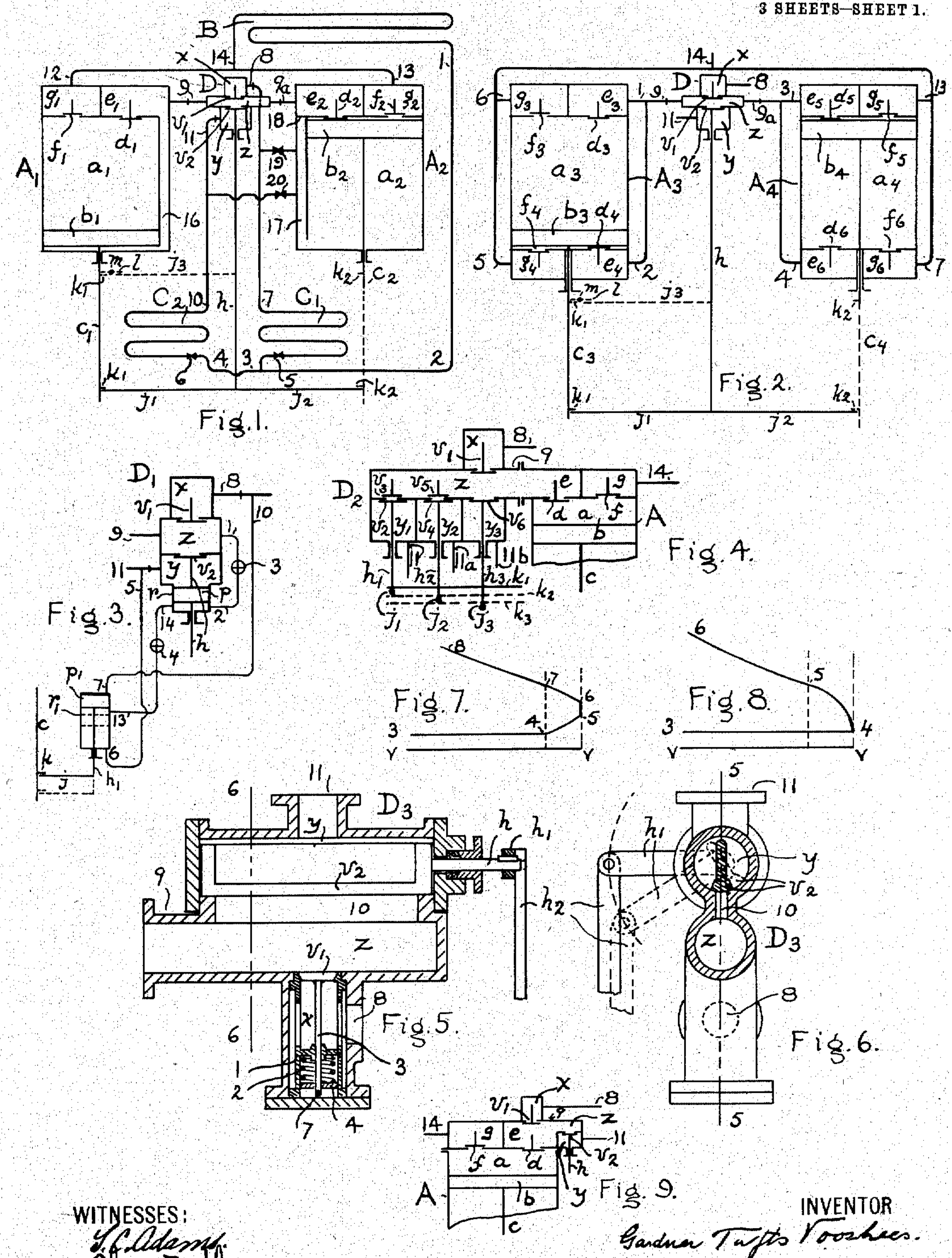
G. T. VOORHEES.

MULTIPLE EFFECT GAS COMPRESSING APPARATUS.

APPLICATION FILED DEC. 27, 1909.

982,753. Patented Jan. 24, 1911.

