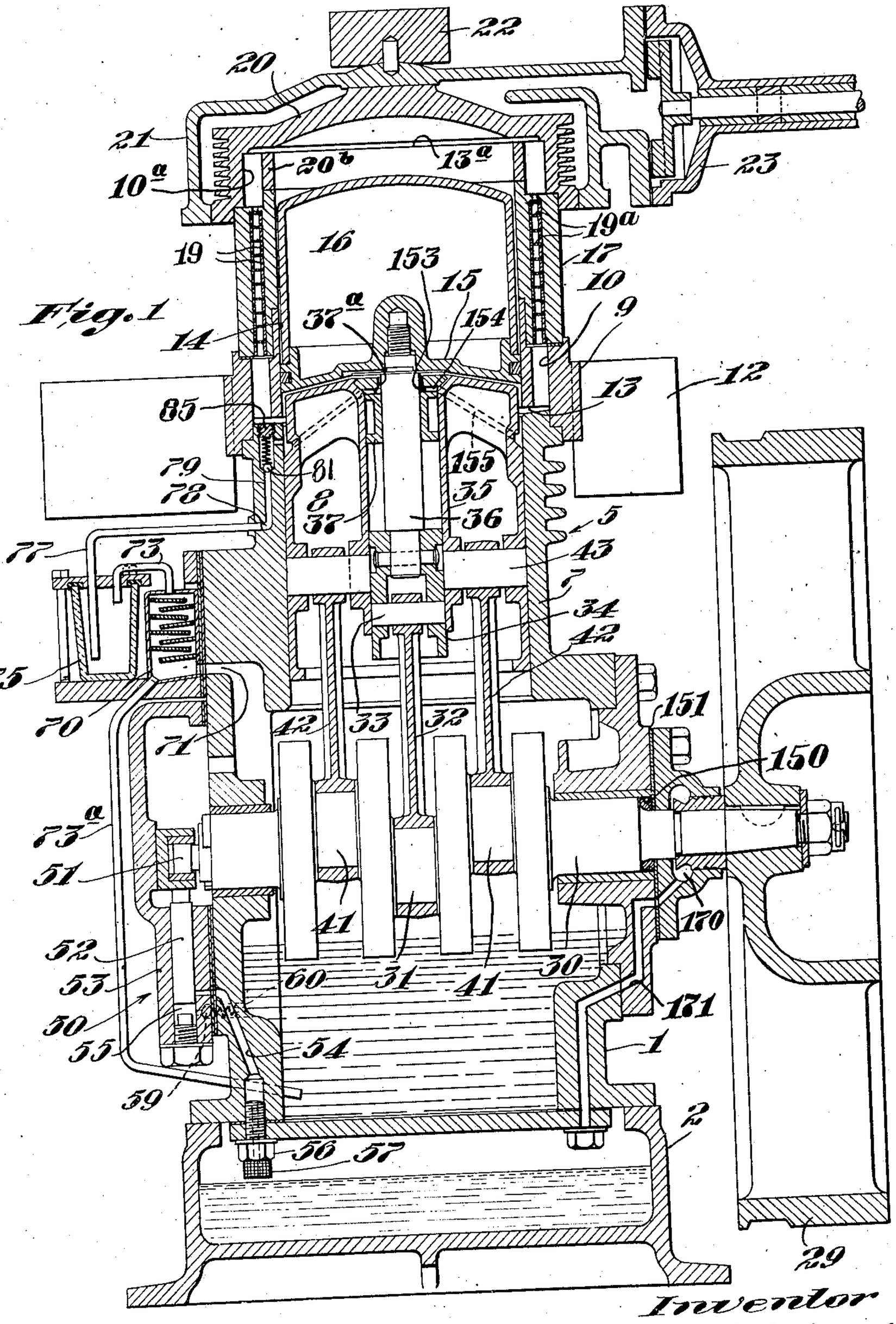
Aug. 20, 1935. M. J. AJAM 2,011,964

REFRIGERATING MACHINE

Filed July 28, 1931 3 Sheets-Sheet 1

Fig. 1



Inventor

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Att'ys.

