June 25, 1940. F. B. HUNT 2,205,793

COMPRESSOR

Filed Aug. 10, 1936 2 Sheets-Sheet 1

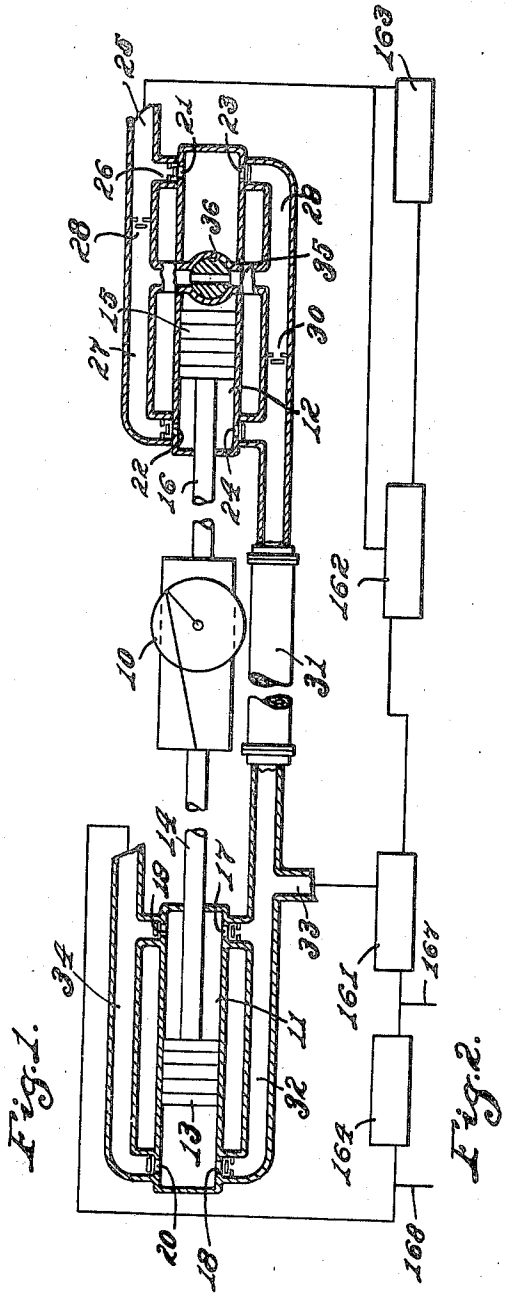


Fig. 1.

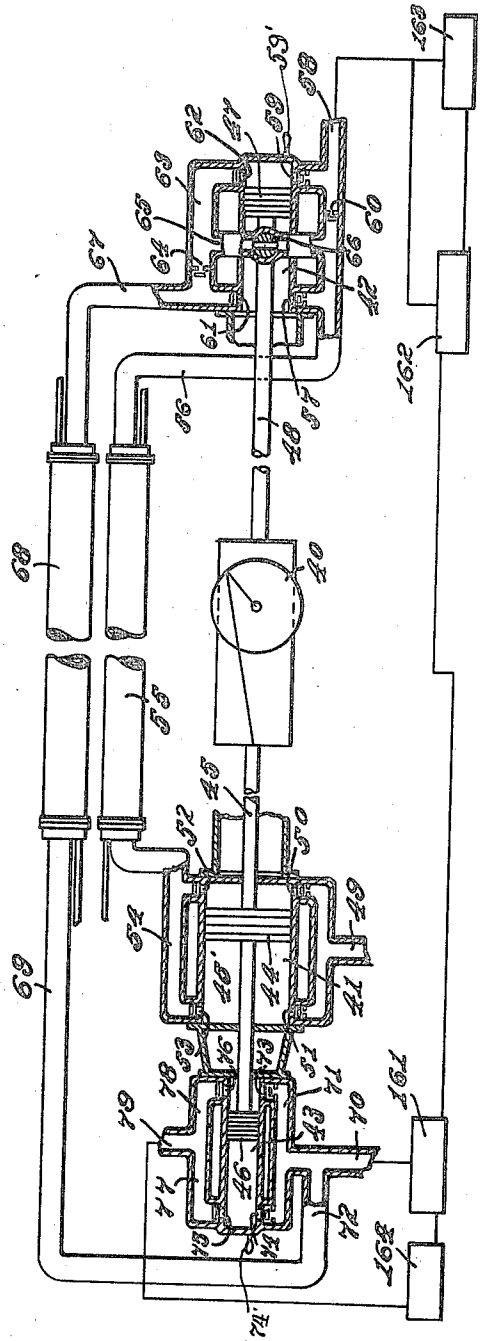


Fig. 2.

