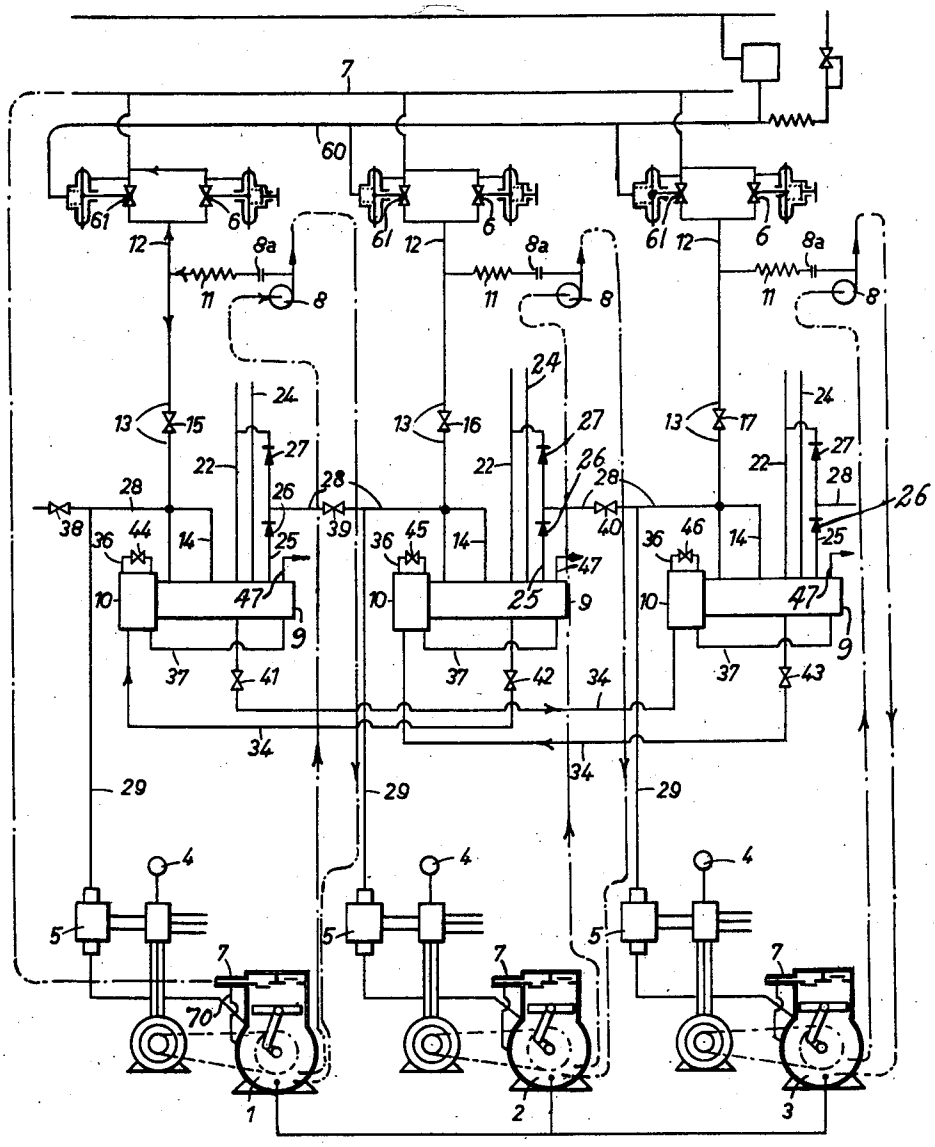
Jan. 22, 1963 N. E. B. LARSSON ET AL 3,074,619

METHOD OF AND MEANS FOR COMBINED OPERATION OF AUTOMATICALLY CAPACITY REGULATED COMPRESSORS

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FIG. 1.