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REFRIGERATING MACHINE

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Fig. 2

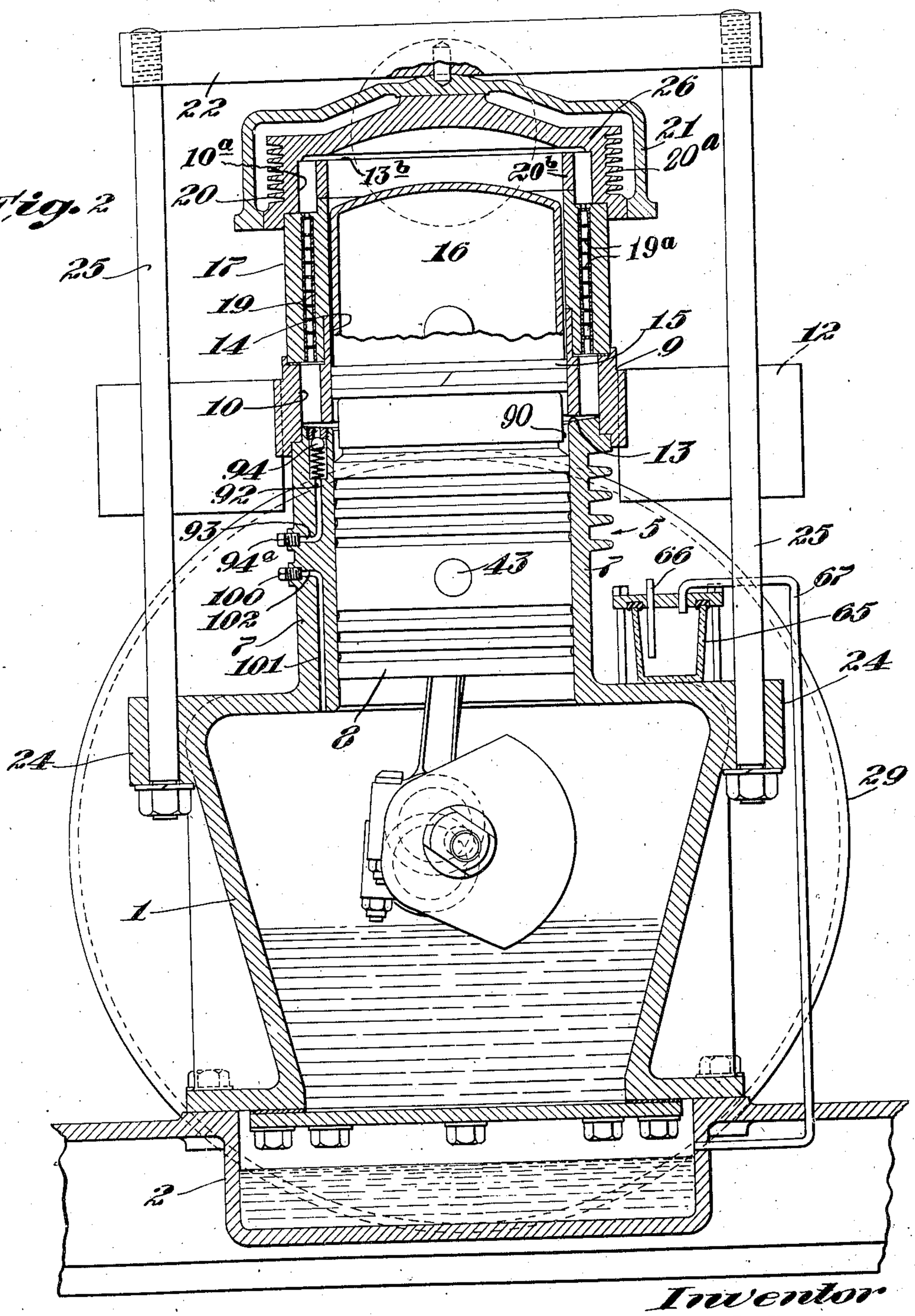

