 7 is a temperature detector 8 which is connected to an automatic temperature controller 9. The output of automatic temperature controller 9 is connected to a capacity control valve of low stage compressor 1 so as to control the degree of opening of such valve.

A transducer 10 for converting pressure into an analogical electricity is provided at the suction side of low stage compressor 1, and a transducer 11 for converting pressure into an analogical electricity is provided at the discharge side of high stage compressor 2. The two transducers 10 and 11 are connected to an automatic computing unit 12 which is in turn connected to a balanced controller 14 to which is also connected a transducer 13 provided in intermediate cooler 3 for converting pressure into an analogical electricity. The output of balanced controller 14 is connected to high stage compressor 2 so as to automatically control the degree of opening of a capacity control valve of high stage compressor 2.

Operation of this invention will now be described. If the heat load for evaporator 7 undergoes a change, temperature detector 8 will detect the change in temperature which is supplied to automatic temperature controller 9 as its input and compared with a value at which automatic temperature controller 9 is set beforehand. The change is amplified and enlarged as a positive or negative deviation from the set value and used as a signal for controlling the degree of opening of the capacity control valve of low stage compressor 1. Accordingly, the capacity of low stage compressor 1 is adjusted to a level which is commensurate with the heat to be absorbed by the liquid-state refrigerant in evaporator 7.

The refrigerant changed back to a gaseous state by absorbing heat in evaporator 7 is drawn by suction into low stage compressor 1 for compressing therein and then drawn by suction into high stage compressor 2 after being cooled in intermediate cooler 3 by a heat exchange taking place between the recompressed gaseous-state refrigerant and cooling water.

The gaseous-state refrigerant is further compressed in high stage compressor 2 and passed on to condenser 4 where it gives off heat and changes to a liquid state as the result of a heat exchange taking place between the gaseous-state refrigerant and cooling water. The refrigerant thus changed back to a liquid state is supplied to liquid-state refrigerant sump 5 where it is stored as a liquid-state refrigerant.

The liquid-state refrigerant stored in sump 5 has its pressure reduced as it is passed through throttle valve 6 and then introduced into evaporator 7 where it is changed back to a gaseous state and absorbs heat from the heat load.

On the other hand, transducer 10 converts the pressure at which gas is drawn by suction into low stage compressor 1 into an electric quantity P_L and transducer 11 converts the pressure at which gas is dis-

charged from high stage compressor 2 into an electric quantity P_H , the electric quantities P_L and P_H being either in the form of voltage or current. The electric quantities P_L and P_H are supplied to automatic computing unit 12 where the square root of the product of P_L and P_H or an output $P_m = \sqrt{P_L \cdot P_H}$ is computed instantly and automatically. The output P_m is compared with an output P_m' of transducer 13 provided in intermediate cooler 3 at balanced controller 14, and the degree of opening of the capacity control valve of high stage compressor 2 is automatically controlled in accordance with the result of the comparison.

From the foregoing, it will be appreciated that according to this invention the output P_m is computed based on the pressure at which gas is drawn by suction into the low stage compressor and that, at the same time, the capacity of the high stage compressor is controlled in accordance with the working capacity of the low stage compressor.

It is to be understood, however, that in effecting control of the refrigeration system as a whole by detecting a change in the temperature of the evaporator, the invention is not limited to the manner of control based on controlling the capacity of the low stage compressor as described hereinabove, and that the capacity of the high stage compressor may instead be controlled to obtain the output P_m by computing which is compared with the output P_m' during operation so as to thereby control the capacity of the low stage compressor.

In case the heat load shows no large change and the capacity of low stage compressor 1 can be controlled ideally, there is no appreciable change in the pressure at which gas is drawn by suction into the low stage compressor. If, therefore, the pressure at which gas is drawn by suction into the low stage compressor is considered to be constant ($\sqrt{P_L} = C$) in such case, $P_m = \sqrt{P_L \cdot P_H} = C \cdot \sqrt{P_H}$. The control device could be simplified by using a non-linear element or computing circuit having the aforementioned characteristics. More specifically, low stage compressor 1 could be controlled by the detected suction pressure of gas at low stage compressor 1 and high stage compressor 2 can be controlled by the square root of the discharge pressure of gas at high stage compressor 2.

According to this invention, the capacity of either the low stage compressor or high stage compressor is automatically controlled in accordance with a change in the temperature or pressure of the evaporator, the square root of the product of the pressure at which gas is drawn by suction into the low stage compressor and the pressure at which gas is discharged from the high stage compressor or an approximation thereof is computed by the automatic computing unit, and the value obtained by computing is compared with the pressure of the intermediate cooler so as to continuously control the ratio of the capacity of the low stage compressor to that of the high stage compressor in accordance with the result of the comparison. The invention offers many advantages. For example, the control of the compressor can be effected merely by setting the temperature controller inserted in the evaporator at a suitable value. The invention permits the compressor to be operated positively and readily and a high operation efficiency to be attained.

What is claimed is:

1. A method of controlling high stage and low stage compressors in a refrigeration system comprising

automatically controlling the capacity of the low stage compressor during operation in accordance with a change in the temperature of the surface of the evaporator,

automatically computing the square root of the product of a quantity of electricity which has been varied in accordance with a pressure at which gas is discharged from the high stage compressor and a quantity of electricity which has been varied in accordance with a pressure at which gas is drawn by suction into the low stage compressor by means of an automatic computing unit,

comparing the output of the automatic computing unit with a quantity of electricity which has been varied in accordance with a pressure of an intermediate cooler interposed between the low stage compressor and high stage compressor, and

automatically controlling the capacity of the high stage compressor by the result of the comparison such that the output of the automatic computing unit becomes identical with the quantity of electricity corresponding to the intermediate cooler.

2. A method of controlling high stage and low stage compressors in a refrigeration system comprising automatically controlling the capacity of the low stage compressor during operation in accordance with a change in the temperature of the refrigerant in the evaporator,

automatically computing the square root of the product of a quantity of electricity which has been varied in accordance with a pressure at which gas is discharged from the high stage compressor and a quantity of electricity which has been varied in accordance with a pressure at which gas is drawn by suction into the low stage compressor by means of an automatic computing unit,

comparing the output of the automatic computing unit with a quantity of electricity which has been varied in accordance with a pressure of an intermediate cooler interposed between the low stage compressor and high stage compressor, and

automatically controlling the capacity of the high stage compressor by the result of the comparison such that the output of the automatic computing unit becomes identical with the quantity of electricity corresponding to the intermediate cooler.

3. A method of controlling high stage and low stage compressors in a refrigeration system comprising automatically controlling the capacity of the low stage compressor during operation in accordance with a change in the pressure of the refrigerant in the evaporator,

automatically computing the square root of the product of a quantity of electricity which has been varied in accordance with a pressure at which gas is discharged from the high stage compressor and a quantity of electricity which has been varied in accordance with a pressure at which gas is drawn by suction into the low stage compressor by means of an automatic computing unit,

comparing the output of the automatic computing unit with a quantity of electricity which has been varied in accordance with a pressure of an intermediate cooler interposed between the low stage compressor and high stage compressor, and

automatically controlling the capacity of the high stage compressor by the result of the comparison such that the output of the automatic computing unit becomes identical with the quantity of electricity corresponding to the intermediate cooler.

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