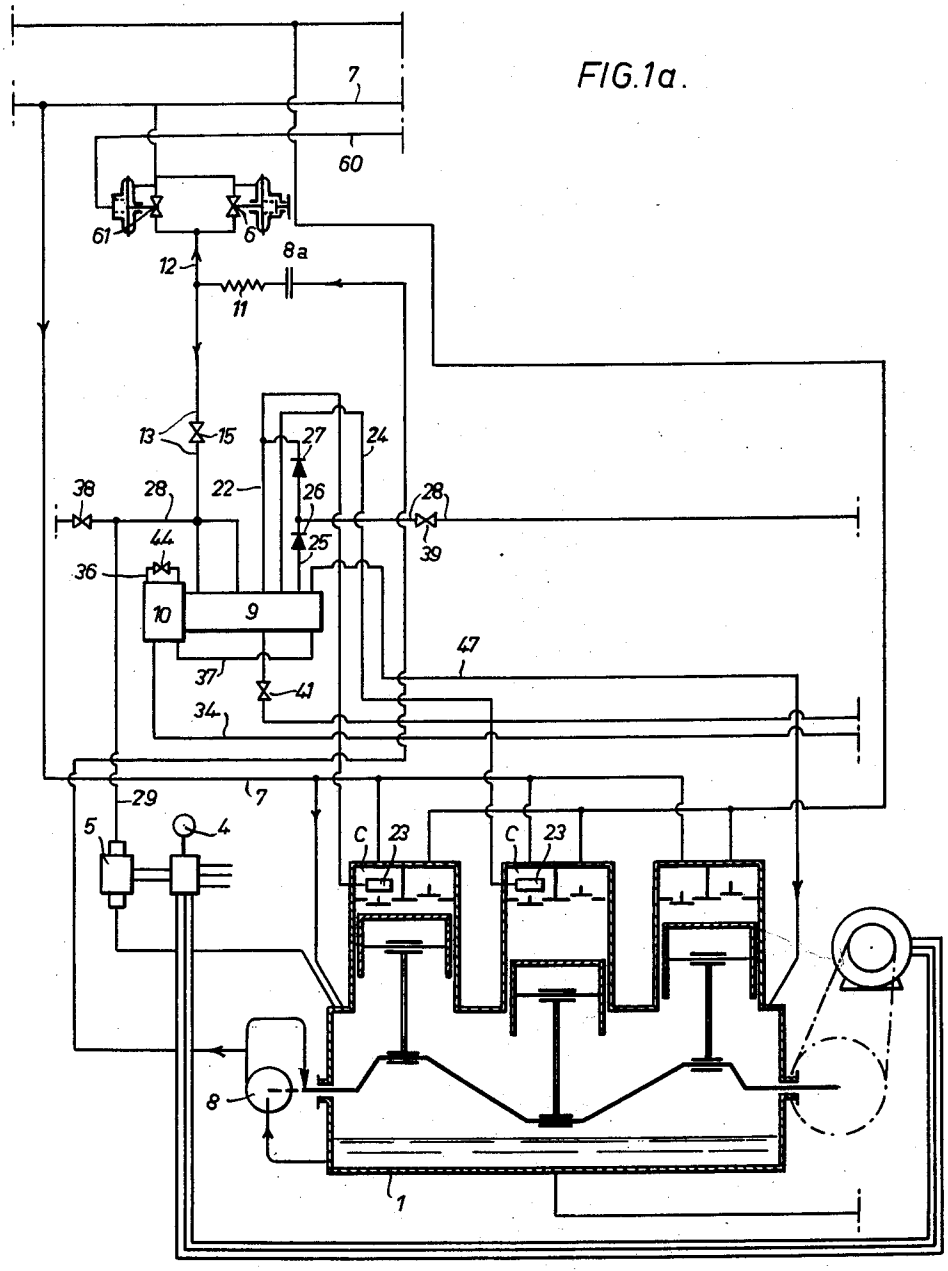
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FIG.1a.



