April 13, 1926. 1,580,435

F. D. HOLDSWORTH

AIR COMPRESSOR

Original Filed April 22, 1918 6 Sheets-Sheet 1

Fig. 1.

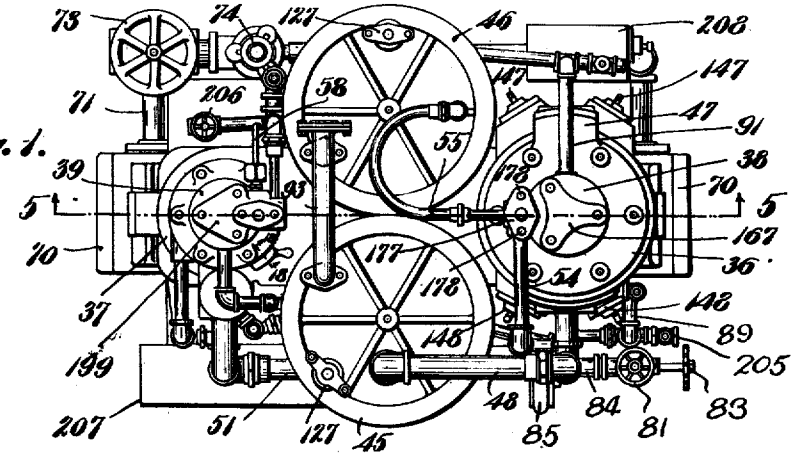
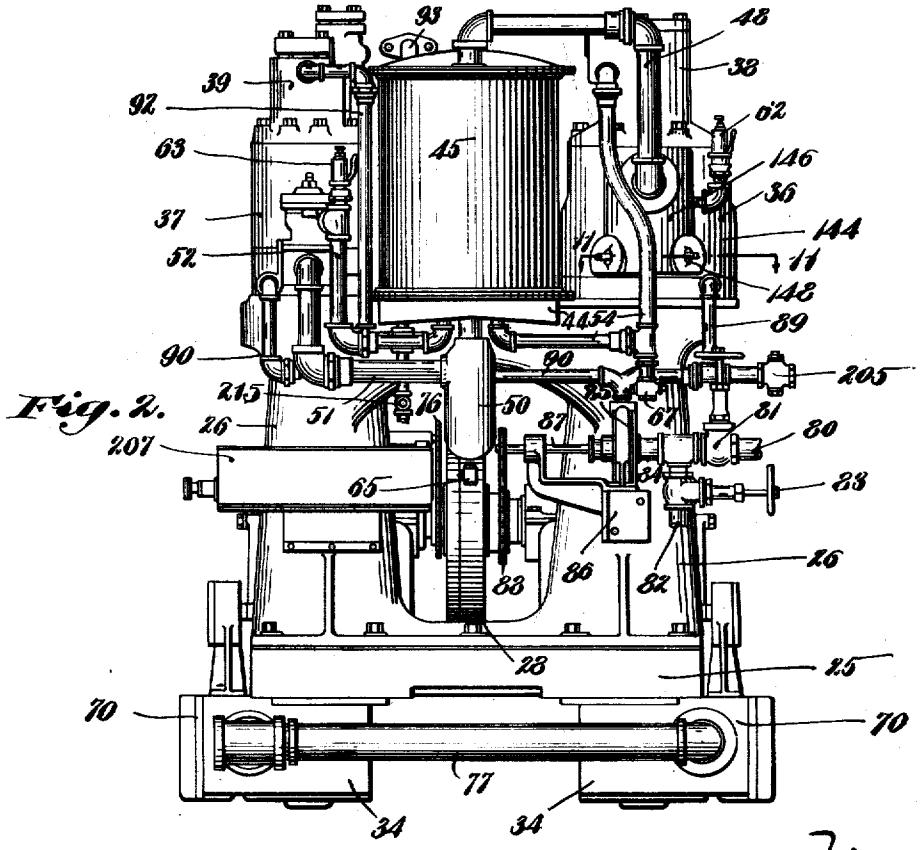


Fig. 2.



Inventor:
Fred D. Holdsworth
by Grace L. Holdsworth Atty.

April 13, 1926. 1,580,435

F. D. HOLDSWORTH

AIR COMPRESSOR

Original Filed April 22, 1918 6 Sheets-Sheet 2

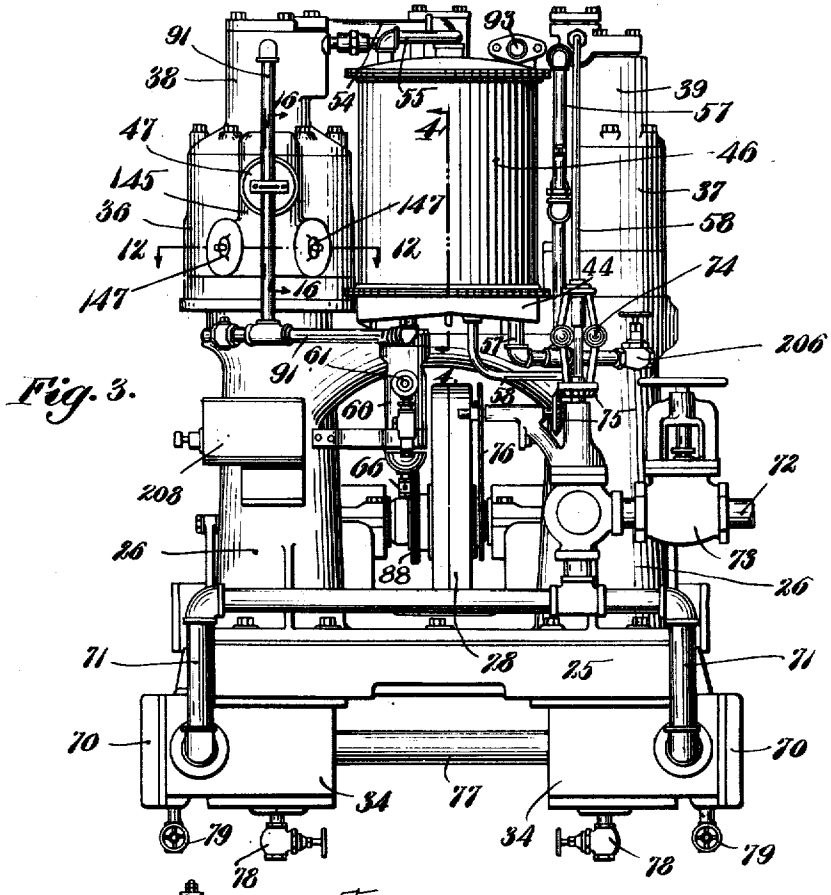


Fig. 3.

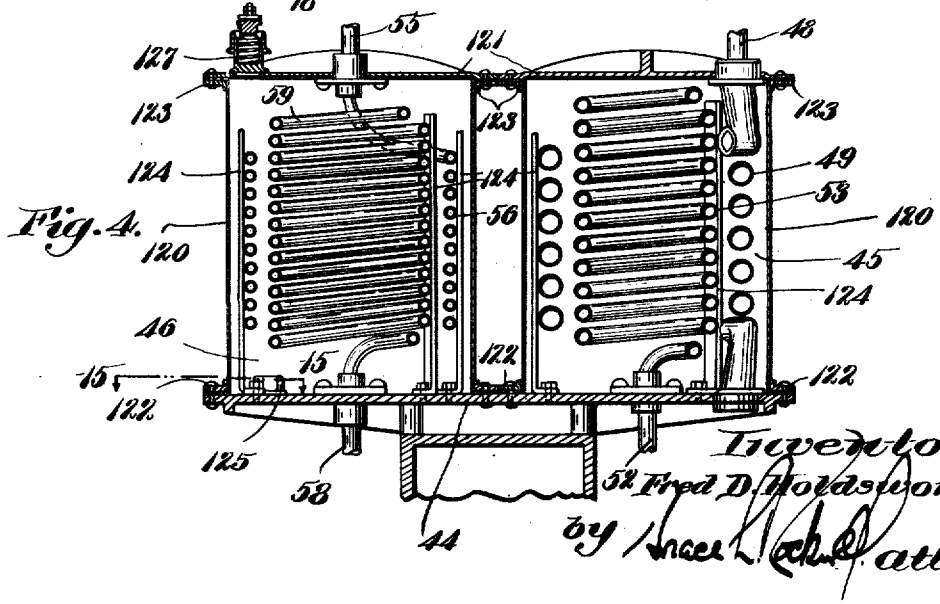


Fig. 4.

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by Lucien L. Patty.