3 SHEETS—SHEET 1.



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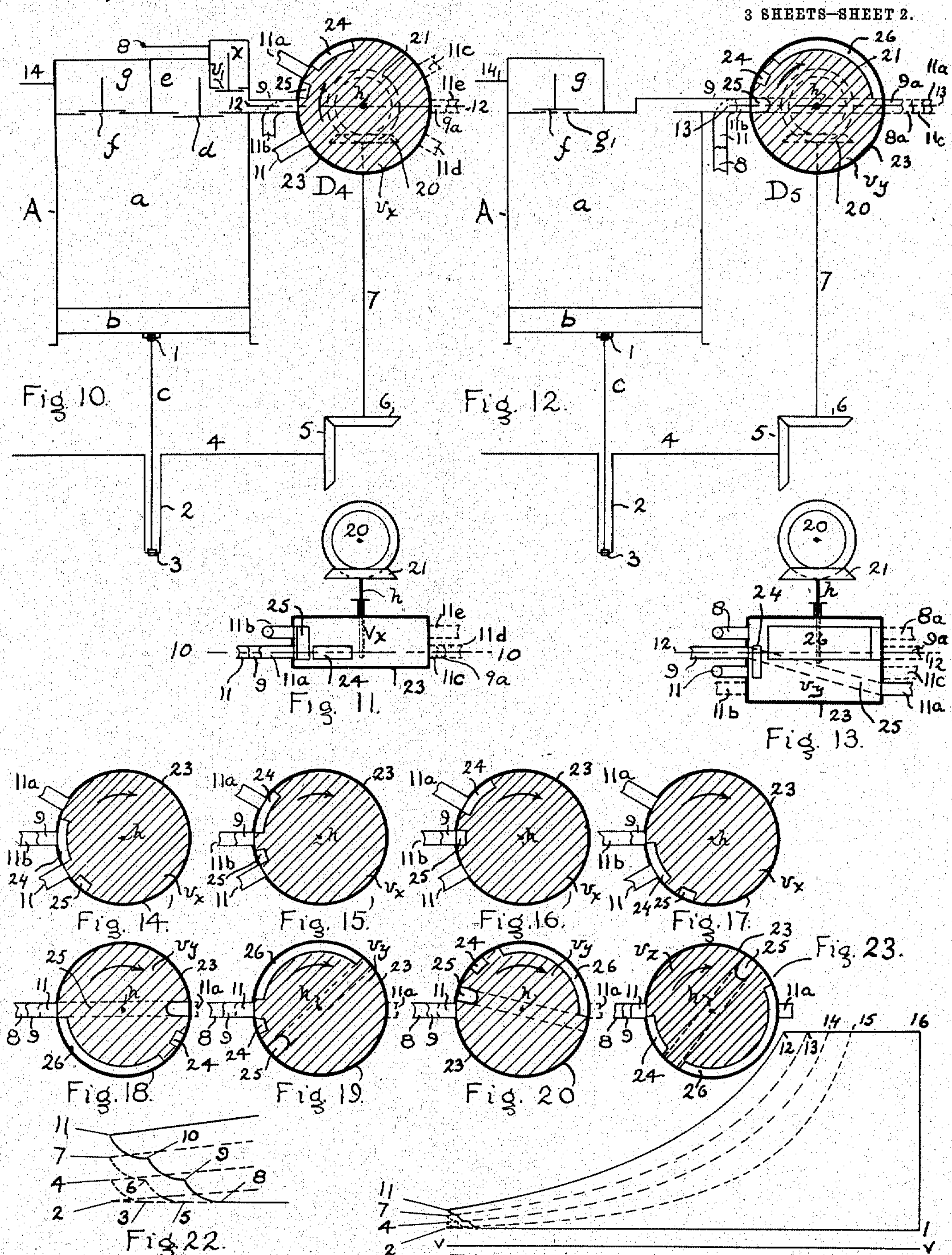

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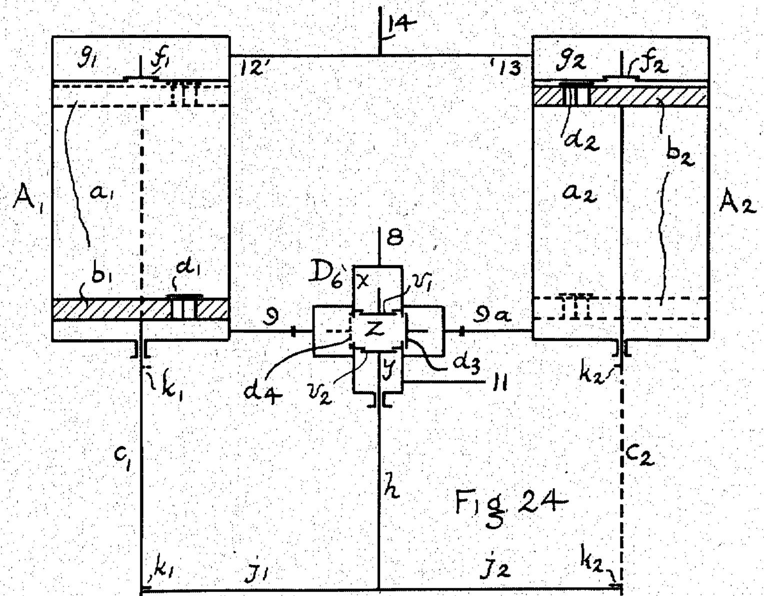

Fig. 24

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MULTIPLE-EFFECT GAS-COMPRESSING APPARATUS.

982,753. Specification of Letters Patent. Patented Jan. 24, 1911.

Application filed December 27, 1909. Serial No. 534,928.

To all whom it may concern:

Be it known that I, GARDNER TUFTS VOORHEES, a citizen of the United States of America, and a resident of Boston, in the county of Suffolk and State of Massachusetts, have invented a Multiple-Effect Gas-Compressing Apparatus, of which the following is a specification.

My invention relates to multiple effect gas compressing apparatus, particularly to compressors of refrigerating systems, particularly of volatile liquid refrigerating systems. Its objects are, to make simpler multiple effect compressors and to more simply make ordinary compressors multiple effect and by the insertion of a device in the suction pipe of an ordinary compressor to make it multiple effect without changing its cylinder piston or valves and to enable such a single device to make two or more ordinary compressors multiple effect.

The nature of the invention enables a compressor of a given swept volume of piston in its cylinder, by virtue of being multiple effect, to have greater capacity or better economy, or both, than an ordinary compressor of like displacement would have, by enabling the compressor to take into its cylinder *seriatim*, through a single opening therein, gas at two or more different suction pressures, in the increasing order of said pressures.