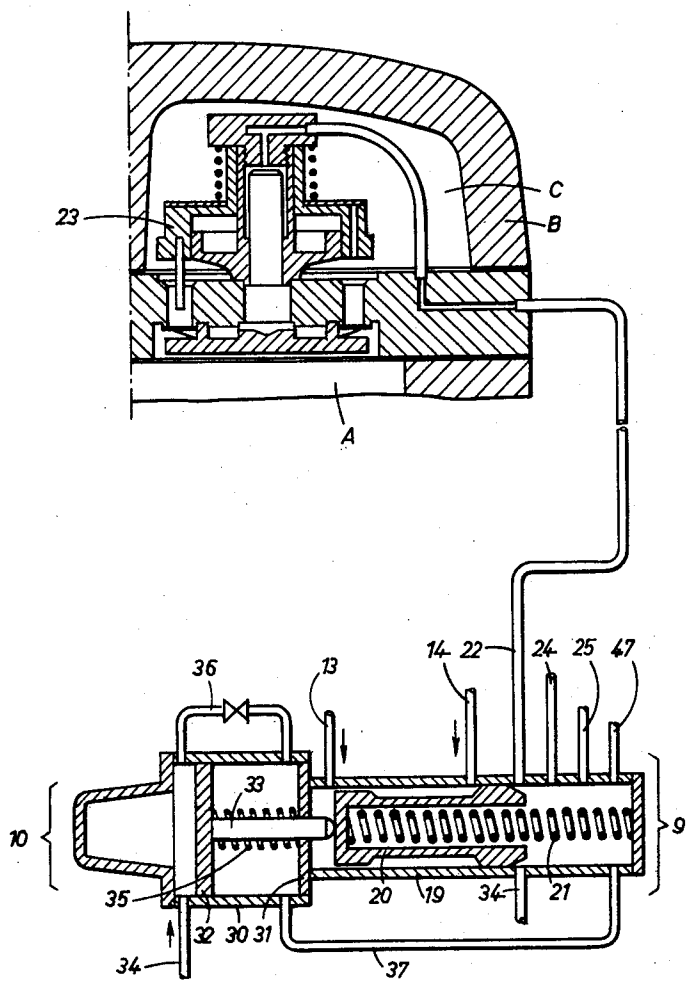
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FIG. 2.



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METHOD OF AND MEANS FOR COMBINED OPERATION OF AUTOMATICALLY CAPACITY REGULATED COMPRESSORS

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8 Claims. (Cl. 230—2)

The present invention relates to a method of controlling the combined operation of two or more automatically capacity regulated compressors and means for carrying said method into effect.

In the hitherto known systems for controlling the combined operation of a number of multicylinder compressors operating in parallel in a compressor refrigerating system, in which one or more cylinders of each compressor are equipped with means for automatically regulating the capacities, as for instance, in accordance with the French Patent No. 1,101,890, the relation between the regulations of the various compressors is unstable, that is to say, certain compressors may reduce their capacity while the remaining compressors increase their capacity, furthermore, as a rule, more compressors are in operation than necessary to yield the capacity required, and the compressor last started may start and stop incessantly in case the capacity required falls within the range of full effects of the remaining compressors in operation. In order to avoid these drawbacks it was hitherto necessary to adjust the regulating ranges of the individual compressors with relation to each other with a resulting impairment of the exactness of the regulation.

The present invention has for its object to avoid said drawbacks. To this end a feature of the invention involves that the running compressor situated next before the compressor last started is regulated with a view to reducing its capacity so that the sum of the effect (that is, the minimum effect) of the compressor last started, the effect of said regulated compressor and the full effect of the remaining compressor or compressors correspond to the capacity required.

Another feature of the invention involves that the compressor last started is stopped only after the capacity of the compressor in operation next before that last started is reduced to such an extent that the effect reduction resulting may be compensated by increasing the capacity of said compressor.

Still another feature of the invention which has for its object to prevent more compressors from running at the same time than what is required to satisfy the capacity required, involves that the capacity regulation of the compressors is locked so that only one compressor may run at a reduced capacity except in such cases where the compressor last thrown into action yields its minimum effect.

In addition to the advantages already stated the invention has the further advantages that any compressor of a compressor refrigerating system including a plurality of compressors may be selected as leader compressor, that the compressors may be started in sequence, and that a compressor may be removed from running, as for revision, without inconvenience.

In the accompanying drawings an example of the invention is illustrated. FIG. 1 is a diagram of a system for controlling the operation of three compressors having automatic capacity regulation means. FIG. 1*a* is a more complete diagram of that part of the system shown in FIG. 1 which has reference to the first compressor of the system. FIG. 2 is a longitudinal section

of a distributor including locking means and a longitudinal section through the suction chamber of a compressor having a capacity regulating mechanism built therein.

