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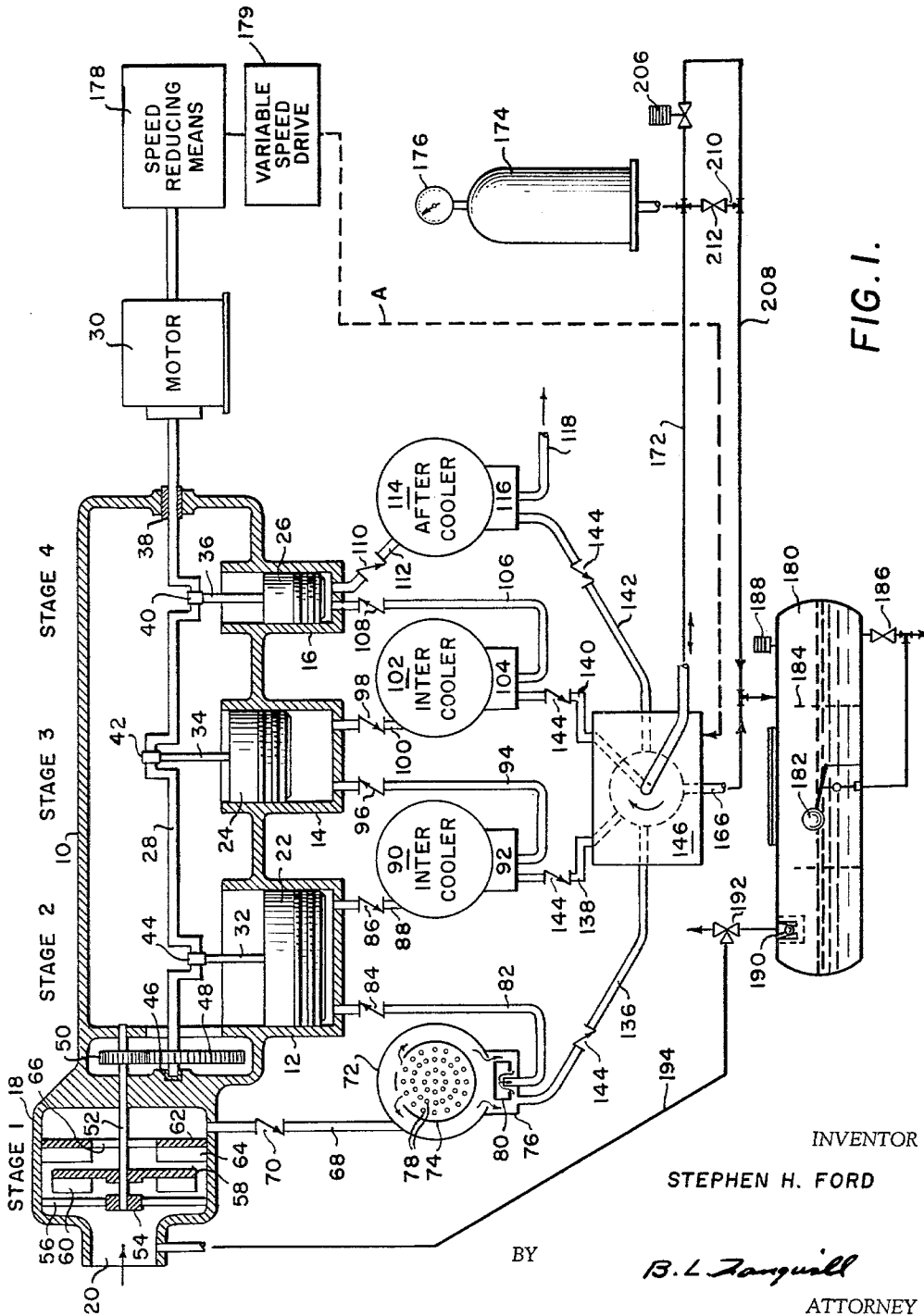
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AUTOMATIC BLOWDOWN SYSTEM FOR COMPRESSORS

Filed April 2, 1962

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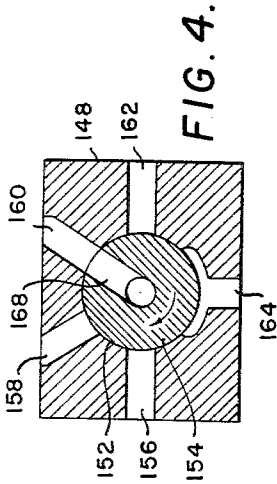


FIG. 4.