In the drawings which are on three sheets:—Figure 1 is a diagrammatic part sectional elevation of a refrigerating system with my invention applied to either one or two single acting compressors. Fig. 2, is a diagrammatic part sectional elevation of two double acting compressors having my invention applied thereto. Fig. 3, is a diagrammatic part sectional elevation of a two stage multiple effect suction device with certain modifications. Fig. 4 is a diagrammatic part sectional elevation of a four stage multiple effect suction device. Figs. 5 and 6 are elevations, partly in section, of a modified form of two stage device having a Corliss type of valve, Fig. 5 being sectioned on line 5, 5 of Fig. 6 and Fig. 6 being sectioned on line 6, 6 of Fig. 5. Figs. 7 and 8 are parts of indicator cards (toes) taken from the cylinder of a compressor. Fig. 9 is a diagrammatic part sectional elevation of a part of a compressor showing the essential parts of a two stage device as an integral part of the compressor's cylinder head. Fig. 10 is a diagrammatic part sectional elevation of a single acting compressor with a modified form of multiple effect suction device, having a rotating valve, and is sectioned on line 10—10 of Fig. 11. Fig. 11 is a diagrammatic part sectional plan of the rotating valve, casing, connections, etc., of Fig. 10, sectioned on line 12—12 of Fig. 10. Fig. 12 is a diagrammatic part sectional elevation of a single acting compressor, with another modified form of rotating valve, and wherein the ordinary suction or discharge valves of a common compressor can be replaced by the rotating valve and is sectioned on line 12—12 of Fig. 13. Fig. 13 is a diagrammatic part sectional plan of the rotating valve, casing and connections of Fig. 12 sectioned on line 13—13 of Fig. 12. Figs. 14, 15, 16, 17 are diagrammatic sectional elevations of rotating valve, casing and connections of Fig. 10, showing different positions of the rotating valve. Figs. 18, 19, 20 are similar diagrammatic sections of the rotating valve its casing and connections of Fig. 12. Fig. 21 is a series of indicator diagrams taken from a compressor cylinder. Fig. 22 is an enlarged portion of the toes of the cards of Fig. 21. Fig. 23 is a diagrammatic section of a special valve, to fit in casing and replace the valve of Fig. 12, to do away with the ordinary discharge valve of Fig. 12. Fig. 24 is a diagrammatic part sectional elevation of two "valve in the piston type" compressors with a two stage multiple effect suction device.

In all the figures similar parts generally have like letters or numbers sometimes with different subscripts.

In Fig. 1, liquid anhydrous ammonia flows from condenser B (cooled by any desired means as by water trickling over its surface) through pipe 1, 2, 3, 4 to expansion valves 5, 6 of refrigerators, C_1, C_2. Heat from any desired source, from products being cooled, evaporates the liquid ammonia in these refrigerators; in refrigerator C_1 at 15 pounds absolute pressure per square inch, and in refrigerator C_2 at 20 pounds pressure. The low pressure gas from refrigerator C_1 flows through pipe 7, 8 to low pressure suction chamber x of multiple effect suction device D, forces open valve v_1 and flows past it into main chamber z and through pipe 9 to suction valve chamber e_1 (of compressor A_1) and past valve d_1 into cylinder a_1 and continues to fill cylinder a_1 from the time piston

b_1 started on its down stroke, or suction stroke, until any desired point in its stroke as at b_1 (here just before the end of the down stroke). During this time the higher pressure gas from refrigerator C_2 flowed through pipe 10, 11 to high pressure suction valve chamber y of multiple effect suction device D. When piston b_1 reaches the position shown a further downward movement of it causes a projection k_1 carried on its piston rod c_1 to engage arm j_1 and pull valve stem h and so open valve v_2 which allows the high pressure gas from chamber y to flow past valve v_2 into chamber z and through pipe 9, chamber e_1, past valve d_1, into cylinder a_1 to join and partially compress the low pressure gas therein. Valve v_1 being kept shut by the superior pressure on its free face. Then a little upward movement of piston b_1 releases k_1 from arm j_1 and the pressure in cylinder a_1 rises due to compression so closing valve d_1, and when the pressure is sufficient valve f_1 is forced open and the compressed gas discharged from cylinder a_1 past valve f_1 through chamber g_1 and pipe 12, 14 to condenser B wherein it is condensed to a liquid and again starts on its cycle through pipe 1, 2, etc. And on the beginning of the down stroke of piston b_1 valve f_1 closes and valves d_1 and v_1 open and valve v_2 shuts, all because of proper differences of pressure on their faces and the cycle is repeated. An indiactor card taken from cylinder a_1 would be like 1, 4, 14, 16, 1 of Fig. 21 and its toe like, 5, 3, 4 of Fig. 22; v v being the vacuum line, 1, 3 the admission, or suction line, of 15 pound pressure gas, 3 the point where valve v_2 opened to admit 20 pounds pressure gas, 4 the point where valve d_1 closed and where compression began, 4, 14 the compression line, 14 the point where valve f_1 opened; 14, 16 the discharge line, 16 the point where valve f_1 closed and 1 the point where valves d_1 v_1 opened and where valve v_2 closed. An ordinary card, without the use of device D, taken from compressor A, at 15 pounds suction pressure, would be 1, 2, 15, 16, 1, the relative lengths of lines 14, 16 and 15, 16 indicating generally the increased weight of ammonia handled by the two stage compressor just described. It will be clear to those skilled in the art without further description how compressor A_2 can similarly be served with 15 and 20 pound pressure gas by device D, and how projection k_2 on piston rod c_2 can engage arm j_2 to operate valve v_2 or how projection k_1 can engage pivoted piece l, pivoted at m, and so engage arm j_3 to open valve v_2 through its stem h. In compressors A_1 and A_2 the pistons b_1 b_2 always move in opposite directions and valve d_1 or d_2 is always closed during compression in its cylinder by the superior pressure on the cylinder face of the valve. In the type of compressor here shown it is desirable to have the gas passage as 16 of compressor A_1 cut off from valve chamber e_1, as is done with a similar passage 17 of compressor A_2, by a partition 18, to avoid clearance thereby. It is here evident that passage 17 can connect with low pressure or high pressure suction gas by having valve 19 open and valve 20 shut or vice versa. It is preferable to have the high pressure suction pressure under the piston in this type of compressor for by so doing, although the mean effective pressure is the same, yet the down thrust during compression and discharge on piston rod, and so on all the parts to take it up, is less than if the low pressure gas were under the piston.

In Fig. 2 compressors A_3 A_4 are double acting and their pistons b_3 b_4 move in opposite directions. As parts similar to those of Fig. 1 generally have similar letters or figures, some with different subscripts, it will be clear to those skilled in the art without further description how device D can serve one double acting compressor or the two double acting compressors and how, first low pressure and then high pressure suction gas is admitted to and compressed in cylinders a_3 and a_4 at the same time, on the upper side of piston b_3 when on the under side of piston b_4 and vice versa. The compressed gas being discharged from cylinders a_3 a_4 through pipes 6, 14 and 7, 14 or through pipes 5, 14 and 13, 14. Pipe 8 is for low pressure and pipe 11 for high pressure gas as in Fig. 1.

