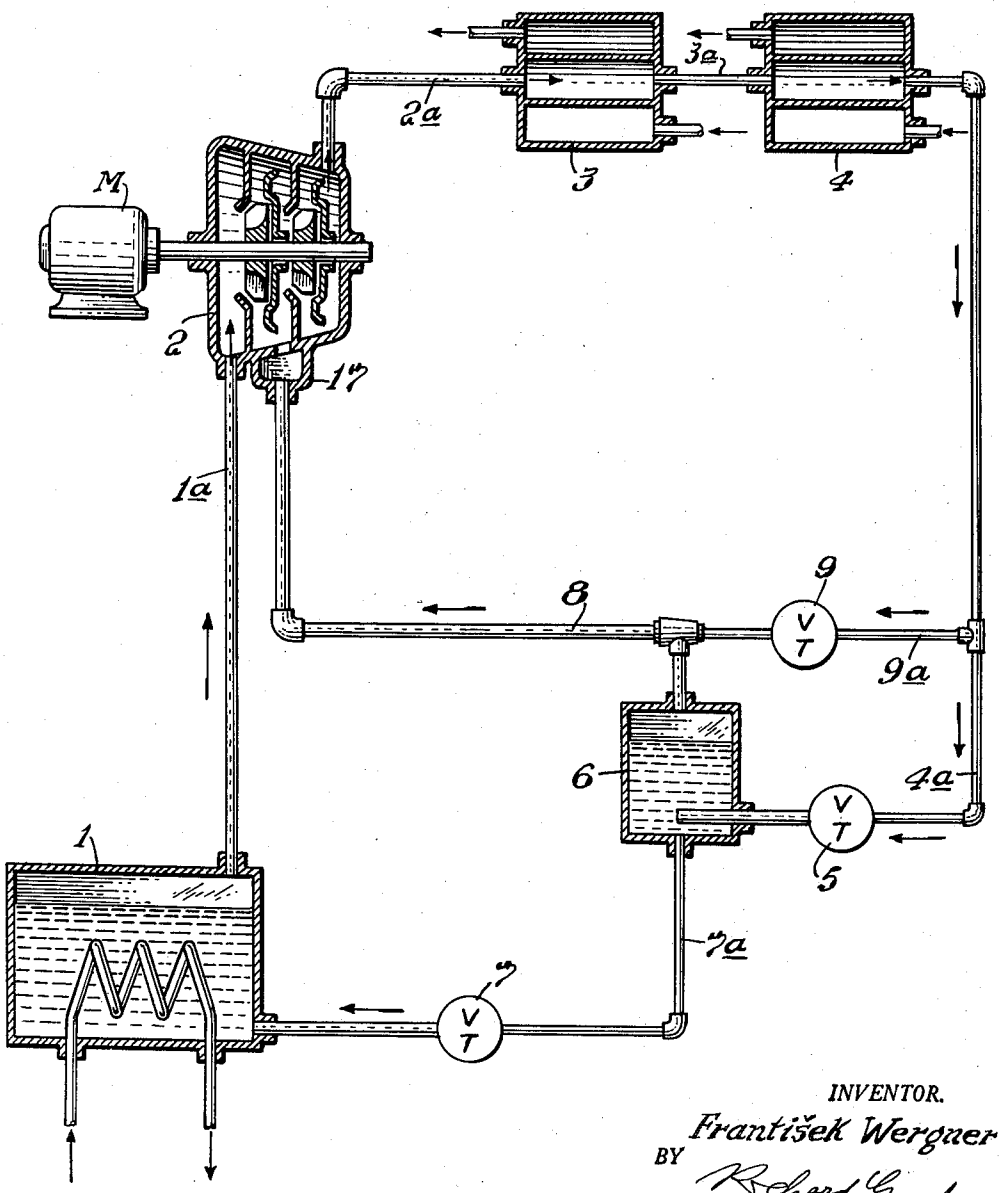
Aug. 4, 1959 F. WERGNER 2,897,659

APPARATUS FOR GAS AND LIQUID COOLING IN COMPRESSOR PLANTS WITH TWO-OR MULTISTAGE COOLING CIRCUIT