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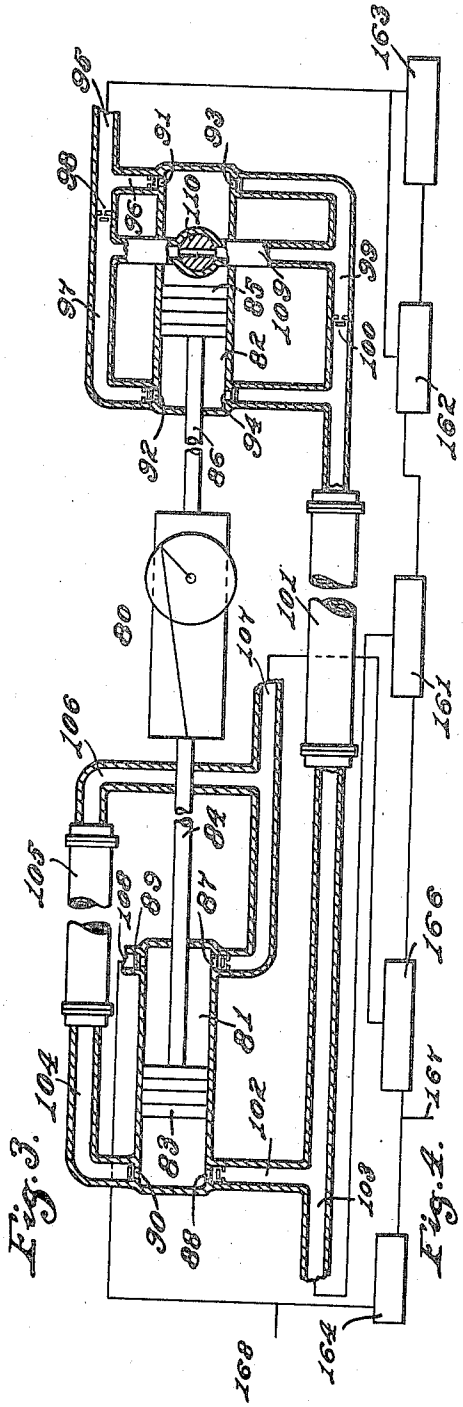


Fig. 3.

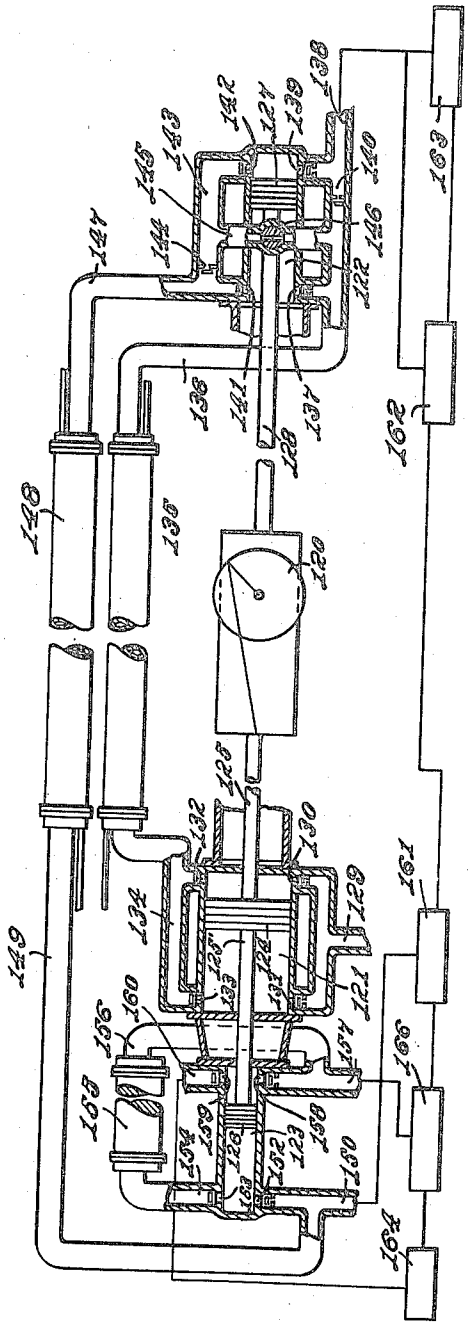


Fig. 4.