In Fig. 3 low pressure gas is conducted to chamber x of device D_1 through pipe 8 and to chamber y through pipe 11 and both high and low pressure gas flows from chamber z through pipe 9 to a compressor's suction valve chamber (not shown here) like e_1 of Fig. 1. c is a piston rod of a compressor, (not shown) having projection k. Referring again to Fig. 1 it is observed that valve v_2 opens against a higher pressure on its under side than on its upper side and so requires a pull on stem h sufficient to overcome this unbalanced difference of pressure on the valves' faces. In order to nearly balance valve v_2 I sometimes provide its stem h of Fig. 3 with a piston p of smaller area than that of valve v_2, said piston fitting in cylinder r. Then I connect chamber z and the under side piston p by pipe 1, 2 and so nearly balance v_2 when valve 3 is open. If desired valve v_2 may be actuated by piston p if the piston's area is greater than that of valve v_2. To do this I shut valve 3 and open valve 4 and provide an auxiliary cylinder r_1 with piston valve p_1 having rod h_1 and arm j adapted to be engaged by projection k. When projection k engages arm j and moves it from the full line to the dotted line position, piston valve p_1 is moved from its full line to its dotted line position through rod h_1 and so allows communication through pipes 14, 13 and 7, 10 of low pressure gas on the under side of piston p and (because of unbalanced pressure on piston p) it opens valve v_2 by a pull on rod h. When arm j and therefore piston valve p_1 have returned to their full line positions through the upward movement of k_1 and because of the high pressure on the lower side of piston valve p_1 then both the upper and under sides of piston p are exposed to high pressure through pipes 5, 6 and 13, 14 and so, when the pressure in chamber z is again less than that in chamber y, valve v_2 is shut by piston p through stem h because of the unbalanced pressure on the two sides of valve v_2.

Fig. 4 shows how the device D_2 may have additional inlets for other higher suction pressures, four such suction inlets being shown. When piston b of compressor A is at a desired position as near the end of its suction stroke, after having taken in 15 pound pressure gas through inlet 8, chamber x, past valves v_1 and d through chambers z and e then arm k_1 actuated from piston rod c (connection not shown) engages projection j_1 on stem h_1 and opens valve v_2 and so allows 20 pound pressure gas supplied to chamber y_1 through pipe 11 to flow to cylinder a past valves v_2 v_3 d and through chambers z and e to join and partially compress the 15 pound pressure gas in cylinder a, the superior pressure in chamber z shutting valve v_1. Then arm k_1 is moved to position k_2 and engages projection j_2 on stem h_2 and opens valve v_4 and so allows 25 pound pressure gas supplied to chamber y_2 through pipe 11_a to flow to cylinder a past valves v_4 v_5 d and chambers z and e to join and partially compress the 20 pound pressure gas in cylinder a, the superior pressure in chamber z shutting valves v_1 and v_3. Then arm k_1 is moved to position k_3 and engages projection j_3 on stem h_3 and opens valve v_6 and so allows 30 pound pressure gas supplied to chamber y_3 through pipe 11_b to flow to cylinder a past valves v_6 d and chambers z and e to join and partially compress the 25 pound pressure gas in cylinder a, the superior pressure in chamber z shutting valves v_1 v_3 v_5. Then piston b begins its compression stroke and arm k_1 disengages projections j_1 j_2 j_6 and valve d closes because of superior pressure in cylinder a and valve f is forced open by superior pressure and the compressed gas discharged past valve f through chamber g and pipe 14 and the piston b then starts a new suction stroke so that valve d opens and the pressure in chamber z falls so that valve v_1 again opens and valves v_2 v_4 v_6 shut and the cycle is repeated. An indicator card taken from cylinder a is shown in Figs. 21 and 22 where line 1, 8 indicates suction line of 15 pound pressure gas, point 8 the opening of valve v_2, line 8, 9 compression of 15 pound pressure gas by 20 pound pressure gas, point 9 the opening of valve v_4, line 9, 10 compression of 20 pound pressure gas by 25 pound pressure gas, point 10 opening of valve v_6, line 10, 11 compression of 25 pound pressure gas by 30 pound pressure gas, point 11 the beginning of compression of gas by piston b which continues as shown by line 11, 12; point 12 opening the valve f; line 12, 16 discharge of gas from cylinder a past valve f, point 16 the point of closure of valve f and the beginning of the suction stroke and point 1 the opening of valves v_1 d and closing of valves v_2, v_4 v_6.

In Figs. 5 and 6 device D_3 has a Corliss type of valve v_2, here 8 is the low pressure inlet leading to valve chamber x having valve v_1 provided with cage 1, spring 2, stem 3, disk 4, pin 7. Corliss valve v_2 is in chamber y having high pressure suction inlet 11 and is actuated by stem h and link mechanism h_1, h_2, actuated from an eccentric or some moving part of a compressor not shown. In operation chamber z is connected through connection 9 to a suction valve chamber (as e_1 of A_1 of Fig. 1 of a compressor not shown). Low pressure gas flows to the compressor's cylinder through inlet 8 chamber x past valve v_1, chamber z connection 9, up to any desired point of a piston's position in the cylinder of the compressor, then preferably, either near the end of the suction stroke of said piston, at the end of its suction stroke or at the start of its compression stroke, the link mechanism h_1 h_2 actuates stem h and valve v_2 and opens communication of chambers y and z through port 10, link mechanism h_1. h_2 and valve v_2 being moved from full line to dotted line positions. Now high pressure gas from connection 11 flows through chamber y past valve v_2 through port 10 and chamber z and connection 9 to join the low pressure gas in the compressor's cylinder and partially compress it. Then link mechanism h_1 h_2 is again moved to its full line position thereby cutting off communication of chambers y and z and the gas in the compressor's cylinder is compressed and discharged by the compressor's piston. If desired the Corliss valve v_2 can have a trip motion like that of a steam valve of a Corliss engine to shut it quickly. If valve v_2 opened near the end of suction stroke and closed near the beginning of a compression stroke the toe of an indicator card taken from the compressor's cylinder would be like Fig. 7 where v v is the vacuum line; 3, 4 part of the low pressure admission line, 4 the point of opening of the valve v_2; 4, 5, 6, 7 the compression line of the low by the high pressure gas and 7 the point of closure of valve v_2 and 7, 8 part of the compression line. If valve v_2 opened at the end of a suction stroke the toe of an indicator card taken from the compressor's cylinder would be like Fig. 8. 3, 4 being part of the low pressure admission line, 4 the point of opening of valve v_2; 4, 5 the compression line of the low by the high pressure gas, 5 the point of closure of valve v_2 and 5, 6 part of the compression line.