April 13, 1926. 1,580,435

F. D. HOLDSWORTH

AIR COMPRESSOR

Original Filed April 22, 1918 6 Sheets-Sheet 3

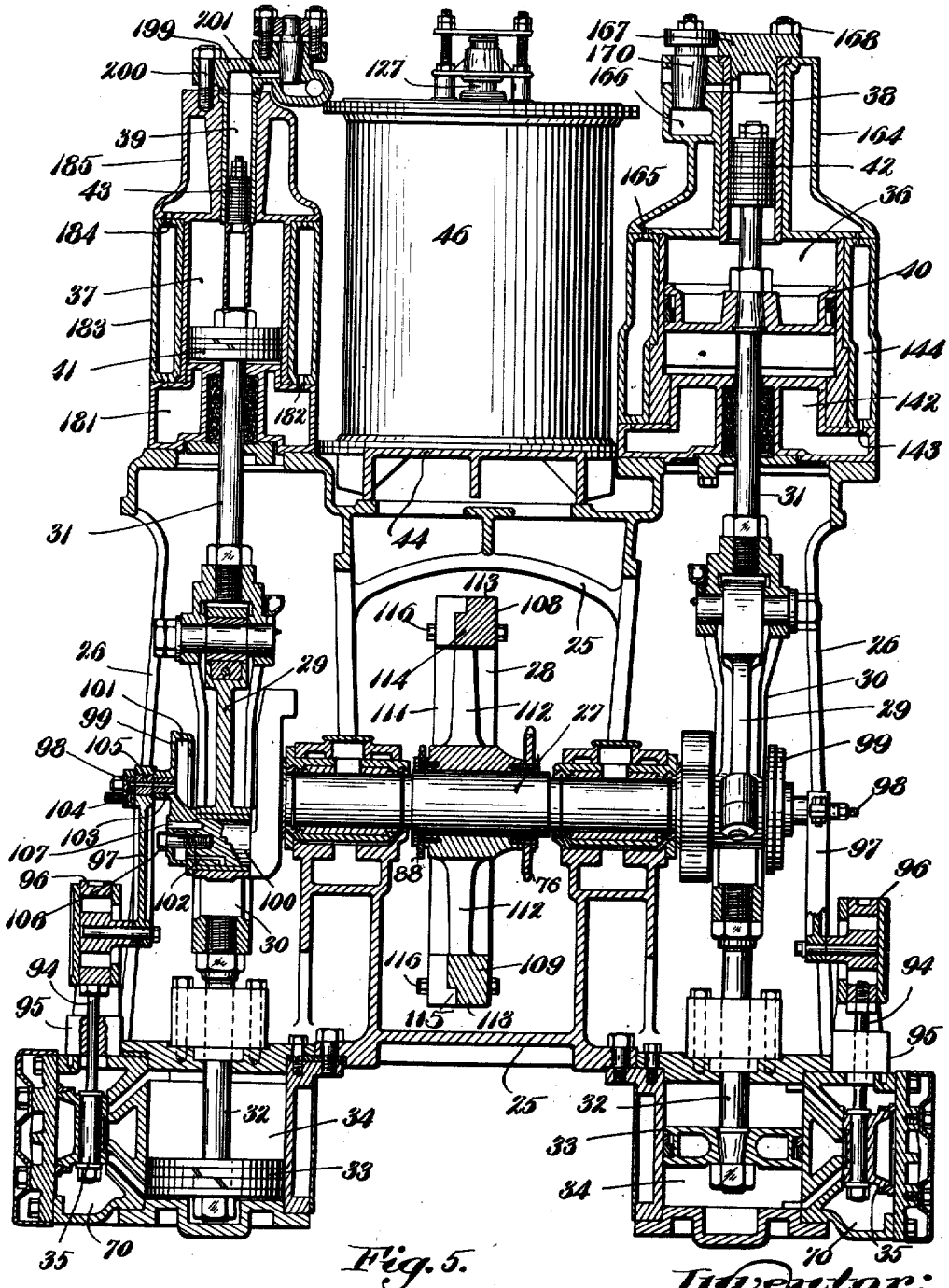

Fig. 5.

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April 13, 1926. 1,580,435

F. D. HOLDSWORTH

AIR COMPRESSOR

Original Filed April 22, 1918 6 Sheets-Sheet 4

Fig. 6.

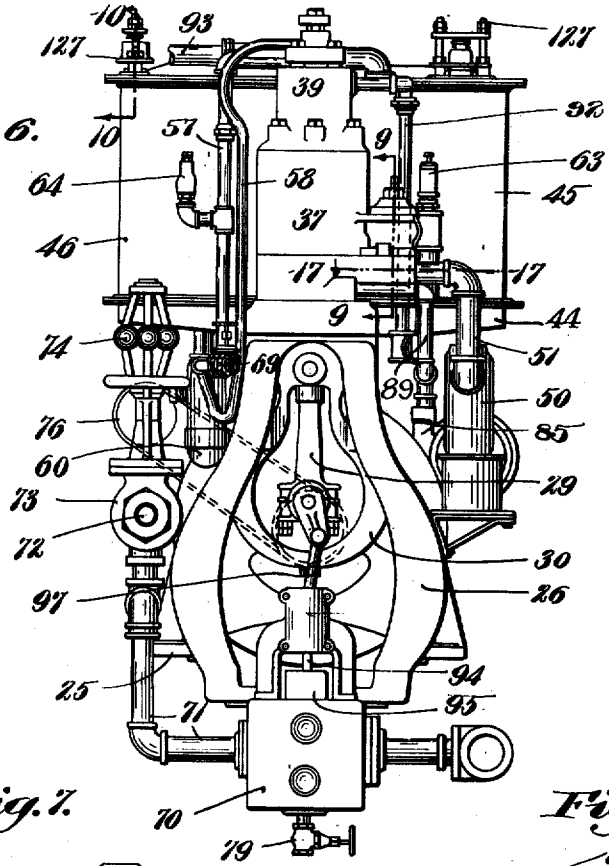


Fig. 7.

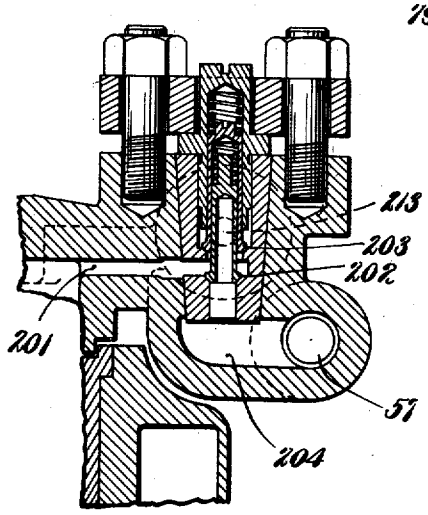
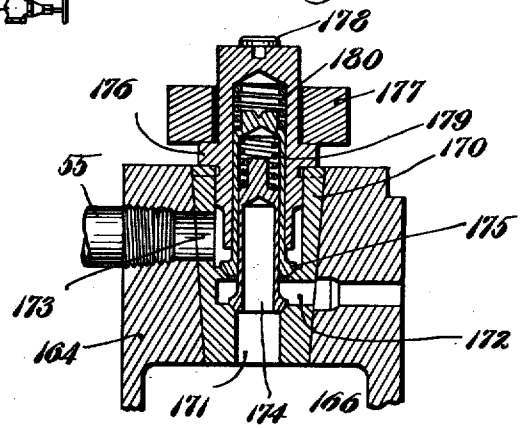


Fig. 8.



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April 13, 1926. 1,580,435

F. D. HOLDSWORTH

AIR COMPRESSOR

Original Filed April 22, 1918 6 Sheets-Sheet 5

Fig. 9.

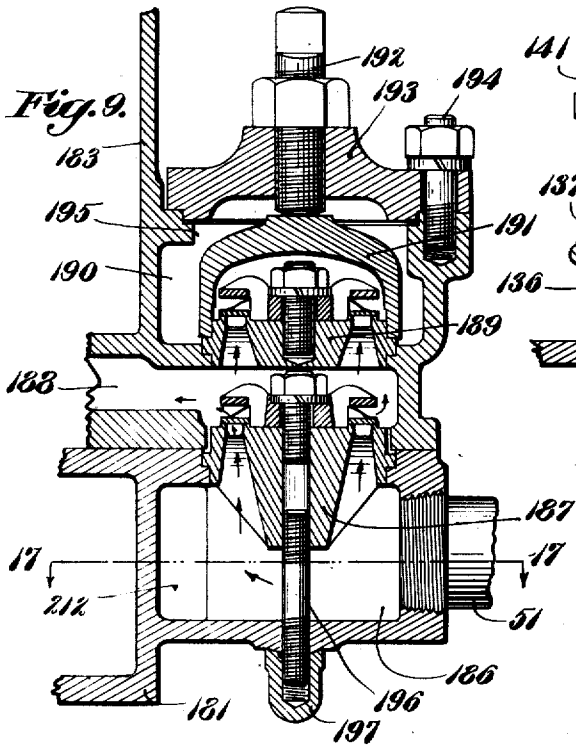
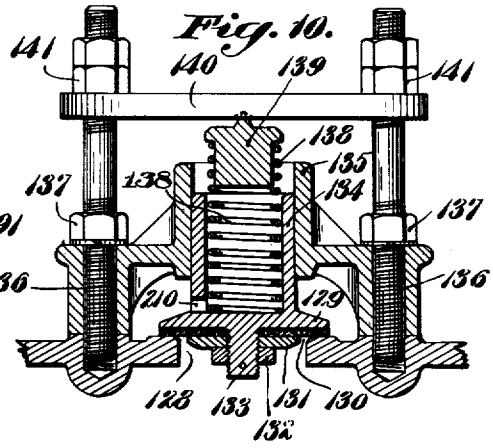


Fig. 10.