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UNITED STATES PATENT OFFICE

2,205,793

COMPRESSOR

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Application August 10, 1936, Serial No. 95,083

5 Claims. (Cl. 230—40)

The present application relates to compressors, and more particularly to compressors of the multi-stage type. The primary object of the invention is to provide means whereby the number of stages of compression is greater than the number of working pistons in the complete machine. A further object of the invention is to provide, in a machine of the class described, means whereby, by a simple adjustment, the number of compression stages may be varied, in a given machine.

To the accomplishment of the above and related objects, my invention may be embodied in the forms illustrated in the accompanying drawings, attention being called to the fact, however, that the drawings are illustrative only, and that change may be made in the specific construction illustrated and described so long as the scope of the appended claims is not violated.

Fig. 1 is a diagrammatic view of a two cylinder multi-stage compressor,

Fig. 2 is a diagrammatic illustration of a three cylinder compressor connected in a carbon dioxide plant,

Fig. 3 is a view similar to Fig. 1, but showing a modified form of compressor, and

Fig. 4 is a view similar to Fig. 2, illustrating a compressor of the general type of that illustrated in Fig. 3.

As is disclosed in the copending application of Franklin B. Hunt, Jabez H. Pratt, Henry S. Tirrell and Robert L. Turner, Serial Number 686,486, for Method of and apparatus for producing carbon dioxide, one advantageous method of manufacturing liquid and solid carbon dioxide involves the steps of compressing gaseous carbon dioxide, in a multiple stage compressor, to a pressure sufficient to cause liquefaction of gas, and passing the liquid through a series of successive evaporators, wherein portions of the liquid are evaporated to cool the remaining liquid; the final evaporating step illustrated in the copending application causing solidification of the remaining liquid. As is disclosed in said copending application, the gas evolved in the various evaporating chambers is returned to the compressor at the various stages, the stage at which gas from a given evaporator is reintroduced into the compressor depending upon the pressure of the gas evolved in each individual evaporating chamber.

In the drawings, the primary evaporating chamber is indicated by the reference numeral 161. Gas is evolved in this chamber at a pressure of 300 pounds per square inch. Gas is evolved in the secondary evaporating chamber 162 at approximately 75 pounds per square inch; and, during a freezing operation, gas is evolved in the freezing chamber 163, likewise at a pressure of approximately 75 pounds per square inch absolute.

However, after a suitable quantity of solid has been formed, it is necessary to pump the freezing chamber pressure down to atmospheric pressure. Obviously, if gas at a pressure materially below 75 pounds per square inch absolute is to be led from the freezing chamber into the compressor, and into a cylinder of the compressor which normally receives gas at a pressure of 75 pounds, the compression ratio in that cylinder is greatly increased. When atmospheric conditions are reached in the freezing chamber, that ratio of compression will be approximately 20, which is excessive.

When a compressor of the type illustrated in Fig. 1 is used in connection with such a plant, gas is led from the primary evaporating chamber 161 to the high pressure cylinder 11; and gas is led from the freezing chamber 163 and/or from the secondary evaporator 162 to the cylinder 12.

This compressor comprises a driving means, indicated generally at 10, the two cylinders 11 and 12 being positioned, in alignment, upon opposite sides of the driving means. A piston 13 is operatively positioned in the cylinder 11 and is connected by piston rod 14, to the driving means 10. Similarly a piston 15 is operatively positioned in the cylinder 12 and is connected by a piston rod 16 to the driving mechanism 10.