If desired a compressor's cylinder head as shown in Fig. 9 can contain the essential parts of a multiple effect suction device, here shown as such a two stage arrangement. Here low pressure gas enters chamber x through pipe 8 and high pressure gas enters chamber y through pipe 11 and gas is discharged from compressor through pipe 14, chambers z and e are so closely connected as to practically form one chamber. The operation is similar to that of device D with compressor A_1 of Fig. 1 as will be clear to those skilled in the art without further description.

Valve v_2 may be of any desired type to fulfil its requirements, as the puppet type of Figs. 1, 2, 3, 4, 9, the Corliss type of Figs. 5, 6 or any other type, a rotating type being shown in Figs. 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 23. In Figs. 10, 11 the piston b of compressor A is reciprocated by a connection c pivoted to piston b at 1 and to crank 2 at 3, crank 2 is actuated by shaft 4 driven from any desired source of power and having gear 5 which drives gear 6 having shaft 7 and gear 20 which drives gear 21 having shaft h connected to rotating valve v_x. Valve v_x is cylindrical or slightly tapering and so slightly conical and fits in casing 23 having connections; 9 leading therefrom to valve chamber e; 11 for 20 pound pressure gas; 11_a for 25 pound pressure gas; 11_b for 30 pound pressure gas. Valve v_x has slots 24 and 25 to cause connections *seriatim* between connection 9 and connections 11, 11_a and 11_b. Different positions of valve v_x in its casing are shown in Figs. 14, 15, 16, 17.

In operation 15 pound pressure gas enters chamber x through pipe 8 and flows past valves v_1 d through chamber e to cylinder a, during the time valve v_x has revolved with no communication between connection 9, slots 24, 25 and connections 11, 11_a, 11_b and until piston b (as shown in in Fig. 10), has nearly reached the end of its suction stroke. Then as shown in Fig. 17 slot 24 allows communication between connections 11 and 9 and so 20 pound pressure gas flows to chamber e and by its superior pressure closes valve v_1 and flows past valve d to join and partially compress the 15 pound pressure gas in cylinder a and then valve v_x revolves so slot 24 closes this communication and then opens communication between connections 9 and 11_a as shown in Figs. 14 and 15 and allows 25 pound pressure gas to join and partially compress the 20 pound pressure gas in cylinder a, then as shown in Fig. 15 valve v_x further revolves and cuts off this communication, then as shown in Fig. 16 slot 25 now allows communication between connections 9 and 11_b and allows 30 pound pressure gas to join and partially compress the 25 pound pressure gas in cylinder a and then closes this communication as shown in the valve section of Fig. 10 and the valve v_x then further revolves during the compression stroke of piston b and allows no communication of connection 9 through the slots 24 and 25 with the other connections until near the end of the next suction stroke of piston b. The compressed gas being discharged from cylinder a past valve f through chamber g and pipe 14. If desired valve v_x can serve another compressor's stroke of same compressor if double acting, or of another compressor, during its revolution, by a duplicate set of connections 9_a, 11_c, 11_d, 11_e, as shown dottod in Fig. 10. An indicator card from cylinder a as shown in Figs. 21 22, is 1, 8, 9, 10, 11, 12, 16, 1.