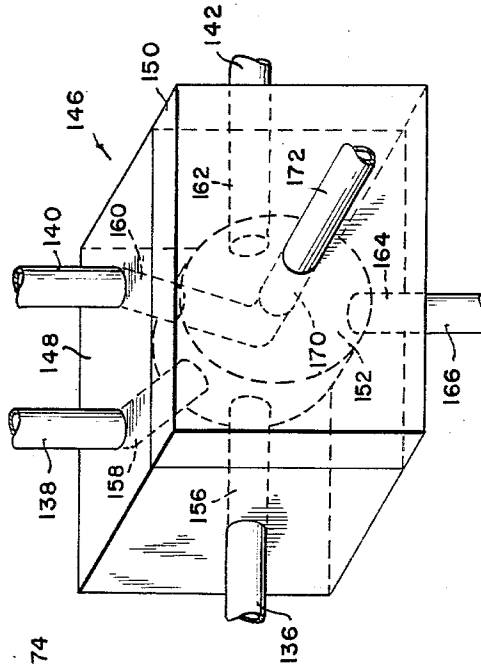


FIG. 3.

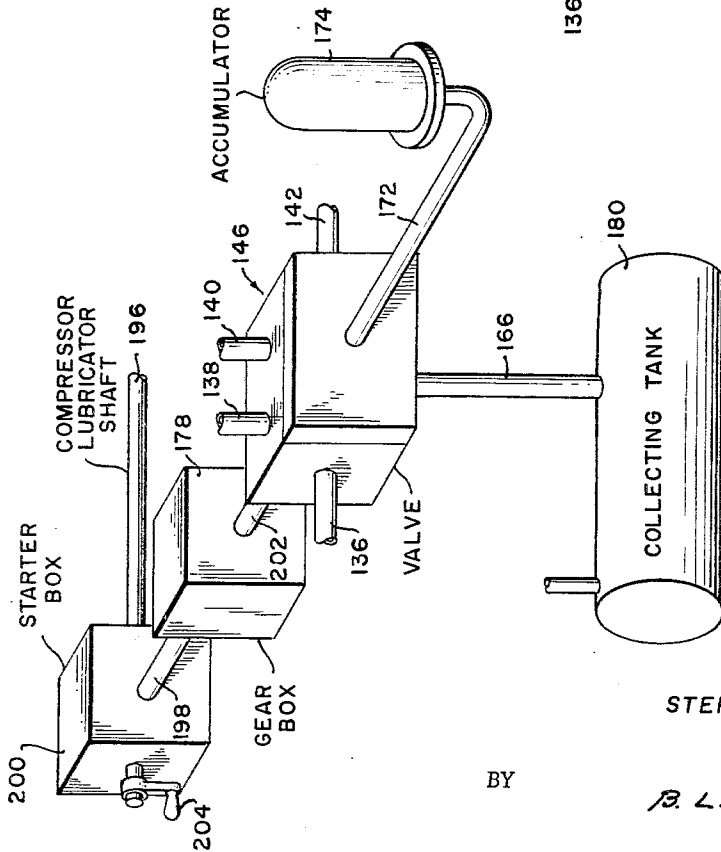


FIG. 2.

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3,216,648 AUTOMATIC BLOWDOWN SYSTEM FOR COMPRESSORS

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13 Claims. (Cl. 230-1)

(Granted under Title 35, U.S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

This case is a continuation-in-part of application Serial No. 177,138, filed March 2, 1962, now abandoned.

This invention relates to multi-stage compressor systems and more particularly to a method and means for removing condensate from the successive stages of a multi-stage compressor.