The cylinder 11 is provided with a valved inlet port 17 and a valved outlet port 19 at its end adjacent the driving means; and with a valved inlet port 18 and a valved outlet port 20 at its end remote from the driving means. Obviously, because of the presence of the piston rod 14, the effective cross-sectional area of that end of the cylinder 11 adjacent the driving means is less than the effective cross-sectional area of that end of the cylinder remote from the driving means.

Similarly, the cylinder 12 is provided with a valved inlet port 22 and a valved outlet port 24 at its end adjacent the driving means, and with a valved inlet port 21 and a valved outlet port 23 at its end remote from the driving means. In the same way the effective cross-sectional area of that end of the cylinder 12 adjacent the driving means is smaller than the effective

cross-sectional area of that end of said cylinder remote from the driving means.

The conduit 25 leads gas from the freezing chamber 163 and the secondary evaporator 162 to a conduit 26 communicating with the inlet port 21 of the cylinder 12. Said conduit 25 is provided with a branch 27 leading to the inlet port 22 of said cylinder 12; said branch being provided with a check valve 28 therein, permitting flow toward the port 22, but preventing flow in a direction away therefrom.

A conduit 29 is provided with branches communicating with the outlets 23 and 24, and has a check valve 30 positioned therein, permitting flow away from the port 23, but preventing flow toward said port.

The conduit 29 leads to and through an intercooler 31, and a conduit 32 leads from the opposite end of said inter-cooler, being provided with branches communicating with the ports 17 and 18 of the cylinder 11. A conduit 33 connects the primary evaporator 161 with said conduit 32. A conduit 34 leads from the ports 19 and 20 of the cylinder 11, through a condenser 164 to the primary evaporator 161.

While the freezing operation is going on, and gas is being supplied from the freezing chamber 163 through the conduit 25 at a pressure of 75 pounds per square inch absolute, the compressor operates in a normal manner, both of the cylinders 11 and 12 operating as double-acting compressors. This operation will continue until the intake pressure in the conduit 25 falls below a predetermined value, such, for instance, as 50 pounds per square inch absolute.

A passage 35 communicates with the conduits 27 and 29; the point of communication with the conduit 27 being between the valve 28 and the port 22, and the point of communication with the conduit 29 being between the port 23 and the valve 30. Flow through this passage 35 is controlled by a valve 36, of any desired positively actuated type. When the pressure in the conduit 25 falls below the predetermined value, the valve 36 is opened; thereby converting the cylinder 12 into a two-stage compressor, instead of a double-acting compressor. With the valve 36 open, gas will flow, upon movement of the piston 15 toward the left, from the conduit 25 through the port 21 into the right hand end of the cylinder 12. Upon movement of the piston to the right, the gas in the right hand end of the cylinder will be forced through the port 23, conduit 29, passage 35, and conduit 27, and so through the port 22 into the left hand end of the cylinder 12. Upon movement of the piston 15 toward the left again, the gas so drawn through the port 22 will be forced through the port 24 and so through the intercooler 31 and to the cylinder 11. Thus, gas is pumped from the right hand end of the cylinder 12 into the left hand end of said cylinder, which is of smaller volume because of the presence of the rod 16, and thence to the intercooler. Because of this difference in the volumes of the respective ends of the cylinder 12, we get a two-stage compression which, when the intake pressure is 15 pounds per square inch and the pressure of discharge from the cylinder as a whole is 300 pounds per square inch, involves a compression ratio of from 3 to 3½ in the right hand end of the cylinder and a compression ratio of from 6 to 7 in the left hand end of the cylinder. Obviously, neither of these cylinder ratios is excessive, and instead of approaching a zero pumping capacity due to low volumetric efficiency, the right hand end, with more than half of the total cylinder volume, operating with a ratio of 3 to 3½, will have a volumetric efficiency of from 80 to 85%.

As soon as the pressure in the freezing chamber has reached approximately atmospheric value, the valve 36 will be closed and the normal operation of the organization will continue. Suitable valves are, of course, provided to control the flow through the system.