Referring to the diagram shown in FIG. 1, the numerals **1**, **2** and **3** indicate the three compressors which are assumed each to comprise a plurality of cylinders one or more of which is or are provided with capacity regulating means. As an alternative, the cylinders of the compressors may be connected in groups. Associated with each compressor are an interrupter **4** for manual or automatic operation and an automatic starting apparatus **5**. The diagram shown also includes for each compressor a control valve **6** connected to a suction conduit **7** common to all the compressors, an oil pump **8** having an oil filter **8***a*, a distribution device **9** and a locking device **10**. The pressure oil pumps **8** are connected via filters **8***a* and capillary tubes **11** with the respective control valves **6** via conduits **12** and are further connected to the respective distribution devices **9** via conduits **13** and branch conduits **14** leading therefrom. The conduits **13** contain each a cut off valve which in the conduit system belonging to the compressor **1** is indicated by **15**, in the conduit system belonging to compressor **2** by **16**, and in the conduit system belonging to compressor **3** by **17**. The lubricating system is of conventional design and is provided with a pressure regulating by-pass valve (not shown) whereby the pressure will be substantially constant at valve **8***a*. Valve **6** opens upon a sinking pressure in suction conduit **7** and closes upon a rise of pressure in said conduit. Its control diaphragm is spring-loaded, and its point of regulation is when the suction pressure equals the spring pressure.

The control valve **6** is set to a predetermined evaporation pressure in suction conduit **7** and has for its object to control, according to variations of the evaporation pressure, the emission of pressure oil from the conduits **12** to **13** admitted to said conduits via the capillary tubes **11** from the pumps **8**, and thus also to control the oil pressure in the distribution devices **9**. The quantity of oil passing through valves **6** and **61** is rather small compared with the quantity circulating in suction conduit **7** which is passed back to the crankcase by way of the connection between the conduit and the crankcase. Valve **61** of FIG. 1*a* opens upon a sinking pressure in suction conduit **7** and closes upon a rise of pressure. Its control diaphragm is loaded by the pressure prevailing in conduit **60** and by a constant spring pressure. Its point of regulation is when the suction pressure equals the spring pressure minus the pressure prevailing in conduit **60**. If the pressure in conduit **60** sinks, the valve will close. The course of operation of valves **6** and **61** is:

(*a*) During cooling: only valve **6** is regulating. (The pressure medium in conduit **60** is cut off.)

(*b*) During heat pump operation valve **61** regulates the control impulse pressure in conduit **60** which is determined by the pressure in the pressure conduit common to the compressors. Valve **6** is not regulating; it can only start operation, if the suction pressure sinks to its set valve, as it opens and limits the compressor capacity independent of valve **61**. The function of the distribution devices will be hereinbelow described in connection with the description of the operation of the compressor system as a whole.

FIG. 2 shows in its upper part an axial section of an upper portion of a compressor cylinder. A designates the piston of the compressor, B is the cover of the pressure cylinder, and C is the suction chamber provided in the cylinder cover. The structure is similar to that shown in the above stated French Patent 1,101,890.

The distribution device designated as a whole by the reference numeral 9 comprises a cylinder 19, a piston 20 mounted to reciprocate therein, and a retraction spring 21 acting on said piston. Leading to the distribution cylinder 19 are the conduits 13 and 14 above referred to, which in a modified embodiment of piston 20 may be combined into a single conduit, and, in addition, there is a group of other conduits connected to the cylinder. Thus, a control conduit 22 leads from said cylinder to a mechanism 23 provided in the suction chamber C for automatic capacity regulation. Said regulating mechanism is driven by oil under pressure which, in a given position of piston 20, is admitted from the pressure oil conduit 14 via the control conduit 22 whereby the regulating mechanism is caused to assume the position shown in FIG. 2 in which the compressor cylinder will be loaded, as will appear from the above said French patent. Extending from cylinder 19 is also a control cinduit 24 leading to a mechanism, not shown, for effecting an automatic capacity regulation in connection with another cylinder belonging to the same compressor.

Extending from cylinder 19 is further a pressure oil conduit 25 leading to a point of the control conduit 22, as shown in FIG. 1. Leading from a point between two non-return valves 26 and 27 inserted in the conduit 25 is a conduit 28 which extends to the connecting point between the conduits 13 and 14 associated with the next compressor system.

Leading from each conduit 28 to the automatic starting apparatus 5 of the respective compressor is a conduit 29.