Since accumulations of liquid condensate, particularly water, in a compressor system can cause damage to the compressor as well as contamination of the system, it is necessary to provide a means for periodically removing or blowing down such accumulations. In the past, the most common method of draining this condensate was by having the operator manually drain each stage of the compressor at frequent intervals. This required considerable diligence on the part of the operator since inattention or inadvertence on his part could result in serious damage to the installation. Furthermore, for the operator to do a proper job, it was necessary that he devote almost full time to the menial task of manually draining each stage of the compressor. In an effort to improve upon the situation where the stages were drained by the operator, certain automatic or semi-automatic methods of draining were developed. One such method was to provide float controlled valves for each stage of the compressor so that when the condensate in a stage reached a certain level, the valve for that stage would open. Another such method was to provide solenoid controlled valves which were electrically timed so they would open at predetermined intervals. These so-called automatic methods of draining were an improvement over the manual method but they still had many shortcomings. Each time a valve was opened, the compressor was exposed to atmospheric pressure, thus reducing its efficiency. Each time a valve was closed, it had to be seated properly or a leak developed and compressed air would escape. Also, particles of scale and metal, ever present in the blowdown effluent made proper seating of these types of valves uncertain, since the particles often would lodge between the valve and its seat. Furthermore, there was no indication whether the "blowdown" of the condensate from the compressor was incomplete, excessive or normal. In an effort to overcome these shortcomings, the present invention was developed.

An object of this invention is to provide an improved method and apparatus for automatically blowing down the condensate from the stages of a multi-stage compressor, which method and apparatus require little if any attention from the compressor attendant, which are reliable in operation, and which are practical and convenient to use and to install on existing compressors.

Another object of this invention is to provide an improved method and apparatus for removing condensate from the stages of a multi-stage compressor in which the stages of the compressor remain unexposed to atmospheric pressure as the condensate is removed, thus maintaining the full efficiency of the compressor.

A further object of this invention is to provide an improved method and apparatus for removing condensate

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from a compressor, which is simple, practical and economical to produce and operate.

Further objects and advantages will become apparent from the ensuing descriptive matter.

This invention broadly is comprised of a selector means or valve which selectively connects an accumulator with a multi-stage compressor or with a collecting means. The selector means is connected to each stage of a multi-stage compressor and a rotary valve member within the selector means is driven by the compressor. The valve member is slowly rotated so that it successively communicates with each stage of the compressor, thereby transferring the condensate from each stage, through the selector means, to the accumulator. When the valve member is rotated to its discharge position, the condensate is transferred from the accumulator to the collecting means from which it can be readily discharged.

The invention will be more completely understood from the following detailed description and claims, read in conjunction with the annexed drawings, in which:

FIG. 1 is a diagrammatic view, partly in section, of a preferred embodiment of the invention;

FIG. 2 is a diagrammatic view of a preferred driving means;

FIG. 3 is a diagrammatic view of the selector means; and

FIG. 4 is a transverse sectional view of the selector means.

Referring now to FIG. 1, an embodiment of an automatic blowdown system in accordance with the present invention is shown, which system comprises a multi-stage positive displacement compressor including a casing 10 with cylinders 12, 14 and 16 formed therein, and a forward portion 18 housing a centrifugal unit which draws air into the compressor through an inlet 20. The air is compressed in the casing cylinders by means of pistons 22, 24, and 26 which operate in cylinders 12, 14 and 16 respectively. The pistons are reciprocated by means of a crankshaft 28 driven by a motor 30 mounted outside the casing at one end thereof. Connecting rods 32, 34 and 36 connect the pistons 22, 24 and 26 respectively to the throws 44, 42 and 40 respectively of the crankshaft 28. The crankshaft 28 and the connecting rods are journaled in main bearings 38 and 46.

A gear wheel 48 is affixed to the end of the crankshaft 28 at its forward end, to mate with and drive a spur gear 50 which in turn drives a shaft 52 to which it is affixed. The forward end of the shaft 52 is mounted in a journal bearing 54 in a spider 56 which is affixed to the inner walls of the forward portion 18 of the casing. A disc member or rotor 58 with vanes 60 affixed to its forward face is mounted on the shaft 52 between the spider 56 and the spur gear 50. Adjacent the rear face of the rotor 58, a stator 62, with diffuser blades 64 and a central aperture 66, is affixed to the interior walls of the forward casing portion 18.

The rotor and stator cooperate in the conventional manner to comprise a single stage centrifugal compressor. As the shaft 52 is rotated, air or some other gas to be compressed is drawn in through the inlet 20 by the spinning rotor 58. The vanes 60 of the rotor force the incoming gas over the outer periphery of the rotor and into the diffuser blades 64 of the stator. These diffuser blades are curved, in a manner conventional in the art, to present a concave surface to the gas being delivered by the rotor. The diffuser blades 64 thus deflect the gas inwardly causing it to flow through the central aperture 66 of the stator.