The above organization is, of course, merely a recompressor arrangement, into which carbon dioxide is introduced either in the liquid phase through conduit 167 or in the gaseous phase through conduit 168. In Fig. 2, there is shown a three cylinder combination compressor. In said Fig. 2, the reference numeral 40 indicates driving mechanism, with which are associated cylinders 41, 42 and 43. All of the cylinders are in alignment, and the cylinder 42 is preferably positoned on one side of the driving mechanism, while the cylinders 41 and 43 are positioned on the other side thereof, the cylinder 43 being spaced from the driving mechanism by the cylinder 41. A piston 44 is reciprocably positioned in the cylinder 41 and is carried upon a piston rod 45 connected to the driving mechanism. An extension 45' of the rod 45 carries the piston 46 which is reciprocably mounted in the cylinder 43. A piston 47 is operatively positioned in the cylinder 42 and is connected to the driving mechanism by a piston rod 48.

Process gas (that is, gas which is entering the conversion cycle for the first time) is led into the combination machine through the branched conduit 49 which communicates with the valved inlet ports 50 and 51 of the first cylinder 41 which, operating as a double acting compressor, compresses the gas and forces it out through the ports 52 and 53 and the branched conduit 54 to and through a first stage intercooler 55. Thence, the compressed and cooled gas, at a pressure of 50 to 75 pounds per square inch absolute, is led through the conduit 56 to the inlet port 57 of the second cylinder 42.

Concurrently, gas from the freezing chamber 163 is led, through the conduit 58, to the valved inlet port 59 of the cylinder 42. An operating handle 59' is provided for manually holding open the valve in port 59, at times. The cylinder 42 operates as a double acting compressor, drawing gas for its left hand end from the cylinder 41, drawing gas for its right hand end from the freezing chamber 163 and secondary evaporator 162; and forcing gas drawn from both sources through the respective outlet ports 61 and 62 and thus through the conduits 63 and 67 to the second stage intercooler 68. A check valve 64 is interposed in the conduit 63, and a check valve 60 is positioned in the conduit 58, for a purpose which will later appear.

A passage 65 communicates with the conduits 58 and 63, the point of communication with the conduit 58 being between the check valve 60 and the inlet port 57, and the point of communication with the conduit 63 being between the port 62 and the check valve 64. Flow through the passage 65 is permitted or prevented, depending upon the position of a control valve 66.

From the second stage intercooler 68, gas is led through the conduit 69, at a pressure of approximately 300 pounds per square inch absolute. Concurrently, gas is led from the primary evaporator 161 through a conduit 70; and the conduit 69 joins the conduit 70 before said conduit 70

splits into branches 71 and 72 communicating, respectively, with valved inlet ports 73 and 74 of the cylinder 43. An operating handle 74' is provided for manually holding open the valve in port 74, at times. Said cylinder 43, operating as a double acting compressor, forces the gas so fed to it through the valved outlet ports 75 and 76 and the conduit branches 77 and 78 to the high-pressure descharge line 79, the gas flowing through said line 79 at a pressure of approximately 1,000 pounds per square inch.

When the complete organization is being operated to produce solid carbon dioxide, the above description applies properly. As in the case of the organization of Fig. 1, when it is desired to pump down the freezing chamber 163, the valve 66 is opened to provide an extra stage of compression in the cylinder 42.

If it is desired to operate the plant to make liquid carbon dioxide for sale, or if, for any other reason, the freezing chamber 163 is not in use, manually operable means is provided for holding permanently open the valves 59 and 74, thereby unloading the right hand end of the cylinder 42 and the left hand end of the cylinder 43, so that the organization comprises a double-acting first-stage and single-acting second and third stages.

The desirability of this arrangement is increased by the fact that the cylinder 41 cannot, in many instances, be used to pump down the freezing chamber to atmospheric pressure. In many commercial applications, this first stage of compression has an intake pressure of 20 to 30 pounds per square inch absolute; and of course, in such cases, it would be impossible to pump the freezing chamber down to a pressure below this value. In all cases where the process gas is coming from a chemical process, it is absolutely necessary to avoid the building up of any increased suction pressure on the first stage, since such an increase would affect the chemical process. Thus, the combination disclosed in Fig. 2 not only eliminates the necessity for an additional cylinder in order to attain the advantages of four-stage compression, but permits the handling of both process gas and recompressed gas without affecting the chemical process supplying the process gas.