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Fig. 3

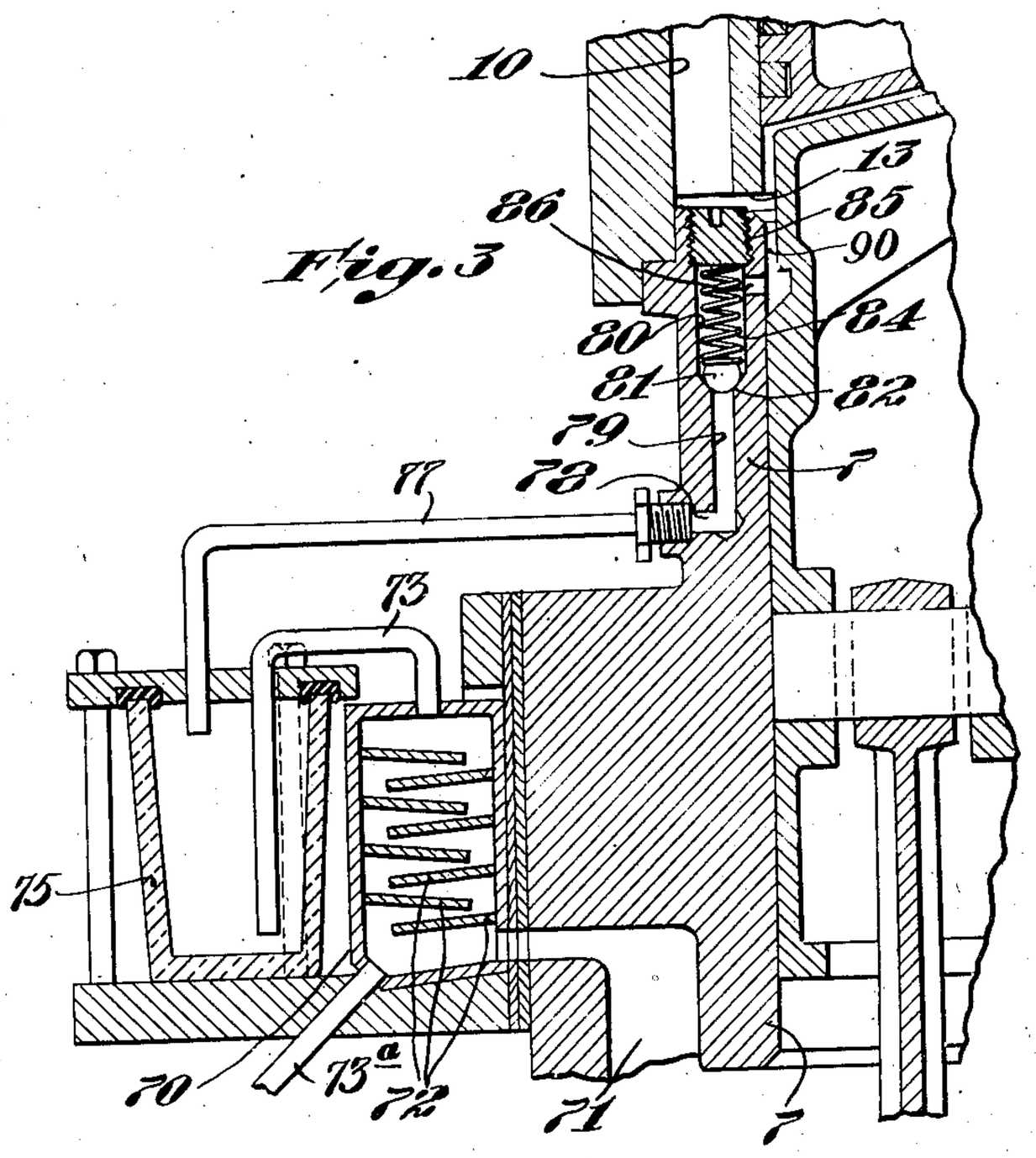

Fig. 4

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Attys.