Puppet suction valve d or puppet discharge valve f of Fig. 10 may either or both be dispensed with by a modified form of valve, one type of which is shown in Figs. 12, 13, 18, 19, 20 and another form of this type for dispensing with the discharge valve f is shown in Fig. 23. When the discharge valve f is dispensed with its port is shown closed by dotted line g_1 of Fig. 10. When the discharge valve f is used and the suction valve d of Fig. 10 is dispensed with as in Fig. 12, the compressor A has piston b reciprocated by connection c pivoted to piston b at 1 and to crank 2 at 3, crank 2 is actuated by the shaft 4 driven from any desired source of power and has gear 5 which drives gear 6 having shaft 7 and gear 20 which drives gear 21 having shaft h connected to rotating valve v_y, valve v_y is cylindrical or slightly tapering and so slightly conical and fits in a casing 23 having connections; 9 leading therefrom to cylinder a, 8 for 15 pound pressure gas, 11 for 20 pound pressure gas, 11_a for 25 pound pressure gas. Valve v_y has slots 24, 25, 26 to cause communication *seriatim* between connection 9 and connections 8, 11, 11_a. Different positions of valve v_y in its casing are shown in Figs. 18, 19, 20. In operation 15 pound pressure gas flows from connection 8 through slot 26 and connection 9 to cylinder a, during the time valve v_y has revolved with connection 8 communicating with connection 9 through slot 26, the start of such communication being shown in Fig. 18, and until piston b (as shown in Fig. 12) has nearly reached the end of its suction stroke. Then as shown in Fig. 19 slot 26 revolves to cut off this communication and slot 24 opens communication between connections 11 and 9 so that 20 pound pressure gas joins and partially compresses the 15 pound pressure gas in cylinder a and then valve v_y revolves so slot 24 cuts off this communication and slot 25 revolves into place to permit communication between connections 9 and 11_a as shown in valve section of Fig. 12 and 25 pound pressure gas joins the 20 pound pressure gas in cylinder a and partially compresses it and then valve v_y revolves to cut off this communication as shown in Fig. 20 and further revolves during the compressor's stroke with no slots opening to allow communication between connections until near the end of the next suction stroke. The compressed gas being discharged from cylinder a past valve f through chamber g and pipe 14. An indicator card from cylinder a would be like 1, 5, 6, 7, 13, 16, 1 of Figs. 21, and 22. If desired valve v_y can serve another compressor's stroke of same compressor if it be double acting, or of another compressor, during its revolution, by a duplicate set of connections 8_a, 9_a, 11_b, 11_c shown dotted. If desired valve f of Fig. 12 is dispensed with, then Fig. 23 valve v_z a modification of valve v_y in that the position of slot 24 is changed and its width is greater, is used. Valve v_z fits in and revolves in the same casing with the same connections, some of which are used for different purposes, as shown in Figs. 12, 13. The operation is as follows: see Fig. 23 with Figs. 12 and 13. 15 pound pressure gas flows from connection 8 through slot 26 and connection 9 to cylinder a from beginning until near the end of suction stroke of piston b when this communication closes as valve v_z revolves and slot 25 then allows communication between connections 11_a and 9; 20 pound pressure gas now flowing from connection 11_a to join and partially compress the 15 pound pressure gas in cylinder a, a further revolving of valve v_z cuts off this communication and allows no communication for part of the compression stroke of piston b when slot 24 revolves into position to permit communication of connections 9 and 11 and the compressed gas is discharged from cylinder a through connection 9, slot 24 and connection 11 until the end of the compression stroke when valve v_z so revolves that slot 24 closes this communication and on the beginning of the next suction stroke slot 26 again opens communication between connections 8 and 9. An indicator card from cylinder a would be like 1, 3, 4, 14, 16, 1 of Figs. 21, 22. If desired valve v_z can serve another compressor's stroke of same compressor if it be double acting, or of another compressor, during its revolution, by a duplicate set of connections 8_a, 9_a, 11_b, 11_c shown dotted.

In Fig. 24; A_1 A_2 are two "valve in piston type" single acting compressors having valves d_1 and d_2 in their pistons b_1 and b_2. If my device D_6 is applied to one of these compressors as to A_1 its operation is similar to that described in Fig. 1. With valve d_4 omitted and compressor A_2 not in use, low pressure gas enters chamber x through pipe 8 passes valve v_1 chamber z and pipe 9 to the under side of piston b_1 in cylinder a_1 and continues to so fill cylinder a_1 during the movement of piston b_1 from its full line to its dotted line position, or during its compression stroke, for discharging gas from the upper side of its piston past valve f_1, through chamber g_1 and pipe 12, 14. Then piston b_1 moves from its dotted to its full line position and the low pressure gas in cylinder a_1 is transferred past valve d_1 from the under to the upper side of piston b_1. And when piston b_1 reaches the full line position shown, a projection k_1 on its piston rod c_1 engages arm j_1 and through stem h opens valve v_2 and allows higher pressure gas to flow from pipe 11 through chambers y and z and pipe 9 into cylinder a_1 and past valve d_1 to the upper side of piston b_1 to join and partially compress the low pressure gas in cylinder a_1 then the up or compression stroke, of piston b_1 is repeated and so the above cycle is repeated. It is evident that in the above described cycle, the space below piston b_1 is the equivalent of chamber e_1 of Fig. 1. If the device D_6 is to serve both compressors A_1 and A_2 operated from a common source of power so that their pistons always move in opposite directions, by a single opening of valve v_2, the operation is as follows: valve d_4 and projection k_2 being omitted. The operation of compressor A_1 is as was just described, but when higher pressure gas is admitted to its cylinder a_1 through valves v_2 d_1 to the upper side of piston b_1 in its full line position, to join and partially compress the low pressure gas in cylinder a_1, higher pressure gas is at the same time admitted to cylinder a_2 through valves v_2 d_3 and pipe 9^a to the under side of piston b_2 in its full line position to join and compress the low pressure gas in cylinder a_2, piston b_2 having just discharged compressed gas through valve f_2, chamber g_2 and pipe 13, 14. Then on the down stroke of piston b_2 from its full to dotted line position the higher pressure gas in cylinder a_2 is transferred through valve d_2 from the under to the upper side of piston b_2 and on the return or upstroke from the dotted to the full line position of piston b_2 the gas above the piston is again compressed and discharged and low pressure gas is taken in below piston b_2 through valves v_1 d_3 and conduit 9^a until the full line position of piston b_2 is again reached and until higher pressure gas is again admitted to cylinder a_2 as just described. Here it is evident that valve d_3 prevents flow of high pressure gas from cylinder a_2 to cylinder a_1 and that as high pressure gas is admitted to cylinder a_2 on the underside of piston b_2 to compress the low pressure gas, valve d_3 is here the equivalent of valve d_2 of Fig. 1. If it is desired to have higher pressure gas from valve v_1 admitted first to cylinder a_1 and then a_2 *seriatim* to the under sides of pistons b_1 b_2 then valve d_4 and projection k_2 are added, k_2 adapted to engage arm j_2 of stem h, and higher pressure gas is admitted *seriatim* to a cylinder full of low pressure gas each time piston b_1 is in its dotted position and each time piston b_2 is in its full line position. Here it is evident that valves d_1 and d_2 of Fig. 24 now serve only as check valves during compression strokes and as transfer valves during suction strokes, and valves d_3 d_4 are the equivalents of valves d_2 d_1 of Fig. 1. It will also be evident to those skilled in the art without further description how additional higher pressure suction valves as shown and described in Fig. 4 and as otherwise shown and described can be added to device D_6 of Fig. 24.