The locking device 10 comprises a cylinder 30 having an end wall 31 common with the distribution cylinder 19. Reciprocating in said cylinder 30 is a piston 32 having a piston rod 33 which tightly extends through an opening in said end wall 31 and abuts by its free end against the closed end of piston 20 in cylinder 19. The piston 32 is under the action of oil under pressure admitted from a pressure oil conduit 34 which is connected to the distribution device of an adjacent compressor. In the diagram shown in FIG. 1 said conduit 34 extends from the locking device of compressor 1 to the distribution device of compressor 2 and, similarly, the conduit 34 outgoing from the locking device of compressor 2 leads to the distribution device of compressor 3, while the conduit 34 outgoing from the locking device of compressor 3 leads to the distribution device of compressor 1.

In order to avoid blows on piston 20 the piston 32 is loaded by a spring 35 acting to keep the piston rod 33 in constant contact with the end wall of piston 20.

In order to allow the locking devices to be manually set out of action said devices are provided with valve controlled overflow tubes 36 as well as with discharge conduits 37 leading to the cylinder of the respective distribution device next to its end remote from the locking device, where they communicate with an outlet 47 for restoring the control oil to the oil sump.

In order to facilitate the description of the operation of the system mutually corresponding valves inserted in the conduit systems of the various compressors are indicated by different reference numerals. Thus, cut off valves inserted in the conduits 28 of the compressors 1, 2 and 3 are indicated by 38, 39 and 40, respectively. For the same reason cut off valves inserted in the conduits 34 are indicated by 41, 42 and 43, respectively, and cut off valves inserted in the overflow tubes 36 are indicated by 44, 45 and 46, respectively.

The operation is as follows:

In starting a compressor plant including automatically capacity regulated compressors which embodies the invention any of the compressors of the plant may be selected as leader compressor; in the description hereinafter to follow of the operation of the system shown as an example of the invention the compressor 1 is assumed to act as leader compressor. To this end the valves 46, 15, 42, 43, 39 and 40 of the pressure oil conduits and the overflow conduits should be open and the remaining valves of said conduits be closed. The capacity of the compressor plant is regulated with a view to maintain a constant evaporation pressure in the suction conduit 7 and, as will appear from the adjustment of the valves, with valve 15 open, it is only pressure oil delivered by the pressure oil pump 8 of compressor 1 that is allowed to control the operation of the respective distribution device 9. Compressor 1 may be started manually by means of the interrupter 4 or automatically by means of a thermostat connected in parallel to said interrupter which is shunted to the automatic starting device 5, in which case only compressor cylinders which are not capacity controlled are loaded, that is to say, the compressor yields its minimum effect. At the same time, the pressure oil pump 8 is started causing pressure oil to pass from said pump via the capillary tube 11 and the pressure oil conduits 13 and 14 to the distribution device 9 of the compressor. Should the capacity required not be satisfied, then the compressor suction is too low and the evaporation pressure in the suction conduit 7 is too high. This means that the control valve 6 is closed and throttles the oil admission through conduit 12, thereby increasing the oil pressure in the distribution device. Piston 20 is now moved to the right, thereby opening the connection between the pressure oil conduit 14 and the control conduit 22 so as to allow pressure oil to pass to the capacity regulating mechanism 23, causing it to operate and put another compressor cylinder wholly or partially under load depending on the magnitude of the capacity required. The non-return valve 27 in oil conduit 28 which is connected to the control conduit 22 of compressor 1 as well as the pressure oil conduits 28, 29, 13 and 14 of the succeeding compressor prevents oil from passing to the automatic starting device 5 and the distribution device of compressor 2. The second capacity regulated cylinder of compressor 1 may be started in a similar way, if required. The control conduit belonging to the capacity regulating mechanism, not shown, of said compressor is indicated by 24.

If the capacity required is larger than the capacity of the compressor 1, when said compressor runs at full load, the pressure in the distribution device of said compressor will again increase and displace the piston 20 still another length to the right. As a result, pressure oil will flow via pressure oil conduits 25, 28 and 29 to the automatic starting device 5 of compressor 2. Said starting device now reacts to start compressor 2 causing it to yield its minimum effect. Should the capacity added by compressor 2 be too large, the evaporation pressure in suction conduit 7 will fall, allowing control valve 6 to open with resulting increase of the admission of oil from pump 8 through conduit 12. The pressure prevailing in the distribution device 9 of the compressor 1 decreases and the effect of compressor 1 is reduced so that the total of the effects of both compressors will correspond to the capacity required.