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UNITED STATES PATENT OFFICE

2,011,964

REFRIGERATING MACHINE

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Application July 28, 1931, Serial No. 553,552

15 Claims. (Cl. 62—136)

This invention relates to fluid compression apparatus and more particularly to a refrigerating machine designed to use air or other gaseous mediating fluid in a closed thermo-dynamic cycle. This invention is particularly directed to induction and drying arrangements for the mediating gas of a machine of this character, and is particularly applicable to refrigerating apparatus of the character in the United States patent to Ivar Lundgaard No. 1,240,862. A machine of the character disclosed in this patent is provided with a cylinder having a compression piston and a shifter piston, the latter being effective to transfer the mediating gas back and forth between a compression chamber between the shifter and compression pistons, and an expansion chamber between the shifter piston and the cylinder head. The gas moving between the compression and expansion chambers passes through heat exchangers and a regenerator or heat interchanger. The present invention affords an arrangement which is particularly effective in permitting the continued maintenance of a body of dry gas, such as air, at a predetermined superatmospheric pressure within the cylinder, i. e., in the compression and expansion chambers and the passages therebetween.

This invention also is effective in permitting air thus to be maintained in the cylinder while avoiding the movement of oil into the small passages between the compression and expansion chambers, these passages being of a type which might readily be clogged with a relatively small amount of oil. Furthermore, moisture removing factors or dryers are provided to maintain the air within the cylinder in a dry condition, so that the collection of frost is normally avoided, despite the low operating temperatures of the air in the expansion chamber and adjoining the same. In order to attain these desirable results, I provide a check valve arrangement which may be adjustable and which permits the flow of gas from the crank case to the compression chamber while preventing such a flow in the opposite direction. The gas may be supplied by a suitable make-up pump having an outlet into the crank case, such as that disclosed in the United States patent to Ivar Lundgaard No. 1,838,148. A dryer is associated with the inlet of this pump. From the interior of the crank case, air may flow through the check valve to the compression chamber, whenever pressure in the latter falls to a point enabling the opening of the valve. Preferably, the air thus flowing through the check valve first passes into a suitable oil separator. From the oil separator the air may pass into a second dryer, which is adapted to remove any moisture not removed by the first dryer that is associated with the inlet of the make-up pump, and also to remove any moisture which may have been received from the oil in the crank case. Preferably the air passing into the compression chamber is received in an annular space between the upper portion of the compression piston and the cylinder wall, so that any oil not removed from the incoming air collects in a body in the lower part of this annular chamber, and may flow past the piston into the crank case. Such a flow of oil is induced, since the gas within the cylinder is automatically maintained by the induction arrangement at a mean pressure higher than that in the crank case.

Occasionally under unusual operating conditions, sufficient moisture may find its way into the cold head of a machine of this character to cause the formation of frost. It is difficult to melt this frost and to remove the resultant moisture from the air within the machine without disassembly of the machine. The present invention provides means built into the cylinder wall, which may be connected to a suitable auxiliary dryer forming a part of the service equipment. With this arrangement the normal direction of crank shaft movement is reversed, so that the cold head becomes the compression chamber and its temperature rises, thus rapidly melting the collected frost. The air may then be caused to flow through the auxiliary dryer, which collects the moisture. To permit this desirable result I arrange a suitable check valve in a passage between the compression chamber and the crank case, so that air will flow from the interior of the cylinder to the crank case, passing from the auxiliary dryer, and thus having its moisture removed. Ordinarily the connections for the auxiliary dryer may be closed by suitable plugs, which are removed by the service man so that the passage in the cylinder wall can be connected to the auxiliary dryer when the special defrosting operation is necessary.

In the accompanying drawings:

Fig. 1 is a vertical section through an improved machine embodying the principles of this invention, this section being taken in the plane of the crank shaft axis;

Fig. 2 is a vertical section at right angles with that of Fig. 1;

Fig. 3 is an enlarged sectional detailed view, showing the arrangement of the induction passage in the cylinder wall; and

Fig. 4 is an enlarged sectional detail showing

the arrangement of the passage in the cylinder wall, which is employed for the special defrosting operation.