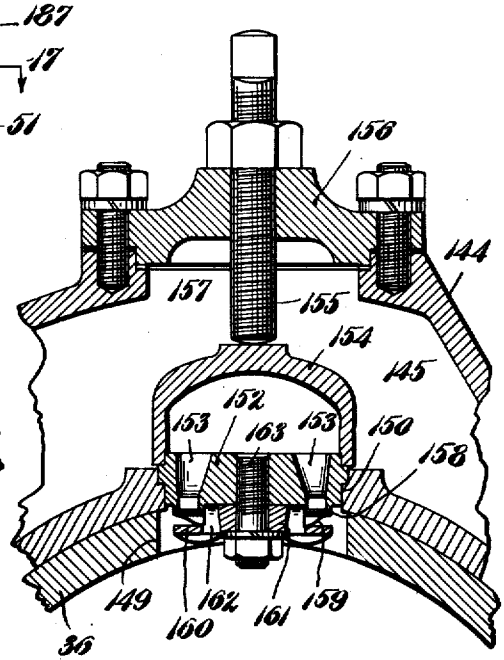


Fig. 12.

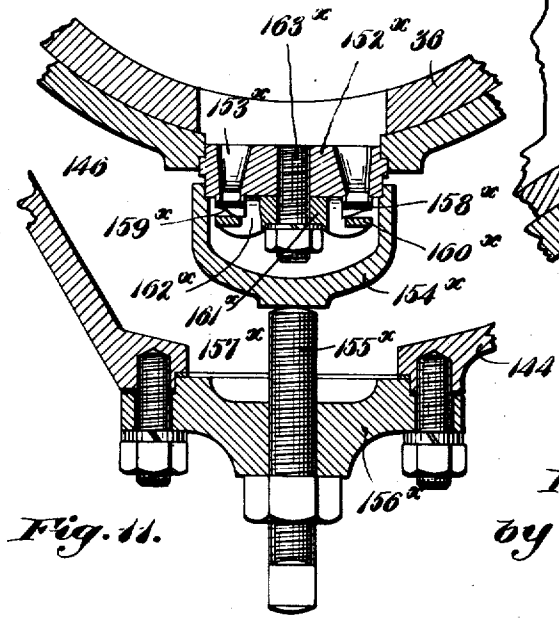


Fig. 11.

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April 13, 1926. 1,580,435

F. D. HOLDSWORTH

AIR COMPRESSOR

Original Filed April 22, 1918 6 Sheets-Sheet 6

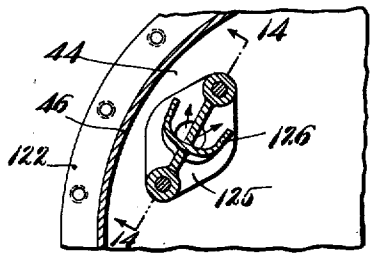

Fig. 15.

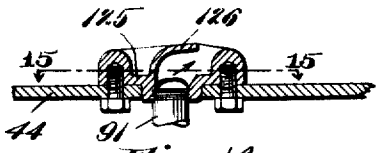

Fig. 14.

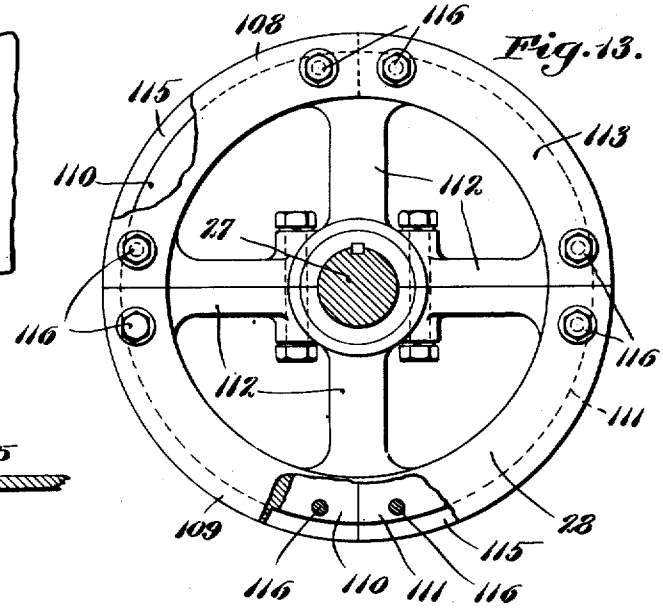

Fig. 13.

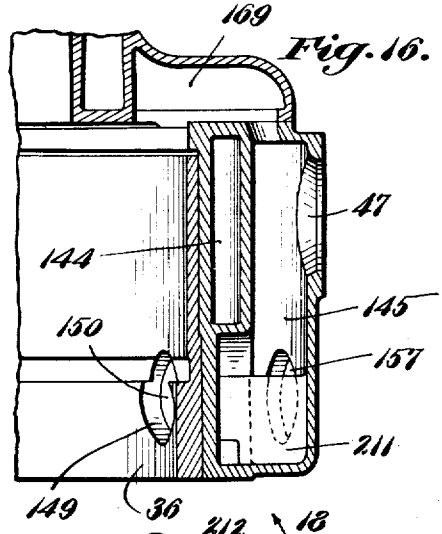

Fig. 16.

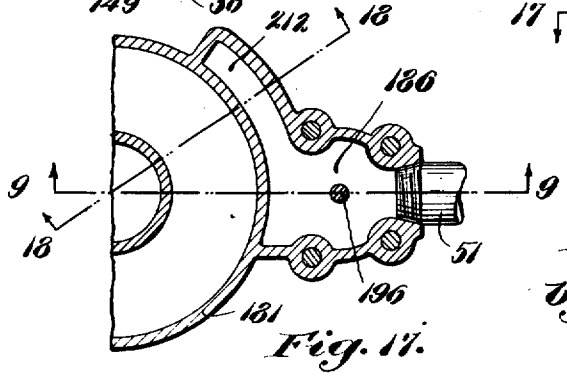

Fig. 17.

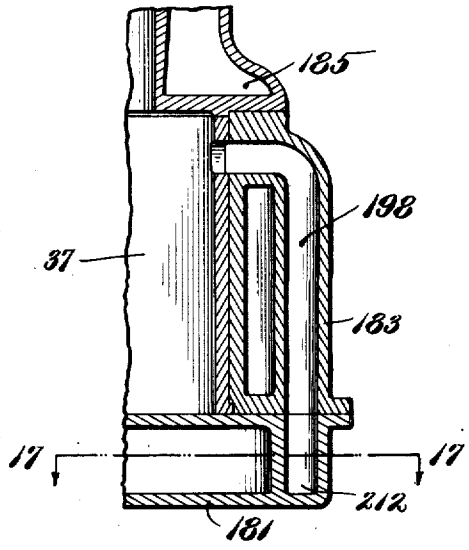

Fig. 18

Inventor.
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Patented Apr. 13, 1926. 1,580,435

UNITED STATES PATENT OFFICE.

FRED D. HOLDSWORTH, OF CLAREMONT, NEW HAMPSHIRE, ASSIGNOR TO SULLIVAN MACHINERY COMPANY, A CORPORATION OF MASSACHUSETTS.

AIR COMPRESSOR.

Application filed April 22, 1918, Serial No. 229,989. Renewed May 27, 1924.

To all whom it may concern:

Be it known that I, FRED D. HOLDSWORTH, a citizen of the United States, residing at Claremont, in the county of Sullivan and State of New Hampshire, have invented certain new and useful Improvements in Air Compressors, of which the following is a full, clear, and exact specification.

This invention relates to compound or multiple stage air or gas compressors, and more particularly to compressors of the marine type, and has for its general object the provision of a highly efficient but exceedingly light and compact machine of this character. In this connection, it will be understood that, for use upon shipboard, and especially upon war vessels, machines capable of rapidly delivering compressed air or gas in relatively large quantities and under a very high degree of compression are required, but that the weight permissible in such machines, and the space available for their accommodation, are extremely limited, my invention having among its objects the provision of a machine satisfactorily meeting these conditions.