In Fig. 3, I have illustrated a modification of the organization of Fig. 1. Driving mechanism is illustrated at 80 and cylinders 81 and 82 are arranged in alignment on opposite sides of the driving means. A piston 83 is operatively positioned in the cylinder 81 and is connected to the driving means by a piston rod 84; and a piston 85 is operatively positioned in the cylinder 82 and is connected to the driving means by a piston rod 86.

The cylinder 81 is provided with valved inlet ports 87 and 88 positioned at its opposite ends, and with valved outlet ports 89 and 90, similarly arranged. In the same way, the cylinder 82 is provided with valved inlet ports 91 and 92 and with valved outlet ports 93 and 94.

Gas from the freezing chamber or the secondary evaporator is fed to the port 91 of the cylinder 82 through a conduit 95 and its branch 96 and to the inlet port 92 through the branch 97 in which is positioned a check valve 98. A branched conduit 99 communicates with the ports 93 and 94 and leads gas, discharged from the ports 93 and 94, into the intercooler 101, a check valve 100 being positioned in the conduit 99. From the intercooler, gas flows through the conduit 102 to the inlet port 88 of the cylinder 81, being joined by gas flowing through the conduit 103 from the primary evaporator. In the left hand end of the cylinder 81, the gas is compressed and ejected through the port 90 and conduit 104 to and through the intercooler 105 and thence, through the conduit 106, which joins the conduit 107 leading from a sub-evaporator 166, to the inlet port 87 at the right hand end of the cylinder 81. Thence, the gas is ejected at a pressure of from 1200 to 1400 pounds per square inch, through the port 89 and the discharge line 108.

As in the organization of Fig. 1, the cylinder 82 may be converted from a double-acting compressor to a two-stage compressor by opening the valve 110 in the passage 109 which leads from a point in the conduit 99 between the port 93 and the valve 100 to a point in the conduit 97 between the valve 98 and the port 92. And, as in the case of Fig. 1, carbon dioxide is introduced into the system either in the liquid phase through the conduit 167 or in the gaseous phase through the conduit 168.

Fig. 4 is similar to Fig. 2, but incorporates the same modifications found in Fig. 3. Thus, the combination compressor of Fig. 4 comprises an operating means 120, a first cylinder 121, a second cylinder 122, and a third cylinder 123, said three cylinders being aligned and the cylinder 122 being positioned on one side of the operating means, with the cylinders 121 and 123 positioned on the opposite side of said operating means, said cylinder 123 being spaced from the operating means by the cylinder 121.

A piston 124 is reciprocable in the cylinder 121, and is carried on a piston rod 125 connecting with the operating mechanism 120. A continuation 125' of the piston rod 125 carries the piston 126 which is reciprocable in the cylinder 123. A piston 127 is reciprocable in the cylinder 122 and is connected by a piston rod 128 with the operating means 120.

Process gas is led into the combination compressor through a conduit 129 having branches communicating respectively with the valved inlet ports 130 and 131 of the cylinder 121. Said cylinder, operating as a double-acting compressor, discharges the gas through valved outlet ports 132 and 133 to a conduit 134 which leads the gas to and through a first-stage intercooler 135. Thence the gas, at a pressure of 50 to 75 pounds per square inch absolute, is lead by a conduit 136 to the inlet port 137 of the cylinder 122. Concurrently, gas from the freezing chamber 163 or the secondary evaporator 162 is led through a conduit 138 to the inlet port 139 of the cylinder 122. Said conduit 138 continues to join the conduit 136 at the inlet port 137, a check valve 140 being positioned therein between the ports 139 and 137.

The cylinder 122, operating as a double-acting compressor, drawing gas for its left hand end from the cylinder 121 and gas for its right hand end from the freezing chamber or secondary evaporator, forces the gas through the valved outlet ports 141 and 142 and through the conduits 143 and 147 to and through the second-stage intercooler 148. A check valve 144 is positioned in the conduit 143 between the port 142 and the conduit 147. A passage 145 communicates with the conduit 143 at a point between the port 142 and the valve 144, and with the conduit 138 at a point between the valve 140 and the port 137; flow of fluid through said passage being controlled by said valve 146.