The air or gas, after being partially compressed by the centrifugal unit, flows through a pipe 68 controlled by a one way check valve 70 and into an intercooler 72 which contains a heat exchanger 74 and a separator 76. The

heat exchanger can be of any suitable standard type, such as a series of metal tubes 78 through which cool air or water flows and over which the hot gas from the centrifugal compressor stage passes. As the hot gas contacts the metal tubes 78, it is cooled, thus causing a certain amount of condensation which manifests itself as a dispersion of water droplets suspended in the gas. The cooled gas, containing the suspended condensate, flows out of the heat exchanger 74 and into the separator 76 by a path such as is illustrated in FIG. 1. In the separator, a baffle 80 is mounted over the end of an outlet pipe 82 in a manner which causes the gas entering the separator to flow a tortuous path to get to the outlet pipe. As the gas follows this tortuous path, the condensate settles out and becomes deposited in the lower portion of separator, which acts as a reservoir, and the gas itself flows through the outlet pipe 82, past an inlet check valve 84, and enters the cylinder 12.

As the compressor operates, the piston 22 compresses the gas and forces it out through an outlet check valve 86 in a pipe 88 which connects the cylinder to a second intercooler 90 with a moisture separator 92. In the second intercooler, the gas is cooled in a manner identical to that of the first intercooler 72. It passes through the moisture separator 92 and flows through a pipe 94, past an inlet check valve 96 and into the cylinder 14. The piston 24 compresses the gas further and forces it out past an outlet check valve 98 and through a pipe 100 to a third intercooler 102 with a moisture separator 104. The gas is again cooled, the condensate separated, and the cooled gas flows through a pipe 106, past an inlet check valve 108 and into the cylinder 16. The piston 26 compresses the gas further and forces it out past an outlet check valve 110 and through a pipe 112 to an after-cooler 114 with a moisture separator 116. The after-cooler cools the gas in a manner identical to that of the intercoolers. The cooled gas passes through the moisture separator 116 and then flows moisture free and fully compressed through an outlet pipe 118 to the point where it is to be used.

The compressor hereinbefore described usually has a compression ratio of 4:1 to 5:1 per stage, so it is capable of delivering gas to the outlet at extremely high pressures. It is to be understood that the compressor hereinbefore described can be any type of conventional multi-stage, piston-type compressor, since the compressor itself comprises no part of the present invention.

As the compressor is operated, condensate accumulates in the lower or reservoir portions of the separators 76, 92, 104 and 116. To provide for removal of this condensate, a series of conduits 136, 138, 140 and 142 are mounted in the bottom of the separators 76, 92, 104 and 116 respectively. Each of these conduits is equipped with a one-way check valve 144 which only allows flow out of the casing. Though only four conduits are shown, it is understood that the preferred embodiment of the invention uses a conduit for each stage of the compressor which is to be drained.

The conduits are connected to a selector means, or valve generally indicated as 146, and shown in greater detail in FIGS. 3 and 4. The selector means is comprised of a body 148 and a face plate 150, fastened together in any suitable manner. A cavity 152 is formed in the central portion of the body 148 and a valve member 154 is rotatably mounted within said cavity. A plurality of radial bores or ports 156, 158, 160 and 162 connect the cavity 152 with the conduits 136, 138, 140 and 142 respectively. An additional radial port 164 is formed in the bottom of the body and connected to an outlet conduit 166. A passageway 168 is provided in the valve member 154 and is adapted to communicate with each of the radial ports in the body as the valve member is rotated. The passageway 168 also communicates with an axial bore 170 in the face plate 150.

A conduit 172 has one of its ends connected with the

axial bore 170 and its other end connected to a high pressure collecting vessel or accumulator 174, thereby establishing a constant communication line between the valve member passageway 168 and the accumulator 174. Thus, when the passageway 168 is in a position where it is communicating with a radial bore in the body 148, the conduit supplying that radial bore is in direct communication with the accumulator.