More particular objects of the invention, together with means whereby the same may be carried into effect, will best be understood from the following description of one form or embodiment thereof illustrated in the accompanying drawings. It will be understood, however, that the particular construction and arrangement described and shown has been chosen for illustrative purposes merely, and that the invention, as defined by the claims hereunto appended, may be otherwise embodied without departing from the spirit and scope thereof.

In said drawings,—

Fig. 1 is a plan view, and Figs. 2 and 3 elevations from opposite sides respectively, of the complete machine.

Fig. 4 is a vertical section of the cooling tanks taken substantially on the line 4—4, Fig. 3.

Fig. 5 is an enlarged longitudinal vertical section of the complete machine, taken substantially on line 5—5, Fig. 1, certain pipe connections being omitted for purposes of clearness.

Fig. 6 is an end elevation of the complete machine as viewed from the left in Fig. 2 or from the right in Fig. 3.

Fig. 7 is an enlarged vertical sectional view of the valve devices for the high pressure cylinder, the plane of this section being substantially the same as that of Fig. 5.

Fig. 8 is a similar view of the valves for the second intermediate cylinder.

Fig. 9 is a detail vertical sectional view of the inlet and discharge valves for the first intermediate cylinder, taken substantially on the line 9—9, Figs. 6 and 17.

Fig. 10 is a detail vertical sectional view of one of the relief valves for the cooling tanks, the same being taken substantially on the line 10—10, Fig. 6.

Fig. 11 is a detail horizontal sectional view of one of the discharge valves for the low pressure cylinder, the same being taken substantially on the line 11—11, Fig. 2.

Fig. 12 is a similar view of one of the inlet valves for the low pressure cylinder, taken substantially on the line 12—12, Fig. 3.

Fig. 13 is an elevation, partly broken away, of the flywheel.

Fig. 14 is a detail vertical section of the water inlet for one of the cooling tanks, the same being taken substantially on the line 14—14, Fig. 15.

Fig. 15 is a detail horizontal section on the line 15—15, Figs. 4 and 14.

Fig. 16 is a detail vertical section, substantially on the line 16—16, Fig. 3, of the inlet air chamber for the low pressure cylinder, the inlet valve being omitted.

Fig. 17 is a detail horizontal section, taken substantially on the line 17—17, Figs. 6, 9, and 18, of the air inlet chamber for the first intermediate cylinder.

Fig. 18 is a detail vertical section on the line 18—18, Figs. 1 and 17.

In order that the invention may best be understood, the general construction and arrangement of the several essential parts of the mechanism will first be outlined, and their cooperation explained, after which the preferred construction of these and other parts will be described more in detail.

Referring particularly to Figs. 1, 2, 3, 5, and 6, 25 denotes, as a whole, the machine frame, which provides the necessary supports, bearings, and guides for the various parts of the mechanism, except as hereinafter pointed out. Said frame comprises two upright portions 26 in which is journaled a crank shaft 27 carrying between said upright portions a flywheel 28. At its ends the crank shaft 27 is connected by pitmen 29

with yokes 30 extending about the crank shaft and to the upper ends of which are rigidly secured the compressor piston rods 31, and to the lower ends of which are rigidly secured the steam piston rods 32, each of said piston rods 31 being substantially in alignment with a corresponding steam piston rod 32. Secured to the piston rods 32 are steam pistons 33 working in steam cylinders 34 secured to the bottom of the frame 25 and constituting bases therefor, the admission of steam to said cylinders being controlled by slide valves 35 of any well known type operatively connected, by means hereinafter described, with the crank shaft 27.

The invention is herein shown as embodied in a four-stage compressor comprising a low pressure cylinder 36 having a low pressure piston 40, a first intermediate cylinder 37 having a piston 41, a second intermediate cylinder 38 having a piston 42, and a high pressure cylinder 39 having a high pressure piston 43. Said cylinders are arranged in pairs at opposite ends of the machine and are supported at the top of the machine frame 25 directly above the upright portions 26. The cylinders of each pair are disposed in tandem relationship, so as to form, in effect, a single compound cylinder having two piston portions or chambers, and the pistons for each compound cylinder or pair of cylinder portions are secured to one of the piston rods 31. Located between the compressor cylinders, and supported by a suitable platform 44 at the top of the frame, is a pair of cooling tanks 45 and 46 through which the air passes after its compression in each cylinder and before reaching the next successive cylinder for further compression. This disposition of the cooling tanks between the compressor cylinders provides an exceedingly compact construction, as well as a very convenient one, inasmuch as the air can be conveniently passed through said tanks in its passage from one cylinder to the next succeeding without materially changing its normal path or course.

As herein shown, the low pressure cylinder 36 is combined in one pair with the second intermediate cylinder 38, while the first intermediate cylinder 37 is combined with the high pressure cylinder 39, the pistons 40 and 42 being mounted upon one of the piston rods 31 and the pistons 41 and 43 being mounted upon the other of said piston rods. In each pair, the smaller cylinder, representing a relatively higher stage of compression, is superimposed upon the larger cylinder, representing a relatively lower stage of compression, thereby providing a very compact, symmetrical, and stable arrangement. The compression takes place at the under sides of the pistons 40 and 41 and at the upper sides of the pistons 42 and 43, so that it will be seen that in the construction shown the cylinder heads through which the piston rods 31 pass are those subjected to relatively low pressures in the several stages of the operation, thereby reducing the difficulties of packing the piston rods to a minimum.

It will, of course, be understood that all of the compressor cylinders are provided with suitable inlet and exhaust valves (whose construction will be hereinafter more fully described), whereby air may be drawn into said cylinders and discharged therefrom after compression therein. Atmospheric air enters the low pressure cylinder 36 through an air inlet 47 (see Figs. 1 and 3) and after compression therein passes, by a pipe 48 (see Figs. 1 and 2), to a coil 49 (see Fig. 4) in the cooling tank 45, downwardly through said coil, and thence through a chamber 50 (Figs. 2 and 6) and pipe 51 to the first intermediate cylinder 37. After further compression in the cylinder 37 the air is conveyed through a pipe 52 (Fig. 2) passing through the bottom of the cooling tank 45 to the top thereof, and thence downwardly through a cooling coil 53 from which said air is conveyed through piping 54 (Figs. 1, 2, and 3) to the second intermediate cylinder 38. After still further compression in the cylinder 38, the air passes by a pipe 55 (Figs. 1 and 3) to the top of the cooling tank 46 and thence downwardly through a coil 56 (Fig. 4) in said tank to a pipe 57 (Figs. 3 and 6) leading to the high pressure cylinder 39. After final compression in the cylinder 39, the air passes by a pipe 58 (Figs. 1 and 6) extending through the bottom of the cooling tank 46 to the top thereof and thence downwardly through a coil 59 (Fig. 4) in said tank to a receiver 60 having an outlet 61 (Fig. 3) whence said air may be conducted, by suitable means, to its point of utilization or to a suitable storage receptacle.

The air system above described may, if desired, be provided with suitable relief or safety valves, such valves being shown, for example, at 62, 63, and 64 (Figs. 2 and 6) in the connections between the several cylinders. The receivers 50 and 60 are preferably provided with suitable drainage cocks 65 and 66, respectively, (Figs. 2 and 3) for the withdrawal of any water of condensation which may accumulate therein; and similar drain cocks may, if desired, be provided at other points in the air system, as shown, for example, at 67 and 69 in Figs. 2 and 6.

The general organization, arrangement, and operation of the complete apparatus having thus been outlined, the preferred construction of the parts referred to, as also of certain auxiliary devices, will now be described.

Steam is supplied to the valve chests 70 of

the steam cylinders 34 from any suitable source through pipes 71 (Fig. 3) communicating with a supply pipe 72 having a suitable inlet valve 73, the admission of said steam being controlled by a governor 74 of any suitable type, actuated through beveled gearing 75 and chain and sprocket gearing 76 from the crank shaft 27. The exhaust ports of the valve chests 70 are connected with an exhaust pipe 77 (Figs. 2 and 3) leading to any suitable point. The steam cylinders 34 and valve chests 70 are preferably provided with drainage valves 78 and 79, respectively, as shown in Fig. 3.