From the second-stage intercooler, the gas is

led through a conduit 149, at a pressure of approximately 300 pounds per square inch absolute, to a conduit 150 leading from the primary evaporator 161 to the inlet port 152 of the cylinder 123. Gas entering the cylinder 123 through said port 152 is compressed, upon movement of the piston 126 toward the left, and forced through the outlet port 153 and conduit 154, thence through the third-stage intercooler 155, and through the conduit 156 which joins with a conduit 157 leading from the sub-evaporator 166 to the inlet port 158 of the cylinder 123, at a pressure of approximately 550 pounds per square inch absolute. Thence, by a further compression stage achieved in the right hand end of the cylinder 123, the gas is ejected through the outlet port 159 and the high pressure line 160, at a pressure of 1200–1400 pounds per square inch, to the condenser 164. The liquid there produced flows to the primary evaporator 161.

As in previous examples, when it is desired to pump down the freezing chamber 163, the valve 146 is opened to provide two stages of compression in the cylinder 122.

If it is desired to operate the plant to make liquid carbon dioxide for sale, or if, for any other reason, the freezing chamber 163 is not in use, manually operable means is provided for holding permanently open the valves 139 and 152, thereby unloading the right hand end of the cylinder 122 and the left hand end of the cylinder 123, so that the organization comprises a double-acting first-stage and single-acting second and third stages.

While I have shown the piston rods of substantially uniform diameters in all the illustrated forms of my invention, it will be obvious that the rods in a given form may vary in size. For instance, in the embodiment of Fig. 4, the portion of rod 125' which is located in cylinder 123 might be larger than the portion thereof which is located in the cylinder 121. By this means, any desired ratio of cylinder size, within reasonable limits, may be obtained.

I claim as my invention:

1. A compressor comprising a cylinder, a piston reciprocable in said cylinder, a piston rod secured to one end only of said piston and projecting through the adjacent end of said cylinder, a first valved inlet port adjacent said end of said cylinder, a first valved outlet port adjacent said end of said cylinder, a second valved inlet port adjacent the opposite end of said cylinder, a second valved outlet port adjacent said opposite end of said cylinder, a first conduit connecting said first inlet port with said second inlet port, a valve in said first conduit preventing fluid flow from said first inlet port toward said second inlet port but permitting fluid flow in the opposite direction, a second conduit connecting said first outlet port with said second outlet port, a valve in said second conduit preventing fluid flow from said first outlet port to said second outlet port but permitting fluid flow in the opposite direction, a third conduit communicating with said first conduit between said first inlet port and said valve in said first conduit and communicating with said second conduit between said second outlet port and said valve in said second conduit, and a valve controlling fluid flow in either direction through said third conduit.

2. In a device of the class described, a first cylinder, a first piston in said cylinder, a second cylinder, a second piston in said second cylinder, driving means interposed between said cylinders, a third cylinder spaced from said driving means by said first cylinder, a third piston in said third cylinder, all of said cylinders being aligned, a piston rod carrying said second piston and connected to said driving means, a piston rod carrying said first and third pistons and connected to said driving means, valved inlet and outlet ports ajacent each end of each of said cylinders, a first branched conduit leading from a fluid source to both inlet ports of said first cylinder, a second branched conduit leading from both outlet ports of said first cylinder to the inlet port of said second cylinder adjacent said driving means, a third branched conduit leading from a fluid source to the inlet port of said second cylinder remote from said driving means and, through a check valve, to the inlet port of said second cylinder adjacent said driving means, a fourth branched conduit leading from the outlet port of said second cylinder adjacent said driving means, and, through a check valve, from the outlet port of said second cylinder remote from said driving means, to the inlet port of said third cylinder remote from said driving means, a fifth conduit leading from a fluid source to said fourth conduit, a sixth conduit leading from a fluid source to the inlet port of said third cylinder adjacent said driving means, a seventh conduit leading from the outlet port of said third cylinder remote from said driving means to said sixth conduit, and an eighth conduit leading from the outlet port of said third cylinder adjacent said driving means.