As an example, assume that the valve member 154 is rotated to a position where the valve member passageway 168 is in alignment with the radial bore 158 in the body. The conduit 138 connects the second stage separator 92 (according to the drawing of FIG. 1) of the compressor to that radial bore. Accordingly, any condensate which has accumulated in the second stage separator 92 is forced by the compressor pressure in that stage, through the conduit 138, the radial bore 158, the valve member passageway 168, the axial bore 170, the conduit 172 and into the accumulator 174. The pressure in the accumulator 174 is increased substantially up to, but not above, the pressure of the second stage, and the gas in the upper part of the accumulator is correspondingly compressed.

As the valve member 154 continues to rotate in a clockwise direction (as viewed in FIGS. 3 and 4), the leading edge of passageway 168 will come into communication with the radial bore 160 just after the trailing edge of the passageway 168 goes out of communication with the radial bore 158. The length of time the passageway 168 is out of communication with any bore is not critical. The critical factor is that the passageway be proportioned so that it cannot communicate with two radial bores at once, and thereby allow cross-flow between them.

Since radial bore 160 is connected to the third stage separator 104 of the compressor, which is at a pressure higher than the second stage separator 92, the condensate in that third stage separator is transferred to the accumulator. The pressure in the accumulator is further increased to a value above that in the second stage, but not above that in the third stage of the compressor, and the gas in the upper part of the accumulator is correspondingly further compressed.

The condensate collected in the accumulator cannot flow backward through the conduit 172 toward the compressor since the pressure in that conduit increases continually as the valve member 154 rotates in a clockwise direction from radial bore 156 to radial bore 162. Also, the check valves 144 in the conduits prevent backflow from occurring. However, when the valve member rotates past radial bore 162, which connects to the final stage separator 116 of the compressor, the valve member passageway 168 moves into communication with radial bore 164 which connects to the outlet conduit 166. Since the pressure in the outlet conduit is atmospheric, the high pressure fluid in the accumulator 174 will flow through the conduit 172, the axial bore 170, the outlet radial bore 164 and out through the outlet conduit 166. The fluid is forced out of the accumulator 174 by pressure from a head of compressed air trapped at the top of the accumulator. The accumulator vessel is proportioned so that for maximum humidity intake of the compressor, the fluid accumulated by the stage separators will only fill about ninety percent of the volume of the accumulator vessel, thus leaving a space for an adequate supply of compressed air to thoroughly blow down the accumulator 174.

A pressure gage 176 is mounted in the upper portion of the accumulator 174 to indicate, by its pressure reading, which stage of the compressor is being blown down.

The motive power to operate the selector means 146 and make it rotate can be supplied directly by the motor 30 which drives the compressor crankshaft 28. Any suitable speed reducing means 178 can be connected to the motor 30 and to the valve member 154 as indicated by dash line A in FIG. 1, so that the rotary speed of the

motor can be efficiently scaled down in order that the valve member rotates at a slow speed. It has been found that the invention works quite well when the valve member is connected with each stage at least twice as long as is needed to empty that stage. This insures complete drainage of each stage and further insures that the device will be relatively free from shock noises and compression ignition hazards resulting from sudden opening and closing.

In a test conducted with a Navy 13.5 cubic feet per hour (c.p.h.), 4500 p.s.i., four stage, Ingersoll-Rand compressor having a shaft rotating at 1100 r.p.m., satisfactory automatic blowdown was obtained, with the system described, using a selector valve member having a diameter of approximately $2\frac{1}{2}$ inches and ports and passages of approximately $\frac{1}{4}$ inch. In this specific test the valve member was rotated at 2 revolutions per hour (r.p.h.). However, the valve member may be driven at rotational speeds from 1 r.p.h. to 10 r.p.h., more or less.

The valve member may be driven by a compressor lubricator shaft 196, as shown in FIG. 2. The rotational speed of the lubricator shaft, approximately 1 r.p.m. is geared down by a reduction gear 178 to produce the desired valve rotational speed. For example, if it was desired to rotate the valve member at 5 r.p.h., a 12:1 gear reduction would be needed to reduce the lubricator shaft from 1 r.p.m. (60 r.p.h.) down to 5 r.p.h. Thus, for a speed range between 1 r.p.h. and 10 r.p.h., the reduction gearing will have to be varied between 60:1 and 6:1, respectively.