The steam valves 35 are operated by rods 94 passing through stuffing boxes 95 and connected to slides 96 mounted in suitable guides carried by the machine frame. The slides 96 are connected by rods 97 to pins 98 projecting from disks 99 secured by bolts 106 and pins 107 in eccentric relation to the crank pins 100 to which are connected the pitmen 29. The eccentrically mounted disks 99 are formed with internal annular grooves 101 communicating with passages 102 in the crank pins 100 and leading to the periphery of the latter. The eccentric pins 98 are provided with axial passages 103 which extend from the inner faces of the eccentrics 101 to oil cups 104 at the outer ends of said pins, said passages 103 communicating through radial passages 105 with the peripheries of said eccentric pins. Lubricant supplied to the oil cups 104 enters the passages 103, a portion of said lubricant passing through the passages 105 to the periphery of the eccentric pins 98 for lubricating the latter, and the remainder of said lubricant reaching the inner faces of the eccentrically disposed disks 99 and, being thrown by centrifugal force into the grooves 101, finds its way through the grooves 102 to the peripheries of the crank pins 100 for lubricating the latter. The portions of the grooves 101 which communicate with the passages 102 are slightly more remote from the centers of rotation of the eccentrically disposed disks 99 than the other portions of said grooves, whereby the lubricant is caused to accumulate at the outer ends of said passages 102 for ready entry thereinto.

Referring to Figs. 5 and 13, the flywheel 28 is mounted on the shaft 27 between the uprights 26, and between the substantially rigidly connected motor and compressor units or couples, and in order to facilitate the assembly of the parts, which might otherwise be difficult on account of such position of the flywheel, said flywheel is preferably composed of four semi-circular parts 108, 109, 110, and 111, constituting two sets. The parts 108 and 109, which constitute one set, collectively form a complete annulus or split wheel comprising spokes 112 and rim 113, said rim being formed at one edge with a flange 114 which is engaged by a flange or annular rib 115 on the members 110 and 111, which constitute the other set and also collectively form a complete annulus or auxiliary rim portion. The members 108 and 109 may be readily assembled about the shaft 27, and after such assembly the members 110 and 111 are placed in position thereon in staggered relation thereto, and are secured to said members 108 and 109 by means of bolts 116.

Referring to Fig. 2, water for the cooling system may either be supplied under a suitable head through a pipe 80, controlled by a cut-off valve 81, or may be drawn from a lower source through a pipe 82, controlled by a cut-off valve 83. The pipes 80 and 82 unite in an inlet pipe 84 for a centrifugal circulating pump 85 supported by a suitable bracket 86 on the machine frame, the shaft 87 of said pump being operated by chain and sprocket gearing 88 from the crank shaft 27. A discharge pipe for the pump 85 is formed with two branches 89 and 90 leading, respectively, to the water jackets of the cylinders 36 and 37, which jackets, as hereinafter more fully described, communicate with the jackets of the cylinders 38 and 39, respectively. From the upper part of the jacket of the cylinder 38 a water pipe 91 (Fig. 3) communicates with the bottom of the cooling tank 46, while a similar water pipe 92 (Fig. 2) leads from the upper part of the jacket of the cylinder 39 to the bottom of the cooling tank 45. A water outlet pipe 93 (Fig. 1) communicates with the tops of both cooling tanks 45 and 46, whence the overflow from said tanks may be conducted to any suitable point. From the foregoing it will be seen that the water from the pump 85 passes through the pipes 89 and 90, thence upwardly through the water jackets of the compressor cylinders, thence upwardly through the cooling tanks 45 and 40, from which it is discharged through the pipe 93.

The cooling tanks 45 and 46 comprise (see Fig. 4) sheet metal cylinders 120 having flanged upper and lower edges secured, respectively, to the platform 44 (which constitutes a common bottom for both of said tanks), and to cover members or tops 121, by means of rings 122 and 123 engaging the flanges at the ends of said cylinders and bolted or otherwise secured to the platform 44 and covers 121, respectively. The coils 49 and 53 are coaxially arranged, the latter within the former, in the tank 45, and the coils 56 and 59 similarly arranged within the tank 46, the several coils being suitably supported and spaced by uprights 124 to which said coils are secured, the lower ends of said uprights being bolted to the platform 44. Each of the water pipes 91 and 92 communicates with its respective

cooling tank 46 or 45 through a fitting 125 (see Figs. 14 and 15) bolted or otherwise secured in an opening in the platform 44, said fitting having, within the tank, a hood 126 arranged to direct the incoming water substantially tangentially of the tank, whereby said water is caused to flow through the tank in an approximately spiral path from the bottom of said tank to the pipe 93 at the top thereof.

The sheet metal cylinders 120 above referred to provide a tank construction which is extremely light in weight but sufficiently strong to perform the function for which the tanks 45 and 46 are intended, it being seen that, in the normal operation of the machine, said tanks are not subjected to any considerable pressure or other strain. In order to guard against the accidental development of internal pressure within said tanks, as by accumulation of air therein due to leakage into either tank from the air coils, said tanks are provided with relief valves, designated as a whole by the numeral 127 in Figs. 1, 4, and 5 (but omitted, to avoid confusion, from Figs. 2 and 3), the construction of one of these valves being illustrated in detail in Fig. 10. As shown in the latter figure, the top 121 of each cooling tank is provided with an opening 128 which is closed by a valve 129 provided with packing 130 secured thereto by a washer 131 and nut 132 on a threaded stem 133 projecting from the lower or inner face of said valve. The valve 129 is provided with an enlarged hollow stem 134 guided for vertical movement in a suitable opening in a yoke 135 secured to the tank top 121 by bolts 136 in threaded engagement with said top 121 and provided with nuts 137 bearing on said yoke 135. The valve 129 is pressed to its seat by a spring 138 within the hollow stem 134 and engaging at its outer end a follower 139 which bears against a crosshead 140 having adjacent its ends openings to receive the bolts 136, said crosshead being engaged by nuts 141 on the threaded ends of said bolts. By adjusting the nuts 141 the tension of the spring 138 may be varied to cause the valve 129 to remain seated against any desired predetermined pressure in the tanks. In order to prevent injury to the spring 138 by moisture accumulating in the hollow interior of the valve stem 134, the latter is provided with a drainage port 210 communicating with said hollow interior.

Referring to Fig. 5, the lower head of the low pressure cylinder 36 is of hollow construction to provide a water chamber 142 with which the water pipe 89 communicates, said water chamber having passages 143 communicating with a water jacket or casing 144 surrounding the cylinder proper. The jacket or casing 144 is formed with air inlet and outlet chambers 145 and 146, respectively, (see also Figs. 2, 3, and 16) with the former of which the air inlet 47 communicates and from the latter of which the air pipe 48 leads. Communication between the chambers 145 and 146 with the interior of the lower end of the cylinder 36 is controlled by a pair each of inlet and discharge valves designated as a whole in Figs. 2 and 3 by the numerals 147 and 148, respectively.

The two inlet valves 147 are exactly alike, and a description of one will suffice for both. Referring to Figs. 12 and 16, the wall of the cylinder 36 is provided adjacent its lower end with an opening 149 which registers with a similar opening 150 in the inner wall of the air chamber 145. Removably fitted to the opening 150 is a valve seat 152 having air passages 153, said valve seat being held in place in said opening by means of a yoke 154 forced into engagement with said valve seat by an abutment screw 155 in threaded engagement with a cover 156 bolted or otherwise secured in place over an opening 157 in the outer wall of the air inlet chamber 145, said opening 157 being in alignment with the openings 149 and 150. By removing the cover 156 the valve seat 152 and parts carried thereby may be readily removed through the opening 157. Cooperating with the ports 153 in the valve seat 152, is an annular plate valve 158 normally held to its seat by an annular leaf spring 159 interposed between said valve and a flange 160 on a keeper or guide member 161 provided with air passages 162 and secured to the valve seat 152 by means of a screw or bolt 163. The walls of the air chamber 145 may, if desired, be strengthened and supported by one or more spacing webs, one of which is indicated at 211 in Fig. 16.

The discharge valves 148, one of which is illustrated in detail in Fig. 11, are substantially identical with the inlet valves last described except that their position in the cylinder wall is reversed, the inlet valves being of course arranged to permit inward flow only of the air, while the outlet valves are arranged to permit outward flow only thereof. The parts of the discharge valve shown in Fig. 11 are designated by the same numerals as the corresponding parts of the inlet valve shown in Fig. 12, with the exponent x added, and will be fully understood without further explanation.

The second intermediate cylinder 38, which is superimposed upon the low pressure cylinder 36 and is arranged coaxially therewith, is enclosed by a water jacket or casing 164 suitably bolted or otherwise secured to the jacket or casing 144 of the cylinder 36, the water chambers of said jackets communicating with one another through ports 165, and the water chamber of the jacket 164 communicating at its upper end

with the water pipe 91 leading to the cooling tank 46. The jacket or casing 164 is formed with an air chamber 166 with which communicates the air pipe 54. The outer head 167 of the cylinder 38 is secured to the jacket 164 by bolts 168.

By reason of the difference in diameter of the cylinders 36 and 38, it will be seen that the volume of space enclosed between the pistons 40 and 42 will vary according to the position of said pistons, said space being less when said pistons are at or near the limit of their upward stroke than when they are at or near the limit of their downward stroke. In order to avoid any loss of power due to the useless compression of the air in the space between said pistons during their upward stroke, said space is preferably vented to the atmosphere by means of a passage 169 (see Fig. 16), formed in the bottom of the jacket 164, and communicating at one end with the top of the cylinder 36 and at the other with the air chamber 145 and thence with the atmosphere through the air inlet 47.