Filed Aug. 4, 1955 3 Sheets-Sheet 1

Fig. 1



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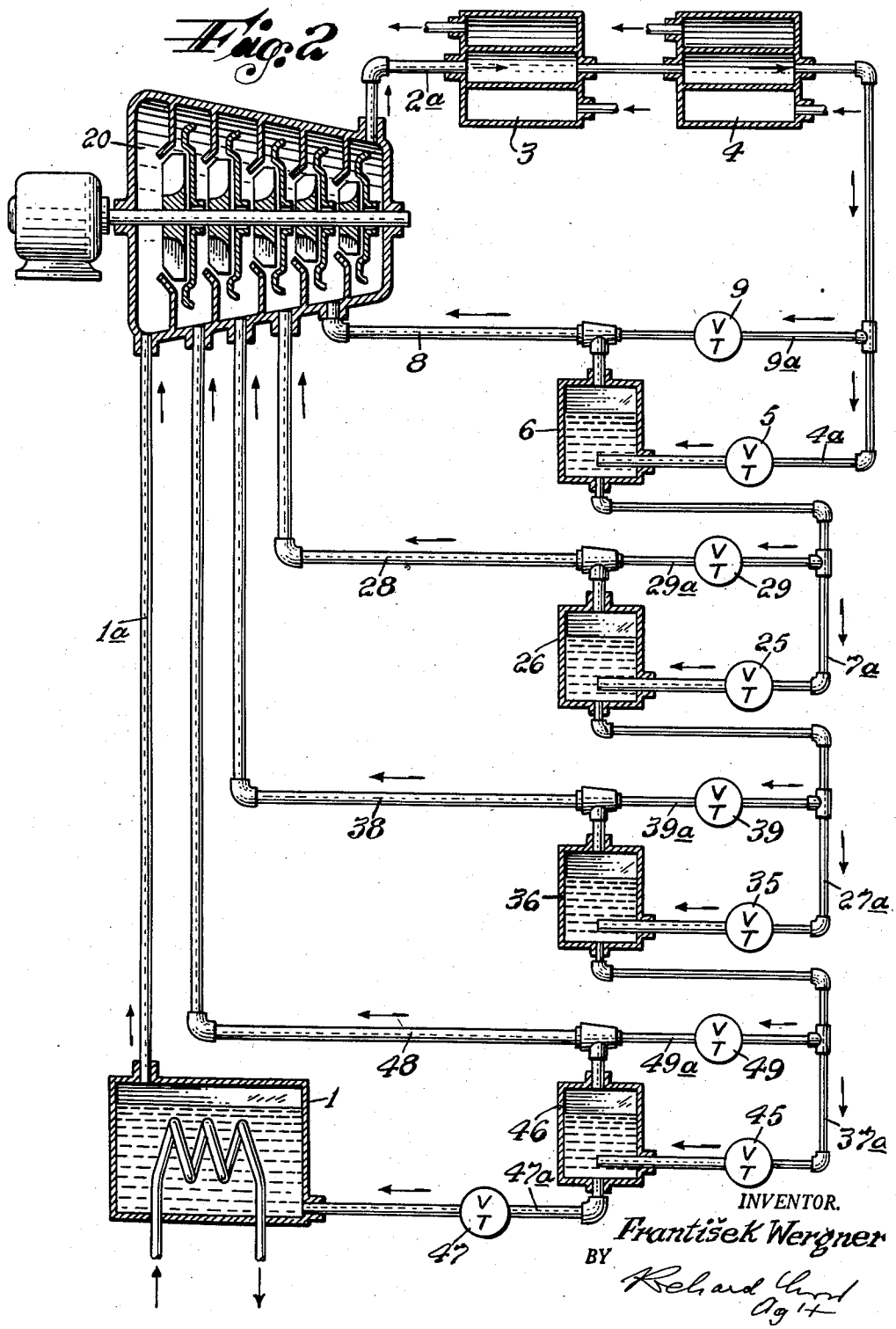
Filed Aug. 4, 1955 3 Sheets-Sheet 2