3. In a device of the class described, a first cylinder, a first piston in said cylinder, a second cylinder, a second piston in said second cylinder, driving means interposed between said cylinders, a third cylinder spaced from said driving means by said first cylinder, a third piston in said third cylinder, all of said cylinders being aligned a piston rod carrying said second piston and connected to said driving means, a piston rod carrying said first and third pistons and connected to said driving means, valved inlet and outlet ports adjacent each end of each of said cylinders, a first branched conduit leading from a fluid source to both inlet ports of said first cylinder, a second branched conduit leading from both outlet ports of said first cylinder to the inlet port of said second cylinder adjacent said driving means, a third branched conduit leading from a fluid source to the inlet port of said second cylinder remote from said driving means and, through a check valve, to the inlet port of said second cylinder adjacent said driving means, a fourth branched conduit leading from the outlet port of said second cylinder adjacent said driving means, and, through a check valve, from the outlet port of said second cylinder remote from said driving means, to the inlet port of said third cylinder remote from said driving means, a valve-controlled passage providing, at times, communication between a point in said third conduit intermediate the check valve therein and the inlet port of said second cylinder adjacent said driving means, and a point in said fourth conduit intermediate the outlet port of said second cylinder remote from said driving means and the check valve in said fourth conduit, a fifth conduit leading from a fluid source to said fourth conduit, a sixth conduit leading from a fluid source to the inlet port of said third cylinder adjacent said driving means, a seventh conduit leading from the outlet port of said third cylinder remote from said driving means to said

sixth conduit, and an eighth conduit leading from the outlet port of said third cylinder adjacent said driving means.

4. In a device of the class described, a first cylinder, a first piston in said cylinder, a second cylinder, a second piston in said second cylinder, driving means interposed between said cylinders, a third cylinder spaced from said driving means by said first cylinder, a third piston in said third cylinder, all of said cylinders being aligned, a piston rod carrying said second piston and connected to said driving means, a piston rod carrying said first and third pistons and connected to said driving means, valved inlet and outlet ports adjacent each end of each of said cylinders, a first branched conduit leading from a fluid source to both inlet ports of said first cylinder, a second branched conduit leading from both outlet ports of said first cylinder to the inlet port of said second cylinder adjacent said driving means, a third branched conduit leading from a fluid source to the inlet port of said second cylinder remote from said driving means and, through a check valve, to the inlet port of said second cylinder adjacent said driving means, a fourth branched conduit leading from the outlet port of said second cylinder adjacent said driving means, and, through a check valve, from the outlet port of said second cylinder remote from said driving means, to the inlet port of said third cylinder remote from said driving means, a fifth conduit leading from a fluid source to said fourth conduit, a sixth conduit leading from a fluid source to the inlet port of said third cylinder adjacent said driving means, a seventh conduit leading from the outlet port of said third cylinder remote from said driving means to said sixth conduit, and an eighth conduit leading from the outlet port of said third cylinder adjacent said driving means, and manually operable means associated with said inlet valve of said second cylinder remote from said driving means and with said inlet valve of said third cylinder remote from said driving means, and operable independently to hold said respective valves open, at will.

5. In a device of the class described, a first cylinder, a first piston in said cylinder, a second cylinder, a second piston in said second cylinder, driving means interposed between said cylinders, a third cylinder spaced from said driving means by said first cylinder, a third piston in said third cylinder, all of said cylinders being aligned, a piston rod carrying said second piston and connected to said driving means, a piston rod carrying said first and third pistons and connected to said driving means, valved inlet and outlet ports adjacent each end of each of said cylinders, a first branched conduit leading from a fluid source to both inlet ports of said first cylinder, a second branched conduit leading from both outlet ports of said first cylinder to the inlet port of said second cylinder adjacent said driving means, a third branched conduit leading from a fluid source to the inlet port of said second cylinder remote from said driving means and, through a check valve, to the inlet port of said second cylinder adjacent said driving means, a fourth branched conduit leading from the outlet port of said second cylinder adjacent said driving means, and, through a check valve, from the outlet port of said second cylinder remote from said driving means, to the inlet port of said third cylinder remote from said driving means, and a fifth conduit leading from the outlet port of said third cylinder remote from said driving means to the inlet port of said third cylinder adjacent said driving means.

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