The inlet and discharge valve mechanism for the second intermediate cylinder 38 is shown in detail in Fig. 8. The upper wall of the jacket or casing 164 is provided with a tapered opening into which is fitted a tapered bushing 170 having an axial port 171 communicating with the air chamber 166, a lateral port 172 communicating with a passage in the casing 164 leading to the upper end of the cylinder 38, and a second lateral port 173 communicating with a passage in the casing 164 with which the air pipe 55 is connected. The passage 172 communicates with the inlet passage 171 and discharge passage 173 through ports controlled, respectively, by an inlet valve 174 and a discharge valve 175, the former having a stem slidably mounted in the hollow stem of the latter, and the stem of the latter being slidably mounted in a sleeve 176 held in place by a crosshead 177 secured to the casing 16 by means of bolts 178 (see Fig. 1). The inlet valve 174 is normally held to its seat by a spring 179 interposed between the end of its stem and the end of the recess in the stem of the valve 175, while the latter valve is similarly held to its seat by a spring 180 interposed between the end of its stem and the bottom of the opening in the sleeve 176. Upon the down stroke of the piston 42 the valve 174 opens, permitting air to be drawn, through the ports or passages 171 and 172, into the cylinder, the valve 175 remaining seated; while on the up stroke of said piston the valve 174 is seated, and the compressed air forces open the valve 175 and passes through the ports or passages 172 and 173 to the pipe 55.

The construction of the first intermediate cylinder 37 (see Fig. 5) is similar to that of the low pressure cylinder 36, said cylinder 37 having a lower head 181 provided with a water chamber with which the water pipe 90 communicates, said water chamber communicating through ports or passages 182 with the water chamber of the jacket or casing 183, which in turn communicates through ports or passages 184 with the water jacket or casing 185 of the high pressure cylinder 39. Referring to Figs. 9, 17, and 18, the cylinder head or casing 181 is provided with an air inlet chamber 186 with which the pipe 51 communicates, said chamber communicating through an inlet valve, designated as a whole by the numeral 187, with a passage 188 in the casing or jacket 183, said passage communicating with the lower end of the cylinder 37. Said passage 188 also communicates through a discharge valve, designated as a whole by the numeral 189, with an air discharge chamber 190 in the casing 183, said chamber 190 communicating with the air pipe 52. The inlet and discharge valves 187 and 189 are substantially identical in construction with the inlet and discharge valves 147 and 148 of the low pressure cylinder, and therefore require no description in detail. The valve 189 is secured in place by a yoke 191, similar to the yoke 154, said yoke being held in place by an abutment screw 192 carried by a cover 193 held in place by bolts 194 and closing an opening 195 in the upper wall of the chamber 190. The valve 187 is held in place by a screw or bolt 196 passing through an opening in the lower wall of the chamber 186 and having a threaded end outside said chamber to receive a nut 197. The chambers 186 and 190 are formed in lateral extensions in the casings 181 and 183, respectively, and the opening 195 is in the upper face of said extension, the valves 187 and 189 being arranged in alignment with said opening, whereby both of said valves may be readily removed upon removal of the cover 193.

As in the case of the pistons 40 and 42 (Fig. 5), means are provided for preventing undue compression of air bewteen the pistons 41 and 43, said means comprising a vent for the upper end of the cylinder 37. As shown in Fig. 18, said vent comprises a passage 198 in the wall of the casing 183, said passage communicating at its upper end with the upper end of the cylinder 37 and at its lower end with an extension 212 (see also Figs. 9 and 17) of the air inlet chamber 186, the upper end of said cylinder 37 being thereby vented, not to the atmosphere, as in the case of the cylinder 36, but to the air inlet chamber 186.

The outer head 199 (Fig. 5) of the high pressure cylinder 39 is secured to the jacket or casing 185 of said cylinder by bolts 200 and is formed with a passage 201 (see also Fig. 7) leading from the upper end of said cylinder and communicating through inlet

and discharge valves 202 and 203, respectively, with an air inlet chamber 204 with which the air pipe 57 communicates, and with a port or passage 213 communicating with the pipe 58. With the exception of a difference in size, corresponding to the reduced volume of air, due to its compression, the construction of the valves 202 and 203 is substantially identical with that of the valves 174 and 175 of the second intermediate cylinder, and require no further description in detail.

It will be observed that, by reason of the fact that the compression takes place at opposite ends, respectively, of the two cylinders of each pair, and consequently at opposite strokes of the corresponding steam piston 33, the work of said steam piston is equalized. In order further to evenly distribute the work of the machine and the load upon the engines, the cranks on the shaft 27 are preferably arranged at approximately 90° from one another, so that when the pistons in one pair of cylinders are at midstroke the pistons of the other pair will be at the extremity of their stroke in one direction or the other and consequently substantially idle.

For draining the cooling system when the machine is not in use, suitable drainage valves may be employed at suitable points in the system, such valves being shown at 205 and 215 in Fig. 2, the valve 215 being employed to empty the tanks 45 and 46 and the valve 205 to drain the water piping and cylinder jackets. Similarly, suitable unloading valves may be employed to relieve the air system of pressure after stopping the apparatus, such a valve being shown at 206 in Fig. 3.

Suitable means are preferably employed for lubricating the various moving parts of the machine, but as the lubricating system (except as hereinbefore pointed out) forms no portion of the present invention, it is not shown nor described in detail herein. In the drawings, however, are indicated at 207 and 208 lubricating devices which may be of any usual or well known type. While I have in this application specifically described one form which my invention may assume in practice, it will be understood that this form of the same is shown for purposes of illustration and that the invention may be modified and embodied in other forms without departing from its spirit or the scope of the appended claims.

What I claim as new and desire to secure by Letters Patent is:

1. A four stage compressor comprising, in combination, a high pressure cylinder, a first intermediate cylinder aligned therewith, pistons in said cylinders, a common piston rod for said pistons, a low pressure cylinder, a second intermediate cylinder aligned with said low pressure cylinder, pistons in said last named cylinders, a second piston rod to which said last named pistons are connected, and actuating means operatively connected with said piston rods.

2. A four stage compressor comprising, in combination, a high pressure cylinder, a first intermediate cylinder aligned therewith, pistons in said cylinders, a common piston rod for said pistons, a low pressure cylinder, a second intermediate cylinder aligned with said low pressure cylinder, pistons in said last named cylinders, a second piston rod to which said last named pistons are connected, a pair of motor cylinders, pistons in said motor cylinders, and means for rigidly connecting said motor pistons with said piston rods, respectively.

3. A four stage compressor comprising, in combination, a high pressure cylinder, a first intermediate cylinder aligned therewith, pistons in said cylinders, a common piston rod for said pistons, said piston rod passing through the head of said intermediate cylinder, a low pressure cylinder, a second intermediate cylinder aligned with said low pressure cylinder, pistons in said last named cylinders, a second piston rod to which said last named pistons are connected, said second piston rod passing through the head of said low pressure cylinder, and actuating means operatively connected with said piston rods.

4. In a multiple stage compressor, in combination, a compound cylinder comprising relatively high and low pressure cylinder portions of different diameters, an inlet chamber for said low pressure portion, inlet valves connecting said low pressure portion and said inlet chamber, and pistons in said chambers respectively, said cylinder having a passage providing communication between the inlet and the space between the pistons.

5. In a multiple stage compressor, in combination, a compound cylinder comprising relatively high and low pressure cylinder portions of different diameters, an inlet chamber for said low pressure portion, inlet valves for said low pressure portion, and a casing providing a cooling jacket for said cylinder and having a passage affording communication between said inlet and the space between said pistons.

6. In a multistage compressor, in combination, a compound cylinder comprising relatively high and low pressure cylinder portions of different diameters, inlet and discharge valves for each of said positions, pistons in said portions, and casings providing cooling jackets for said cylinder portions respectively, the low pressure cylinder casing having an air chamber communicating with said low pressure portion and the high pressure cylinder casing having a passage afford-

ing communication between said air chamber and the space between said pistons.

7. In a multiple stage compressor, in combination, a compound cylinder having an inlet and comprising relatively high and low pressure portions or chambers of different diameters, inlet and discharge valves for each of said chambers, pistons in said chambers respectively, and casings providing cooling jackets for said cylinders, the casing for said low pressure cylinder having a passage affording communication between said inlet and the space between said pistons.

8. In a multiple stage compressor, in combination, a compound cylinder having an inlet and comprising aligned relatively high and low pressure cylinder portions or chambers of different diameters, pistons in said chambers, respectively, and a plurality of juxtaposed directly intercommunicating casings providing cooling jackets for said cylinder portions, respectively, one of said casings having a passage affording communication between said inlet and the space between said pistons.