Fig. 2



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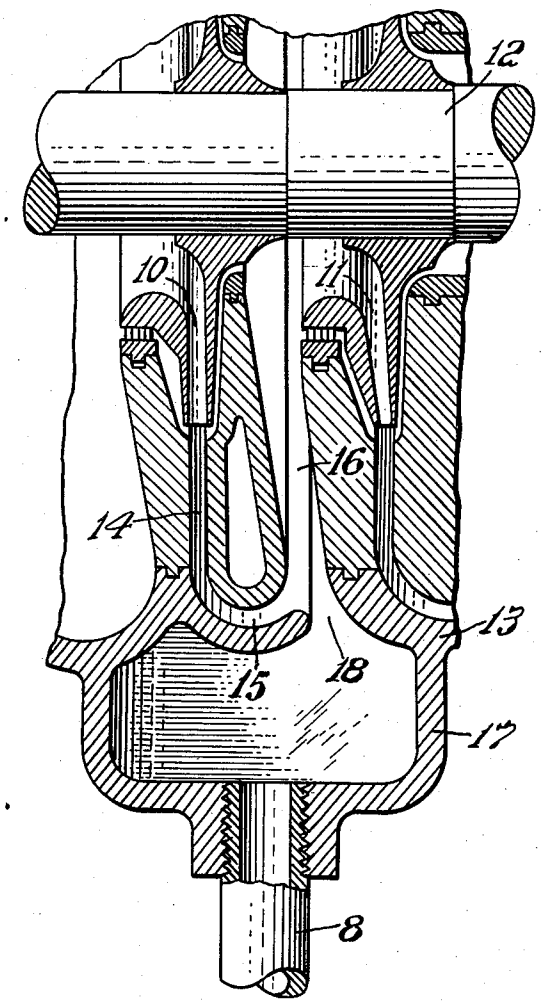
Filed Aug. 4, 1955 3 Sheets-Sheet 3

Fig. 3



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APPARATUS FOR GAS AND LIQUID COOLING IN COMPRESSOR PLANTS WITH TWO- OR MULTISTAGE COOLING CIRCUIT

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3 Claims. (Cl. 62—509)

The present invention relates to cooling or refrigeration systems, and more particularly is directed to improvements in such systems employing multi-stage cooling circuits.

It is an object of this invention to avoid dissipation of the pressure energy of the vapor gained by partial evaporation in the economizer, and in accordance with an aspect of the invention, this is achieved by injecting a small quantity of liquid refrigerant into the suction side of the middle stage or stages of the compressor where refrigerant vapor is supplied from the economizer, such refrigerant in the liquid state being obtained from the conduit leading to the economizer from the condenser or from the aftercooler, when the latter is provided, at a location along said conduit in advance of the main reducing valve.

The above, and other objects, features and advantages of the invention, will be apparent in the following detailed description of illustrative embodiments thereof which is to be read in connection with the accompanying drawings forming a part hereof, and wherein:

Fig. 1 is a diagrammatic view of a refrigerating system having a two-stage compressor and embodying the present invention;

Fig. 2 is a view similar to that of Fig. 1, but showing the application of the invention to a refrigerating system employing a five-stage compressor; and

Fig. 3 is an enlarged fragmentary, axial sectional view corresponding to a portion of Figure 1 and showing the detailed structure of the compressor for receiving a mixture of refrigerant vapor and liquid refrigerant at the suction side of the second stage thereof in accordance with the present invention.