Because of the reduction of pressure taking place in the distribution device 9 of compressor 1 the piston 20 will be moved to the left in FIG. 2 by the action of the retraction spring 21, thereby interrupting the admission of pressure oil to the starting device 5 of the compressor 2. Said starting device will, nevertheless, remain closed because the pressure oil previously supplied through the non-return valve 26 of the pressure oil conduit 25 will prevent the pressure oil from flowing back to the distribution device 9 of compressor 1. Thus, both compressors operate at a reduced capacity with the result that repeated starts and stops of compressor 2 will be prevented, since the capacity required is within the range of full effect of compressor 1.

In case the compressor 1 yields its full effect and the compressor 2 yields its minimum effect and the capacity required increases, then the oil pressure in the distribu-

tion device 9 of compressor 1 is still increased allowing pressure oil to pass to the distribution device of compressor 2 through the respective pressure oil conduits 13 and 14, thereby starting the capacity regulated cylinders according to demands in the same way as above described in connection with compressor 1.

In connection with the starting of the first capacity regulated cylinder of compressor 2, oil under pressure will pass via the respective pressure oil conduit 34 to the locking device 10 provided on the distribution device of compressor 1. The piston 32 of cylinder 30 will then be displaced by the action of the oil pressure to the left to lock the piston 20 of the distribution device in its right hand position, that is to say, the capacity regulation of compressor 1 will be locked at its full effect state. In this case it is only the compressor 2 which operates at a reduced capacity. If a still larger capacity is required, then the compressor 2 will be loaded in the same way as above described in connection with the compressor 1, and the compressor 3 will be started and the capacity regulation of compressor 2 will take place in an analogous way to that above described.

If compressor 1 operates at full load and its capacity regulation is locked and the capacity of compressor 2 is reduced and the capacity required decreases, then the control valve 6 of compressor 1 will be operated by the evaporation pressure in suction conduit 7 which by this time is too low, so that said valve 6 will open and increase the admission of oil from pressure oil pump 8. The oil pressure in the distribution devices 9 of both compressors 1 and 2 decreases. Since the capacity regulation of compressor 1 is locked, the down regulation of the capacity of the compressor 2 will continue until the piston 20 of the distribution device of compressor 2 is moved by the action of its retraction spring 21 to the left to such an extent as to interrupt the communication between the pressure oil conduit 14 and the pressure oil conduit 34 leading to the locking device 10 of compressor 1, thereby relieving the pressure in said device and interrupting the locking of the capacity regulation of compressor 1. At the same time the pressure in the control conduit 22 of the first capacity regulated cylinder of compressor 2 will be relieved allowing the compressor 2 to yield its minimum effect. The pressure oil from the locking device of compressor 1 and the pressure oil from the control conduit 22 of compressor 2 are discharged through the discharge conduit 47 leading from the distribution device 9 of compressor 2.

Upon a continued reduction of the capacity required the reduction of the capacity of the compressors is effected to begin with in connection with compressor 1 until said compressor operates at its minimum effect, that is to say, until its capacity regulated compressor cylinders are disconnected. At the same time that the oil pressure in the control conduit 22 of the compressor 1 is relieved during the reduction period, the oil pressure in the starting device 5 of compressor 2 is relieved.

The pressure oil short circuiting the starting device 5 of compressor 2 is passed via the connection 29, 28 and 27 to the control conduit 22 of compressor 1, thereby bringing the compressor 2 to a stop. The capacity reduction resulting from the stoppage of compressor 2 will be compensated for by an increase of the capacity of compressor 1, if required.

It is to be noted that in the example of function of the compressor refrigerating plant hereinbefore described, the assumption was made that the refrigerating plant had for its object to produce cool and that its capacity should be regulated with a view to maintaining a constant evaporation pressure in the suction conduit. The compressor refrigerating plant may, of course, act as a heat pump in which case its capacity should be regulated with a view to maintaining a constant condensation pressure in the pressure conduit of the plant. For this reason double control valves 6 and 61 are shown, and a conduit 60 is shown by dotted lines to indicate a pneumatic control conduit acting under the control of fluid admitted from the pressure conduit.