9. In a compound fluid compressor, the combination with a cooler, of a high pressure cylinder located at one side of said cooler, an intermediate pressure cylinder alined with said high pressure cylinder, pistons in said cylinders, a common piston rod for said pistons, a low pressure cylinder located at the opposite side of said cooler, a second intermediate pressure cylinder alined with said low pressure cylinder, pistons in said last-named cylinders, a second piston rod to which said last-named pistons are connected, actuating means operatively connected with said piston rods, and means for conveying the compressed fluid through said cooler after its compression in each of said cylinders.

10. In a compound fluid compressor, in combination, a frame, a cooling tank supported by said frame at the top thereof, compressor cylinders supported by said frame at opposite sides of said tank, and means for conveying the compressed fluid through said tank in its passage from one of said cylinders to the other.

11. In a multiple stage fluid compressor, in combination, a cooler, a plurality of compressor cylinders corresponding to the several stages, each of said cylinders being located at the opposite side of said cooler from the cylinder or cylinders of the immediately preceding or succeeding stage or stages and means for conveying the compressed fluid through said cooler alternately in opposite directions in its passage from stage to stage.

12. In a multiple stage fluid compressor, in combination, a cooler, compound compressor cylinders located respectively at opposite sides of said cooler and each comprising a plurality of cylinder portions, pistons in each of said portions, and means for conveying the compressed fluid through said cooler after its compression in each of said cylinder portions.

13. In a multiple stage fluid compressor, in combination, a cooler, compound compressor cylinders located respectively at opposite sides of said cooler and each comprising a plurality of cylinder portions, the several cylinder portions corresponding respectively to the several stages and each of said cylinder portions being located at the opposite side of said cooler from the cylinder portion or portions of the immediately preceding or succeeding stage or stages, pistons in each of said cylinder portions, and means for conveying the compressed fluid through said cooler alternately in opposite directions in its passage from stage to stage.

14. In a compound fluid compressor, in combination, a cooler comprising a plurality of cooling tanks, a plurality of compressor cylinders at each side of said cooler, and means for conveying the compressed fluid through said cooler after its compression in each of said cylinders.

15. In a multiple stage fluid compressor, in combination, a cooler comprising a plurality of cooling tanks, a plurality of compressor cylinders corresponding to the several stages, each of said cylinders being located at the opposite side of said cooler from the cylinder or cylinders of the immediately preceding or succeeding stage or stages, and means for conveying the compressed fluid through one or another of said tanks alternately in opposite directions in its passage from stage to stage.

16. In a multiple stage fluid compressor, in combination, a cooler comprising a plurality of cooling tanks, compound compressor cylinders located respectively at opposite sides of said cooler and each comprising a plurality of cylinder portions, pistons in each of said portions, and means for conveying the compressed fluid through one or another of said tanks after its compression in each of said cylinder portions.

17. In a multiple stage fluid compressor, in combination, a cooler comprising a pair of cooling tanks, compound compressor cylinders located respectively at opposite sides of said cooler and each comprising a plurality of alined cylinder portions, said cylinder portions corresponding respectively to the several stages and each of said cylinder portions being located at the opposite side of said cooler from the cylinder portion or portions of the immediately preceding or succeeding stage or stages, pistons in each of said cylinder portions, a common shaft to which all of said piston rods are connected, and means for conveying the compressed fluid through one or the other of

said tanks alternately in opposite directions in its passage from stage to stage.

18. In a compound compressor, in combination, a plurality of aligned cylinders, a plurality of directly intercommunicating cooling jackets for said cylinders, respectively, a cooler for the compressed fluid, means for supplying a cooling medium to one of said jackets, and means for conveying said medium from another of said jackets to said cooler.

19. In a compound fluid compressor, in combination, a cooling tank, jacketed compressor cylinders located at opposite sides of said tank, means for conveying the compressed fluid through said tank in its passage from one of said cylinders to the other, means for supplying a cooling medium to the jacket of one of said cylinders, and means for subsequently conveying said medium to said tank.

20. In a compound fluid compressor, in combination, a plurality of cylinders, a cooler for the compressed fluid, and means for supplying a cooling medium to said cylinders successively and thence to said cooler.

21. In a compound fluid compressor, in combination, a cooler for the compressed fluid, a plurality of compressor cylinders at each side of said cooler, means for conveying compressed fluid through said cooler after its compression in each of said cylinders, and means for supplying a cooling medium to the cylinders at one side of said cooler, successively, and thence to said cooler.

22. In a multiple stage fluid compressor, in combination, a plurality of compound cylinders each having a plurality of cylinder portions, a plurality of cooling tanks, means for supplying a cooling fluid successively to the several portions of each of said cylinders, and means for conveying said fluid from each of said cylinders to one or the other of said tanks.

23. In a multiple stage fluid compressor, in combination, a plurality of compound cylinders each having a plurality of cylinder portions, a cooler comprising a plurality of cooling tanks located between said cylinders, means for conveying the compressed fluid through said cooler after its compression in each of said cylinder portions, means for supplying a cooling fluid successively to the several portions of each of said cylinders, and means for conveying said fluid from each of said cylinders to one or the other of said tanks.

24. In a compound fluid compressor, in combination, a plurality of cylinders, a plurality of cooling tanks, means for supplying a cooling fluid to each of said cylinders, and means for separately conveying said fluid from each of said cylinders to one or another of said tanks.

25. In a fluid compressor, a cooler comprising a base or platform and a plurality of upright sheet metal cylinders secured to said base and constituting a plurality of cooling tanks, said base forming a common bottom for all of said tanks arranged side by side thereon.

26. In a compound fluid compressor, in combination, a frame, a base or platform supported by said frame at the top thereof, a plurality of upright sheet metal cylinders secured to said base and constituting a plurality of cooling tanks, said base forming a common bottom for all of said tanks, compressor cylinders supported by said frame at opposite sides of said tanks, and means for conveying the compressed fluid through one or the other of said tanks in its passage between said cylinders.

27. In a fluid compressor, in combination, a shaft having a crank pin, a motor operatively connected with said crank pin, compressing means operatively connected with said crank pin, a disk eccentrically carried by said crank pin, a pin carried by said eccentrically mounted disk, a valve for said motor, and a rod connected to said eccentric pin for operating said valve, said eccentric pin having a lubricant passage, said eccentrically mounted disk having an internal annular groove adapted to receive lubricant from said passage, and said crank pin having a lubricant passage communicating with said groove.

28. The combination with a crank pin and a pitman journaled thereon, of a disk eccentrically secured to said crank pin, a pin carried by said eccentrically mounted disk, and a rod journaled on said eccentric pin, said eccentric pin having a lubricant passage, said eccentrically mounted disk having an internal annular groove adapted to receive lubricant from said passage, and said crank pin having a lubricant passage communicating with said groove.

29. A multistage compressor comprising a plurality of motor cylinders, motor pistons therein, a plurality of compressor cylinders disposed in alinement with said motor cylinders, a plurality of compressor pistons therein, a crank shaft between said motor and compressor cylinders, driving connections between said motor pistons and said crank shaft and compressor pistons, and a cooler disposed in the space between said compressor cylinders and wholly to one side of said crank shaft.

30. A multistage compressor comprising a plurality of motor cylinders whose axes lie in a plane making an angle with the horizontal, motor pistons therein, a plurality of compressor cylinders disposed in alinement with said motor cylinders, a plurality of compressor pistons therein, a crank shaft whose axis lies in the same plane with the axes of said cylinders, but at right angles

to said axes, said crank shaft being connected with said motor pistons, driving connections between said motor pistons and compressor pistons, a fly wheel on said crank shaft, and a cooler disposed between said compressor cylinders and above said fly wheel.

31. A multistage compressor comprising a pair of motor cylinders whose axes lie in a plane making an angle with the horizontal, motor pistons in said cylinders, a pair of compressor cylinders disposed in alinement with said motor cylinders, compressor pistons in said compressor cylinders, a crank shaft driven by said motor pistons, driving connections between said motor pistons and said compressor pistons, a fly wheel on said crank shaft between said driving connections, and a cooler disposed in the space between the outer ends of one of said pairs of cylinders and the periphery of said fly wheel and between the cylinders of said pair.

32. In a multi-stage fluid compressor, in combination, a low pressure cylinder, a high pressure cylinder and two intermediate cylinders, a cooler comprising a plurality of cooling tanks located adjacent said cylinders, means for conveying the compressed fluid from said low and first intermediate cylinders through one of said tanks and for conveying the compressed fluid from the second intermediate and high pressure cylinders through the other of said tanks.