Referring to the drawings in detail, and initially to Fig. 1 thereof, it will be seen that a refrigerating system embodying the present invention includes a evaporator 1 containing a suitable refrigerant or coolant, such as, for example, ammonia, freon or the like, and from which saturated refrigerant vapor is conducted through the conduit 1a to the inlet or suction side of the first stage of a compressor 2 having two stages of pressurization therein and which is suitably driven by a motor M having its shaft connected to the rotor of the compressor. All of the refrigerant supplied to the compressor 2 through the conduit 1a flows progressively through all of the stages of the latter and is compressed therein for discharge through a conduit 2a opening into a condenser 3. The condensed or liquified refrigerant is led from the condenser 3 to a suitable aftercooler 4 in which the refrigerant liquid is further cooled. A conduit 4a carries the liquified and sub-cooled refrigerant from the aftercooler 4 through a reducing or throttle valve 5 wherein the refrigerant is converted into a mixture of vapor and liquid having a pressure, referred to as the "medium pressure" which is lower than the pressures in the condenser 3 and aftercooler 4. The mixture of refrigerant vapor and liquid is directed from the throttle valve 5 into a medium-

pressure economizer 6 wherein the refrigerant vapor is separated from the liquid refrigerant, and the latter is then carried, by a conduit 7a, back to the evaporator 1, the conduit 7a having a second throttle or reducing valve 7 interposed therein so that, when the liquid refrigerant from the economizer 6 passes through the valve 7, a further mixture of refrigerant vapor and liquid refrigerant is produced for return to the evaporator. The refrigerant vapor separated from the liquid refrigerant in the economizer 6 is carried, by a conduit 8, from the economizer into the suction side of a middle stage of the compressor 2 where the pressure corresponds to that existing within the interior of economizer 6.

In accordance with the present invention, a refrigerating system of the kind described above with reference to Fig. 1 further includes a conduit 9a extending from the conduit 4a, at a location along the latter in advance of the valve 5, to the conduit 8, and a throttle valve 9 interposed in the conduit 9a. The conduit 9a acts to tap liquid refrigerant from the conduit 4a which is atomized in passing through the throttle valve 9 so that drops of liquid refrigerant are homogeneously mixed with the saturated vapor supplied to the compressor from the economizer 6. When this moist mixture of saturated vapor and drops of liquid refrigerant is mixed with the super heated vapor discharged from the stage of the compressor in advance of the middle stage with which the conduit 8 communicates, a substantially fully saturated vapor is produced in the space at the suction side of the middle stage. The injection of the liquid refrigerant through the conduit 8 to the suction side of a middle stage of the compressor 2 tends to decrease the power required to drive the following stages of the compressor since such following stages of the compressor then are operating to compress a vapor having a lower enthalpy. Accordingly, the injection of liquid refrigerant through the conduit 8 along with the refrigerant vapor from the economizer 6 serves to reduce the overall power required to drive the compressor 2 and thereby increases the efficiency of the refrigerating system.

Fig. 3 shows, merely by way of example, a structural arrangement by which the saturated refrigerant vapor and the drops of liquid refrigerant carried by the conduit 8 can be admitted to the compressor 2 at the suction side of a middle stage of the compressor. As in the usual compressor, the vapors compressed by the impeller 10 are discharged into a channel 14 which, at its radially outer end, communicates with a turnaround channel 15 opening, in turn, into the radially outer end of a suction channel or inlet 16 for the next stage 11. Assuming that the rotor or impeller 11 is a middle stage of the compressor to which saturated vapor and drops of liquid refrigerant are to be supplied through the conduit 8, it will be seen that an additional annular chamber 17 is provided on the outside of the housing 13 in the region of such middle stage with the conduit 8 opening into the chamber 17. Further, openings 18 are provided between the chamber 17 and the radially outer end of the inlet channel 16 of the middle stage 11 so that the mixture supplied to the chamber 17 through conduit 8 will flow through the openings 18 for mixture with the super-heated vapors compressed by the preceding stage rotor 10.