Claims.

1. In a gas compressor, the combination of a cylinder, a piston fitting in said cylinder, means to reciprocate said piston in said cylinder, a port opening into said cylinder, a low pressure suction conduit leading to said port from a source of low pressure gas, a higher pressure suction conduit leading to said port from a source of higher pressure gas, said higher pressure source being external to said compressor, a discharge conduit leading from a port opening into said cylinder to a high pressure gas receiver, valves adapted for *seriatim* governing communication of said conduits, one at a time, with said cylinder in the increasing order of their pressures and for preventing communication of said conduits with each other.

2. In a gas compressor, the combination of a cylinder, a piston fitting in said cylinder, means to reciprocate said piston in said cylinder, a port opening into said cylinder, a low pressure suction conduit leading to said port from a source of low pressure gas, a plurality of higher pressure suction conduits leading to said port from a plurality of sources of higher pressure gas of different pressures, said higher pressure sources being external to said compressor, a discharge conduit leading from a port opening into said cylinder to a high pressure gas receiver, valves adapted for *seriatim* governing communication of said conduits, one at a time, with said cylinder in the increasing order of their pressures and for preventing communication of said conduits with each other.

3. In a gas compressor, the combination of a cylinder, a piston fitting in said cylinder, means to reciprocate said piston in said cylinder, a port opening into said cylinder, a low pressure suction conduit leading to said port from a low pressure refrigerator, a higher pressure suction conduit leading to said port from a higher pressure refrigerator, a discharge conduit leading from a port opening into said cylinder to a condenser, valves adapted for *seriatim* governing communication of said conduits, one at a time, with said cylinder in the increasing order of their pressures and for preventing communication of said conduits with each other.

4. In a gas compressor, the combination of a cylinder, a piston fitting in said cylinder, means to reciprocate said piston in said cylinder, a port opening into said cylinder, a low pressure suction conduit leading to said port from a low pressure refrigerator, a plurality of higher pressure suction conduits leading to said port from a plurality of higher pressure refrigerators of different pressures, a discharge conduit leading from a port opening into said cylinder to a condenser, valves adapted for *seriatim* governing communication of said conduits, one at a time, with said cylinder in the increasing order of their pressures and for preventing communication of said conduits with each other.

5. In a gas compressor, the combination of a cylinder, a piston fitting in said cylinder, means to reciprocate said piston in said cylinder, a suction port opening into said cylinder, a low pressure suction conduit leading to said port from a source of low pressure gas, a higher pressure suction conduit leading to said port from a source of higher pressure gas, said higher pressure source being external to said compressor, a discharge port opening into said cylinder, a discharge conduit leading from said discharge port to a high pressure gas receiver, valves adapted for *seriatim* governing communication of said conduits, one at a time, with said cylinder in the increasing order of their pressures and for preventing communication of said conduits with each other.

6. In a gas compressor, the combination of a cylinder, a piston fitting in said cylinder, means to reciprocate said piston in said cylinder, a suction port opening into said cylinder, a low pressure suction conduit leading to said port from a source of low pressure gas, a plurality of higher pressure suction conduits leading to said port from a plurality of sources of higher pressure gas at different pressures, said higher pressure sources being external to said compressor, a discharge port opening into said cylinder, a discharge conduit leading from said discharge port to a high pressure gas receiver, valves adapted for *seriatim* governing communication of said conduits, one at a time, with said cylinder in the increasing order of their pressures and for preventing communication of said conduits with each other.

7. In a gas compressor, the combination of a cylinder, a piston fitting in said cylinder, means to reciprocate said piston in said cylinder, a suction port opening into said cylinder, a low pressure suction conduit leading to said port from a low pressure refrigerator, a higher pressure suction conduit leading to said port from a higher pressure refrigerator, a discharge port opening into said cylinder, a discharge conduit leading from said discharge port to a condenser, valves adapted for *seriatim* governing communication of said conduits, one at a time, with said cylinder in the increasing order of their pressures and for preventing communication of said conduits with each other.

8. In a gas compressor, the combination of a cylinder, a piston fitting in said cylinder, means to reciprocate said piston in said cylinder, a suction port opening into said cylinder, a low pressure suction conduit leading to said port from a low pressure refrigerator, a plurality of higher pressure suction conduits leading to said port from a plurality of higher pressure refrigerators at different pressures, a discharge port opening into said cylinder, a discharge conduit leading from said discharge port to a condenser, valves adapted for *seriatim* governing communication of said conduits, one at a time, with said cylinder in the increasing order of their pressures and for preventing communication of said conduits with each other.

9. In a gas compressor, the combination of a cylinder, a piston fitting in said cylinder, means to reciprocate said piston in said cylinder, a discharge valve chamber, a port opening into said cylinder from said discharge valve chamber, a puppet discharge valve adapted to govern said port, a conduit leading from said discharge valve chamber to a high pressure gas receiver, a main valve chamber, a port opening into said cylinder from said main valve chamber, a puppet suction valve adapted to govern said port, a low pressure suction valve chamber, a port opening into said main valve chamber from said low pressure suction valve chamber, a puppet suction valve adapted to govern said port, a conduit leading from a source of low pressure gas to said low pressure suction valve chamber, a higher pressure suction valve chamber, a port opening into said main valve chamber from said higher pressure suction valve chamber, a suction valve adapted to be actuated from said piston's reciprocating means to govern said port, a conduit leading from a source of higher pressure gas to said higher pressure valve chamber, said source being external to the gas compressor.