Other drive means can be employed within the scope of this invention. For instance, the valve in the selector means could be driven by a variable speed drive 179 calibrated in terms of relative humidity. In such a set-up, the valve would be driven slowly if the relative humidity of the ambient air was low. As the relative humidity of the ambient air increased, the amount of condensate would increase; thus the speed of the valve would be increased to facilitate removal of the increased amount of condensate.

As was described above, the condensate empties from the accumulator 174 to the outlet conduit 166. It is possible to connect this conduit to other machinery to make use of the exhausted condensate or it is possible to merely allow the condensate to be drained away. Sometimes, it may be desirable to connect the outlet conduit into a circuit to make a completely closed system, thereby eliminating blowdown vapors from the compressor area. Such a set-up is shown in FIG. 1. The outlet conduit 166 is connected to a collecting tank 180 in which the condensate discharged from accumulator 174 can collect. A float 182 is provided in the tank and is connected to a drain valve (not shown) or a float switch (not shown) to operate a drain pump so that when the condensate reaches a predetermined level, the float will operate to open the valve and discharge the condensate. Baffles 184 are mounted on either side of the float to insure that splashing caused by the incoming condensate will not cause the float to rise too quickly and open the valve too soon. A manual drain valve 186 is also provided so that the tank can be emptied by hand, whenever desired. A relief valve 188 is provided to protect the tank against excessive pressure.

A ball float check valve 190 is provided to prevent condensate in the tank from being blown up into the compressor suction or inlet 20, in the event that the float drain mechanism 182 should fail to function. As condensate is introduced into the tank, the pressure of the air therein is increased. The air flows to a bi-directional valve 192 which can either return the air to the compressor inlet through a return line 194, or merely exhaust the air to the atmosphere, as indicated by the arrow from valve 192 in FIG. 1.

It was described above that the driving means for the selector means 146 could be the compressor motor 30, suitably reduced in speed through a speed reducing means 178. FIG. 2 is a slightly more detailed view showing a

preferred method of driving the selector means 146. The compressor lubricator shaft 196 is connected to a drive-shaft 198 by means of a starter box 200. The lubricator shaft 196 is driven by the compressor crank-shaft 28 which in turn is driven by the motor 30. As the lubricator shaft 196 rotates, it causes the drive-shaft 198 to rotate. The driveshaft 198 is connected through a suitable speed reducing means 178, such as a gear box, to the valve shaft 202. The valve shaft 202 is directly connected to the valve member 154 in the selector means to drive said valve member in a clockwise direction. A hand crank 204 is connected to the starter box 200 and can be used to manually operate the valve to drain the compressor stages. This enables the operator to drain the compressor when the compressor is not operating.

As can be seen in FIG. 1, a hydraulic unloading valve 206 is connected to a branch of the conduit 172 so that the accumulator 174 will automatically unload when the compressor is shut down. A discharge conduit 208 connects the hydraulic unloading valve to the collecting tank 180. A branch line 210 with a manually operated valve 212 connects the accumulator 174 to the discharge conduit 208 to allow manual blowdown of the system.

It will be understood that various changes in the details, material, steps and arrangements of parts, which have been herein described and illustrated in order to explain the nature of the invention, may be made by those skilled in the art within the principle and scope of the invention as expressed in the appended claims.

What is claimed is:

1. A method of transferring collected condensate from the separator in each stage of a multi-stage gas compressor which comprises the steps of:

- (a) selectively connecting an accumulator means with each separator in an order of increasing pressure;
- (b) thereby transferring condensate from the separators to the accumulator means; and
- (c) connecting said accumulator means with a drain means.

2. A method as recited in claim 1 wherein said accumulator means is connected to said drain means only after said accumulator means has been connected to the highest pressure separator.