33. In a multi-stage fluid compressor, in combination, a low pressure cylinder, a high pressure cylinder, an intermediate cylinder arranged in alinement with said low pressure cylinder, another intermediate cylinder arranged in alinement with said high pressure cylinder, a cooler comprising a plurality of cooling tanks arranged adjacent said cylinders, and means for conveying the compressed fluid from said low pressure cylinder and one of said intermediate cylinders through one of said tanks and for conveying the compressed fluid from the other intermediate cylinder and the high pressure cylinder through the other of said tanks.

34. In a multi-stage fluid compressor, in combination, a low pressure cylinder, a high pressure cylinder, an intermediate cylinder arranged in alinement with said low pressure cylinder, another intermediate cylinder arranged in alinement with said high pressure cylinder, a cooler comprising a plurality of cooling tanks arranged adjacent said cylinders, one of said cooling tanks being parallel to said cylinders, and means for conveying the compressed fluid from said low pressure cylinder and one of said intermediate cylinders through one of said tanks and for conducting the compressed fluid from the second intermediate cylinder and the high pressure cylinder through the other of said tanks.

35. In a multi-stage fluid compressor, in combination, a low pressure cylinder, a high pressure cylinder, an intermediate cylinder arranged in alinement with said low pressure cylinder, another intermediate cylinder arranged in alinement with said high pressure cylinder, a cooler comprising a plurality of cooling tanks arranged adjacent said cylinders, both of said cooling tanks being parallel to said cylinders, and means for conveying the compressed fluid from said low pressure cylinder and one of said intermediate cylinders through one of said tanks and for conducting the compressed fluid from the second intermediate cylinder and the high pressure cylinder through the other of said tanks.

36. In a multi-stage fluid compressor, in combination, a low pressure cylinder, a high pressure cylinder, an intermediate cylinder arranged in alinement with said low pressure cylinder, another intermediate cylinder arranged in alinement with said high pressure cylinder, a cooler comprising a plurality of cooling tanks arranged adjacent said cylinders, one of said cooling tanks being parallel to said cylinders, and means for conveying the compressed fluid from said low pressure cylinder and one of said intermediate cylinders through one of said tanks and for conducting the compressed fluid from the second intermediate cylinder and the high pressure cylinder through the other of said tanks, the fluid conducting means from said last mentioned cylinders comprising concentric coils in said tank parallel to said cylinders through both of which the compressed fluid flows downwardly.

37. A four-stage compressor comprising, in combination, a high pressure cylinder, a low pressure cylinder, arranged parallel thereto, two intermediate cylinders, arranged one in alinement with each of said previously mentioned cylinders, pistons in all of said cylinders, connections between the pistons in alined cylinders, and driving means for said pistons including a steam cylinder and piston in alinement with one of said pairs of alined cylinders and a crank shaft having angularly disposed cranks connected to said pairs of compressor pistons.

38. A four-stage compressor comprising, in combination, a high pressure cylinder, a low pressure cylinder arranged parallel thereto, two intermediate cylinders arranged one in alinement with each of said previously mentioned cylinders, pistons in all of said cylinders, connections between the pistons in alined cylinders, driving means for said pistons including a steam cylinder and piston in alinement with one of said pairs of alined cylinders and a crank shaft

having angularly disposed cranks connected to said pairs of compressor pistons, and cooling means for the fluid compressed in said various cylinders including a pair of separate tanks each containing fluid conducting means from two of said cylinders.

39. In combination, in a compressor, a low pressure cylinder, a cylinder receiving compressed fluid from said low pressure cylinder and cooperating in the further compression thereof, a crank shaft, an intercooler intermediate said cylinders, said cylinders and intercooler all lying to one side of a plane passing through said crank shaft, means for supplying a cooling liquid to the bottom of said intercooler and discharging the same at the top, and means for conducting the fluid from said first to said second cylinder causing the same to flow from the top to the bottom of said intercooler.

40. The combination with a compressor, a low pressure cylinder, a cylinder receiving compressed fluid therefrom and cooperating in the further compression of said fluid, an intercooler comprising a tank affording a cooling liquid chamber, means within said chamber constituting a conducting means for compressed fluid, means for supplying a cooling liquid to the bottom of the chamber and discharging the same at the top, and means for conducting the fluid from said first mentioned cylinder to the top of said conducting means and leading it from the bottom of the latter to said second mentioned cylinder.

41. In a multi-stage compressor, a plurality of single acting cylinder and piston compressor couples and means for effecting cooperation of the cylinders and pistons of said couples to effect multi-stage compression including piston rods connected to said pistons, a multi-crank shaft, means for effecting rotation thereof, operative connections between said piston rods and said shaft, said parts being arranged so that the piston rods of said low pressure piston and the first intermediate piston are under tension during the compression strokes of their respective pistons, and means for effecting reciprocation of said pistons including a fluid pressure actuated piston coaxial with said low pressure piston and rigidly connected to the rod of the latter.

42. A four-stage compressor comprising, in combination, a high pressure cylinder, a first intermediate cylinder alined therewith, pistons in said cylinders, operative connections between said pistons connecting them for simultaneous movements in like directions, a low pressure cylinder, a second intermediate cylinder alined with said low pressure cylinder, pistons in said last named cylinders, operative connections between said last named pistons connecting them for simultaneous movements in like directions, a crank shaft, and operative connections between said crank shaft and said pairs of pistons.

43. A multi-stage compressor comprising, in combination, a low pressure cylinder having a piston therein, an intermediate cylinder having a piston therein and adapted to receive the fluid compressed in said low pressure cylinder for the next stage of its compression, a high pressure cylinder having a piston therein and arranged in alinement with one of said first mentioned cylinders, said high pressure piston being connected to one of said first mentioned pistons for reciprocation therewith, and actuating means for said several pistons including separate actuating connections to said low pressure piston and said intermediate piston.

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FRED D. HOLDSWORTH.

having angularly disposed cranks connected to said pairs of compressor pistons, and cooling means for the fluid compressed in said various cylinders including a pair of separate tanks each containing fluid conducting means from two of said cylinders.

39. In combination, in a compressor, a low pressure cylinder, a cylinder receiving compressed fluid from said low pressure cylinder and cooperating in the further compression thereof, a crank shaft, an intercooler intermediate said cylinders, said cylinders and intercooler all lying to one side of a plane passing through said crank shaft, means for supplying a cooling liquid to the bottom of said intercooler and discharging the same at the top, and means for conducting the fluid from said first to said second cylinder causing the same to flow from the top to the bottom of said intercooler.

40. The combination with a compressor, a low pressure cylinder, a cylinder receiving compressed fluid therefrom and cooperating in the further compression of said fluid, an intercooler comprising a tank affording a cooling liquid chamber, means within said chamber constituting a conducting means for compressed fluid, means for supplying a cooling liquid to the bottom of the chamber and discharging the same at the top, and means for conducting the fluid from said first mentioned cylinder to the top of said conducting means and leading it from the bottom of the latter to said second mentioned cylinder.

41. In a multi-stage compressor, a plurality of single acting cylinder and piston compressor couples and means for effecting cooperation of the cylinders and pistons of said couples to effect multi-stage compression including piston rods connected to said pistons, a multi-crank shaft, means for effecting rotation thereof, operative connections between said piston rods and said shaft, said parts being arranged so that the piston rods of said low pressure piston and the first intermediate piston are under tension during the compression strokes of their respective pistons, and means for effecting reciprocation of said pistons including a fluid pressure actuated piston coaxial with said low pressure piston and rigidly connected to the rod of the latter.

42. A four-stage compressor comprising, in combination, a high pressure cylinder, a first intermediate cylinder alined therewith, pistons in said cylinders, operative connections between said pistons connecting them for simultaneous movements in like directions, a low pressure cylinder, a second intermediate cylinder alined with said low pressure cylinder, pistons in said last named cylinders, operative connections between said last named pistons connecting them for simultaneous movements in like directions, a crank shaft, and operative connections between said crank shaft and said pairs of pistons.

43. A multi-stage compressor comprising, in combination, a low pressure cylinder having a piston therein, an intermediate cylinder having a piston therein and adapted to receive the fluid compressed in said low pressure cylinder for the next stage of its compression, a high pressure cylinder having a piston therein and arranged in alinement with one of said first mentioned cylinders, said high pressure piston being connected to one of said first mentioned pistons for reciprocation therewith, and actuating means for said several pistons including separate actuating connections to said low pressure piston and said intermediate piston.

In testimony whereof I affix my signature.

FRED D. HOLDSWORTH.

Certificate of Correction.

It is hereby certified that in Letters Patent No. 1,580,435, granted April 13, 1926, upon the application of Fred D. Holdsworth, of Claremont, New Hampshire, for an improvement in "Air Compressors," errors appear in the printed specification requiring correction as follows: Page 5, line 112, for the misspelled word "bewteen" read *between;* page 6, line 124, claim 6, for the word "positions" read *portions:* and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 15th day of June, A. D. 1926.

[SEAL.]

M. J. MOORE,
Acting Commissioner of Patents.

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