10. In a gas compressor, the combination of a cylinder, a piston fitting in said cylinder, means to reciprocate said piston in said cylinder, a discharge valve chamber, a port opening into said cylinder from said discharge valve chamber, a puppet discharge valve adapted to govern said port, a conduit leading from said discharge valve chamber to a high pressure gas receiver, a main valve chamber, a port opening into said cylinder from said main valve chamber, a puppet suction valve adapted to govern said port, a low pressure suction valve chamber, a port opening into said main valve chamber from said low pressure suction valve chamber, a puppet suction valve adapted to govern said port, a conduit leading from a source of low pressure gas to said low pressure suction valve chamber, a plurality of higher pressure suction valve chambers, ports opening into the main valve chamber from each of said plurality of chambers, suction valves adapted to be actuated from said piston's reciprocating means to govern each of said plurality of ports, puppet suction valves adapted for governing all except the highest pressure port of said plurality of ports, conduits leading from a plurality of higher pressure sources of gas at different pressures to the plurality of suction valve chambers, such sources being external to the gas compressor.

11. In a gas compressor, the combination of a cylinder, a piston fitting in said cylinder, means to reciprocate said piston in said cylinder, a discharge valve chamber, a port opening into said cylinder from said discharge valve chamber, a puppet discharge valve adapted to govern said port, a conduit leading from said discharge valve chamber to a condenser, a main valve chamber, a port opening into said cylinder from said main valve chamber, a puppet suction valve adapted to govern said port, a low pressure suction valve chamber, a port opening into said main valve chamber from said low pressure suction valve chamber, a puppet suction valve adapted to govern said port, a conduit leading from a low pressure refrigerator to said low pressure suction valve chamber, a higher suction valve chamber, a port opening into said main valve chamber from said higher suction valve chamber, a suction valve adapted to be actuated from said piston's reciprocating means to govern said port, a conduit leading from a higher pressure refrigerator to said higher pressure suction valve chamber.

12. In a gas compressor, the combination of a cylinder, a piston fitting in said cylinder, means to reciprocate said piston in said cylinder, a discharge valve chamber, a port opening into said cylinder from said discharge valve chamber, a puppet discharge valve adapted to govern said port, a conduit leading from said discharge valve chamber to a condenser, a main valve cham-

ber, a port opening into said cylinder from said main valve chamber, a puppet suction valve adapted to govern said port, a low pressure suction valve chamber, a port opening into said main valve chamber from said low pressure suction valve chamber, a puppet suction valve adapted to govern said port, a conduit leading from a low pressure refrigerator to said low pressure suction valve chamber, a plurality of higher pressure suction valve chambers, ports opening into the main valve chamber from each of said plurality of chambers, suction valves adapted to be actuated from said piston's reciprocating means to govern each of said plurality of ports, puppet suction valves adapted for governing all except the highest pressure port of said plurality of ports, conduits leading from a plurality of higher pressure refrigerators at different pressures to the plurality of suction valve chambers.

13. A multiple suction device for gas compressors comprising a main chamber and two other chambers, each of said other chambers having a valve governed port opening therefrom into the main chamber, an opening in each chamber for connection of a conduit thereto.

14. A multiple suction device for gas compressors comprising a main chamber and a plurality of other chambers, each of said other chambers having a valve governed port opening therefrom into the main chamber, an opening in each chamber for connection of a conduit thereto.

15. A multiple suction device for gas compressors comprising a main chamber and two other chambers, each of said other chambers having a port opening therefrom into the main chamber, a valve adapted to govern one of said ports, a valve adapted to be actuated from a gas compressor's piston reciprocating means to govern the other port, an opening in each chamber for connection of a conduit thereto.

16. A multiple suction device for gas compressors comprising a main chamber and a plurality of other chambers, each of said other chambers having a port opening therefrom into the main chamber, a valve adapted to govern one of said ports, valves adapted to be actuated from a gas compressor's piston reciprocating means to govern the other ports, an opening in each chamber for connection of a conduit thereto.

17. A multiple suction device for gas compressors comprising a main chamber and two other chambers, each of said other chambers having a port opening therefrom into the main chamber, a puppet suction valve adapted to govern one of said ports, a valve adapted to be actuated from a gas compressor's piston reciprocating means to govern the other port, an opening in each chamber for connection of a conduit thereto.

18. A multiple suction device for gas compressors comprising a main chamber and a plurality of other chambers, each of said other chambers having a port opening therefrom into the main chamber, puppet suction valves adapted to govern all but one of said ports, valves adapted to be actuated from a gas compressor's piston reciprocating means to govern all but another one of said ports, an opening in each chamber for connection of a conduit thereto.

19. A multiple suction device for gas compressors comprising a main chamber and three other chambers, each of said other chambers having a valve governed port opening therefrom into the main chamber, an opening in each chamber for connection of a conduit thereto.

20. A multiple suction device for gas compressors comprising a main chamber and four other chambers, each of said other chambers having a valve governed port opening therefrom into the main chamber, each of said other chambers having an opening therein for connection of a conduit thereto.

21. A multiple suction device for gas compressors comprising a main chamber and a plurality of other chambers, each of said other chambers having a valve governed port opening therefrom into the main chamber, an opening in each of the plurality of chambers for connection of a conduit thereto.

22. A multiple suction device for gas compressors comprising a main chamber and three other chambers, each of said other chambers having a port opening therefrom into the main valve chamber, valves adapted to govern two of said ports, a valve adapted to be actuated from a gas compressor's piston reciprocating means to govern the other port, an opening in each chamber for connection of a conduit thereto.

23. A multiple suction device for gas compressors comprising a main chamber and four other chambers, each of said other chambers having a port opening therefrom into the main valve chamber, valves adapted to govern three of said ports, a valve adapted to be actuated from a gas compressor's piston reciprocating means to govern the other port, an opening in each of said other chambers for connection of a conduit thereto.

In testimony whereof I have signed this specification in the presence of two subscribing witnesses.

GARDNER TUFTS VOORHEES.

Witnesses:

PHILIP F. SHANLEY,
JOHN HARTLEY.