It is further to be noted that should the control valves be provided with thermic control means, then the device can regulate a temperature instead of a pressure.

We claim:

1. A compressor system for refrigeration plants comprising at least two multi-cylindered compressors each having automatic fluid-pressure operable capacity regulating equipment in some of the cylinders thereof, a common suction conduit, conduit means connecting said suction conduit with each of said compressors, each of said compressor having a distribution device, each of said distribution devices having a pressure-fluid chamber having a plurality of openings arranged for sequential opening and closing, a control valve in each said chamber movable therein to control said openings and being responsive in its movements to fluid pressure, each of said compressors having a fluid pump, each of said pumps having conduit means connected with the discharge thereof and with both said common suction conduit and with the pressure fluid chamber of the control device corresponding to the respective compressors, said connections with said pressure fluid chambers being on one side of the respective valves thereof, pressure responsive valve means in each of the conduit means between said pump discharges and said common suction conduit, fluid pressure operable valve control means operably connected with each of said last-mentioned valve means respectively, said valve control means being connected with and responsive to the pressure in said common suction conduit and tending to close the respective valves with which they are operably connected when the pressure in said suction conduit rises, whereby more of the discharge from the respective pumps passes to the pressure fluid chamber of the corresponding distribution device to cause said corresponding control valve to move, conduit means connecting one of said sequential openings of each pressure chamber with one of said capacity regulating equipments, whereby when said suction conduit pressure rises said regulating valve of a predetermined one of said compressors opens said conduit means connected with said one of said capacity regulating equipments to increase the capacity of its corresponding compressor, and conduit means connecting a second sequentially arranged opening in the pressure chamber of the distribution device of said predetermined one of said compressors with the fluid pressure chamber of another compressor of the system on one side of its control valve, whereby a magnification occurs of the regulating effect of a pressure variation impulse occurring in said common suction conduit for controlling the capacity regulating equipment of the compressors of said system.

2. A system as claimed in claim 1, and in which said compressors are each provided with an automatic starting apparatus, and with a pressure fluid conducting means connecting the starting apparatus of a succeeding compressor of the system with the control apparatus of said predetermined compressor for operating the respective starting apparatus to start said succeeding compressor.

3. A system as claimed in claim 2, and in which the fluid pressure conduit means between the distribution device of a preceding compressor and the automatic starting apparatus of a succeeding compressor includes a non-return valve for acting during the combined operation of a preceding compressor yielding its maximum effect and a succeeding compressor yielding its minimum effect, to prevent a return flow of pressure fluid from the starting apparatus of said succeeding compressor to the control apparatus of said preceding compressor so as thereby to maintain said starting apparatus in connected state, if during said combined operation the total effect of both compressors should exceed the capacity required, thereby generating an impulse for reducing the capacity

and a resulting reduction of the pressure fluid emission from the distribution device of the preceding compressor with a view to preventing repeated starts and stops of said succeeding compressor.

4. A system as claimed in claim 2, and in which each distribution device is provided with a locking device, each locking device having pressure responsive operating means, fluid conducting means connecting each said locking device operating means with the distribution device of a succeeding compressor for locking the distribution device of its own compressor in the maximum capacity state thereof with the connection to the succeeding compressor closed when the distribution device of said succeeding compressor is set for capacity regulation.

5. A system as claimed in claim 4, and in which the control valves of said distribution devices are piston valves.

6. A system as claimed in claim 4, and in which the locking devices comprise cylinders and pistons reciprocable therein, said pistons having rods bearing with their free ends against the control valve pistons of the respective distribution devices.

7. A system as claimed in claim 6, and in which the pistons of the distribution devices and the pistons of the

locking devices are provided with loading springs tending to move the corresponding control valve pistons towards each other to move said control valve pistons when the pressure on the resepctive control valve pistons is sufficiently low.

8. A system as claimed in claim 7, and in which said compressors are provided with oil sumps, said cylinders of the locking devices being provided with discharge conduits leading to the cylinders of the respective distribution devices at points remote from said locking devices, and conduits connecting said remote points with the respective oil sumps for returning the pressure fluid thereto.

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