Referring now to Fig. 2 wherein the present invention is applied to a refrigerating system employing a five stage compressor 20, it will be seen that, with such a compressor, the refrigerant vapor from the evaporator 1 is carried by the conduit 1a to the inlet of the first stage of the compressor 20 and passes progressively through all five stages of the compressor before discharge through the conduit 2a extending to the condenser 3. As in the first described embodiment of the invention, the condensed refrigerant is

led from the condenser 3 through an aftercooler 4 and, by way of a conduit 4*a*, through a reducing or throttle valve 5 to an economizer 6 which effects the separation of the vapor and liquid phases of the refrigerant. Further, the refrigerant vapor is led from the economizer 6 to the suction side of the last stage of the compressor 20, as by the conduit 8, the liquid refrigerant is tapped from the conduit 4*a* ahead of the valve 5 by the conduit 9*a* and is passed through the throttle valve 9 which atomizes the liquid refrigerant for mixture with the refrigerant vapor in the conduit 8 being led to the compressor 20.

As distinguished from the first described embodiment of the invention, the liquid refrigerant in the economizer 6, rather than being led back to the evaporator 1 is, instead, carried by the conduit 7*a* through a throttling valve 25 to a second economizer 26. Similarly, the liquid refrigerant separated from the refrigerant vapor in the economizer 26 is led by a conduit 27*a* through a throttling valve 35 to a third economizer 36 and, in turn, the liquid refrigerant from the economizer 36 is led by a conduit 37*a* through a throttling valve 45 to a fourth economizer 46. Finally, the liquid refrigerant from the fourth economizer 46 is led by a conduit 47*a* through a throttling valve 47, which corresponds to the valve 7 of Fig. 1, back to the evaporator 1. Conduits 28, 38 and 48 extend from the economizers 26, 36 and 46, respectively, and carry the refrigerant vapor from the related economizers to the suction sides of related middle stages of the compressor 20. It is to be understood that the compressor 20 is provided with an additional chamber, corresponding to the chamber 17 shown in Fig. 3, for receiving the mixture of refrigerant vapor and liquid particles carried by each of the additional conduits 28, 38 and 48 in the embodiment of Fig. 2. The liquid particles to be mixed with the refrigerant vapor in the conduits 28, 38 and 48 are supplied to the latter through conduits 29*a*, 39*a* and 49*a* which extend from conduit 7*a* to conduit 28, from conduit 27*a* to conduit 38, and from conduit 37*a* to conduit 48, respectively, and have throttling valves 29, 39 and 49, respectively, interposed therein and corresponding to the throttle valve 9 of the embodiment in Fig. 1.

From the above, it is apparent that, each of the second, third, fourth and fifth stages of the five stage compressor 20 in the embodiment of Fig. 2 is supplied, at its suction side, with a mixture of saturated refrigerant vapor from the related economizer and liquid refrigerant particles. Thus, each of the later stages of the compressor 20 acts upon vapor having a lower enthalpy than would be the case if the liquid particles were not present in the mixture, so that the power required for driving such later stages of the compressor is comparatively reduced to increase the efficiency of the refrigerating system.

Although the embodiment illustrated in Fig. 2 supplies mixtures of saturated refrigerant vapor and liquid particles to all of the stages of compressor 20 other than the first stage, it is to be understood that such mixtures can be supplied to one or more of such middle stages of the multi-stage compressor without departing from the present invention.

Further, the embodiments of the invention described with reference to Figs. 1 and 2 are to be considered as being merely illustrative, and various changes and modifications can be effected therein within the scope and spirit of the invention, except as defined in the appended claims.