3. A blowdown system for removing liquid which accumulates in compressor comprising:

- (a) a multi-stage compressor having an inlet, an outlet and interstage connections;
- (b) a motor to drive said compressor;
- (c) selector means connected to the several connections of said compressor by a plurality of conduits;
- (d) said selector means comprising a valve body and a rotary valve member;
- (e) said valve body having a central cavity with a plurality of radial ports and an axial port communicating therewith;
- (f) said rotary valve member being rotatably mounted within said central cavity and having a radial passageway therein adapted to selectively communicate with said radial ports and an axial passageway therein in constant communication with said axial port;
- (g) selector drive means operatively connected to said compressor motor and to said rotary valve member to rotate said rotary valve member;
- (h) an accumulator connected with the axial port in the valve body and thereby in communication with both the axial and radial passageways in said valve member;
- (i) whereby when said valve member is rotated by said selector drive means to a position where the valve member radial passageway communicates with the valve body radial ports, the liquid, which has accumulated in the particular stage of the compressor joined by the conduit to that radial port, will flow through said valve body and member and into said accumulator; and

- (j) a collecting tank communicably connected with one of the radial ports in the valve body;
- (k) whereby when said valve member is rotated by said selector drive means to a position where the valve member radial passageway communicates with the valve body radial port which is connected to the collecting tank, all liquid contained in the accumulator will be transferred through said valve member and body and into said collecting tank.
4. A system as described in claim 3 wherein the collecting means has a discharge means for selectively disposing of the collected liquid and a return means for allowing any air which has been transferred from the accumulator to return to the compressor inlet.
5. A system as described in claim 4 wherein said discharge means comprises a float-controlled valve.
6. A blowdown system for removing condensate from a compressor, driven by a drive means, said system comprising:
- a compressor having a plurality of stages of successively higher operating pressures, each stage comprising a gas cooler and condensate collector;
 - an accumulator;
 - a multi-port valve connected to said accumulator and having a selector means for cyclically separately and selectively connecting each of said valve ports to said accumulator for separate periods in each cycle;
 - a plurality of conduit means from said condensate collectors to said ports, there being a separate conduit means from each collector to one of said ports, the conduit means and ports being arranged so that said selector means connects said ports successively in order from the lowest pressure stage to the highest pressure stage of said compressor; and
 - means for draining said accumulator for a period following the period of connection to the highest pressure compressor stages.
7. A blowdown system as defined in claim 6 but further characterized by a one way check valve in each of said conduit means to permit flow only from the associated collector to the valve.
8. A blowdown system as defined in claim 6 but further characterized by said compressor having a drive means, and gearing driven by said drive means for rotating said selector means.
9. A blowdown system as defined in claim 8 wherein said selector means is rotated at a rotational speed range in the order of 1 revolution per hour to 10 revolutions per hour.
10. The method of blowing down a gas compressor to eliminate moisture condensed from the compressed gas which comprises:
- cooling the compressed gas to condense moisture from the gas;
 - periodically discharging such condensed moisture under the pressure of the compressed gas through a driven rotary valve into an accumulator; and
 - releasing such condensed moisture from said accumulator through said driven rotary valve at the completion of each sequence whereby the loss of compressed gas with the condensed moisture is a minimum.

11. The method of blowing down a multi-stage gas compressor to eliminate moisture condensed from the compressed gas, which comprises:
- cooling said compressed gas leaving each stage of compression to condense moisture from the gas compressed in each stage;
 - individually collecting the moisture so condensed by each stage, under the gas pressure created by that stage;
 - sequentially and separately from stage to stage individually discharging such collected condensed moisture, at the gas pressure under which it was collected, into an accumulator at the increasing gas pressures of said stages; and
 - following each such sequence discharging the accumulated condensed moisture from said accumulator.
12. Apparatus for blowing down a multi-stage gas compressor to eliminate from the compressed gas the moisture that is condensed from the compressed gas, which comprises:
- a multi-stage gas compressor;
 - an individual gas cooler for each stage;
 - means for passing the output of each stage through an individual cooler to the next higher stage until the last stage and then from the last stage through its individual cooler to delivery where it is to be used;
 - each cooler having a sump in which the moisture condensed in that cooler may collect;
 - each such sump having an outlet through which condensation may be discharged therefrom;
 - an accumulator;
 - means for connecting said outlets seriatim and individually to said accumulator in a cycle from the lowest stage to the highest; and
 - means for discharging the condensation in said accumulator after each cycle.
13. Apparatus according to claim 12 wherein:
- said means for connecting said outlets to said accumulator and for discharging said accumulator includes a valve having a body with spaced ports leading individually to said sump outlets and to the discharge outlet in the order of said cycle; and
 - a valve element movable in said body and having a passage connected continuously to said accumulator and in its movement, movable into communication with said sump outlets and said discharge outlet seriatim in said cycle.

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