I claim:

1. In a refrigerating system having a centrifugal compressor with multiple stages in a common housing, an evaporator containing a refrigerant, means supplying refrigant vapor from said evaporator to said compressor to pass through all of the stages of the latter to be compressed thereby, condensing means receiving the compressed refrigerant vapor from the compressor, cooling means receiving liquified refrigerant from said condensing means to subcool the same, a main throttle valve receiving the subcooled liquified refrigerant from the cooling means and emitting a mixture of refrigerant vapor and liquid refrigerant at a medium pressure which is less than the pressures in said condensing and cooling means, a medium-pressure economizer receiving said mixture from the main throttle valve and operative to separate refrigerant vapor from the liquid refrigerant, means for returning the separated liquid refrigerant from said economizer to said evaporator, and conduit means extending from the economizer to the suction side of a related middle stage of the multi-stage compressor for supplying the separated refrigerant vapor from the economizer to the related middle stage; the combination of a by-pass conduit opening into said conduit means and receiving liquid refrigerant from said cooling means in advance of the main throttle valve and having an auxiliary throttle valve therein to atomize the liquid refrigerant received by said by-pass conduit for mixing with the refrigerant vapor from the economizer so that the middle stage of the compressor to which the mixture of refrigerant vapor and atomized liquid refrigerant is supplied acts on vapor having a relatively low enthalpy thereby to reduce the power required to drive said middle stage of the compressor.

2. In a refrigerating system; the combination including an evaporator containing refrigerant, a compressor having multiple stages in a common housing, means conducting refrigerant vapor from said evaporator to the first stage of said compressor so that the latter compresses the vapor successively in the multiple stages thereof, condensing means receiving the compressed refrigerant from said compressor and liquifying the refrigerant, cooling means receiving liquid refrigerant from said condensing means and subcooling the same, a main throttle valve receiving the subcooled liquid refrigerant from said cooling means and emitting a mixture of refrigerant vapor and liquid refrigerant at a medium pressure which is lower than the pressures in said condensing and cooling means, a medium-pressure economizer receiving said mixture from said main throttle valve and separating the refrigerant vapor from the liquid refrigerant, a first conduit extending from said economizer to the suction side of a middle-stage of said multi-stage compressor to supply the separated refrigerant vapor from said economizer to said middle-stage, means for returning liquid refrigerant from said economizer to said evaporator, and a second conduit opening into said first conduit and receiving subcooled liquid refrigerant from said cooling means in advance of said main throttle valve, said second conduit having an auxiliary throttle valve interposed therein to atomize the liquid refrigerant received thereby so that atomized liquid refrigerant is mixed in said first conduit with refrigerant vapor from said economizer being supplied to said middle-stage of the compressor, whereby said middle-stage acts on a vapor of relatively low enthalpy to reduce the power required to drive said middle-stage.

3. In a refrigerating system; the combination as in claim 2, wherein said centrifugal compressor has more than two stages and said first conduit extends from said economizer to the suction side of the last stage of said compressor; and wherein said means for returning liquid refrigerant from said economizer to said evaporator includes an additional economizer associated with each stage of said compressor preceding said last stage and following the first stage of said compressor, conduit means conveying liquid refrigerant from each economizer associated with a stage of said compressor following the second stage of the latter to the additional economizer associated with the next preceding stage of the compressor and having an additional throttle valve interposed therein for each additional economizer and emitting a mixture of refrigerant vapor and liquid refrigerant to the related additional economizer so that the latter also separates refrigerant vapor from liquid refrigerant, conduit means

extending from each additional economizer to the suction side of the associated stage of the compressor to convey separated refrigerant vapor to said associated stage, a by-pass conduit for each additional economizer having a throttle valve therein extending between the conduit means supplying refrigerant to the related additional economizer and the conduit means conveying refrigerant vapor from the related economizer so that a mixture of refrigerant vapor and atomized liquid refrigerant is supplied to the stages of the compressor associated with said additional economizers, and conduit means extending from the additional economizer associated with the second stage of the compressor to said evaporator for returning refrigerant to the latter.

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