The accompanying drawings in general illustrate a refrigerating machine of the type disclosed in the above-identified patents to Ivar Lundgaard, this machine having a crank case 1 with an upstanding cylinder 5 and with a sump 2 below the crank case. The cylinder 5 comprises a lower section 7 integral with the crank case, in which the main or compression piston 8 reciprocates. Above the section 7 is a second metal section 9 surrounding the compression chamber and having vertical duct portions 10 separated by radial fins connecting inner and outer annular metal walls. Heat radiating fins 12 are secured to the outer wall of the section 9 and a suitable port 13 connects the ducts 10 with the interior of the cylinder, i. e., with the compression chamber. An upwardly extending continuation 14 of the metal section 9 provides a bearing for the lower metal portion 15 of the shifter piston 16, the body portion of which is formed of heat insulating material. Surrounding the shifter piston 16 is a regenerator 17 comprising inner and outer rings of heat insulating material, such as bakelite, with a plurality of spaced and/or insulated metallic elements 19 disposed in the passage 19a between the inner and outer bakelite rings.

The upper ends of the passages between elements 19 communicate with the lower ends of ducts 10a which are separated by radial fins connecting the inner ring 20b with the outer wall of cold head 20. The upper ends of ducts 10a communicate with the interior of the cold head through an annular port 13a. The cold head 20 is provided with a jacket 21 and fins 20a. Suitable coolant, such as brine or ethylene glycol, may be circulated in the jacket of the cold head by a pump 23. A transverse beam 22 engages the top of the cold head and is connected to tension elements 25 that engage lugs 24 upon the sides of the crank casing, thus clamping the various sections of the cylinder in firm engagement with each other.

During normal operation of this machine, as fully described in Patent No. 1,240,862, air is compressed between the pistons 8 and 16, flowing through the passages 10 of cylinder section 9 and the regenerator 17, this compressed air giving up heat through the fins 12 and to the separate elements 19 in the regenerator 17. The compressed air as thus cooled is received in the cold head 20 and expands due to the downward movement of shifter piston 16, thus affording a refrigerating effect. Downward movement of piston 8 is then effective in drawing the air from the cold head back to the compression chamber, whereupon the cycle is repeated.

Various driving means may be employed for causing relative movement of the main and shifter pistons. As shown, for example, the crank shaft 30, which is driven through an exterior flywheel 29, is provided with a central throw 31 having a connecting rod 32 articulated thereto and engaging a transverse pin 33 in a cylindrical member 34 that reciprocates in a cylindrical boss 35 which is vertically disposed at the center of the piston 8. The member 34 is connected by a vertical rod 36 with the lower metallic portion 15 of the shifter piston 16, a bearing member 37 being provided in the upper part of the boss 35 to guide the rod 36. At each side of the throw 31 of crank shaft 30 are throws 41 with their crank axes in mutual alignment; as shown, the throw 31 may be disposed substantially 70° in advance of throws 41. Connecting rods 42 are articulated to the throws 41 and engage wrist pins 43 which are secured to bosses in the outer wall of piston 8 and upon opposite sides of the central sleeve 35 respectively.

A packing ring 150 is disposed in normal engagement with the crank shaft 30 and a fixed gasket 151. Under normal conditions, the crank shaft is covered with an oil film, and the higher pressure within the crank case presses the shoulder with its oil film against ring 150, so that the latter firmly engages gasket 151. Thus, this arrangement of parts cooperates with oil film to provide a substantially air-tight seal. An annular oil chamber 170 collects oil which leaks past the packing ring and gasket, and a duct 171 in the crank case permits oil from chamber 170 to drain into the sump 2.

A machine of this character may conveniently be supplied with a make-up pump, indicated generally by the numeral 50, which may be of the same type as that disclosed in Patent No. 1,838,148. This pump preferably is driven from a suitable portion of the piston driving mechanism, as shown, having its plunger 52 connected to an eccentric 51 at the end of the crank shaft 30. The pump comprises a suitable vertically disposed cylindrical housing 53 in which the plunger 52 reciprocates, a clearance chamber 55 being provided below the plunger 52. An inlet duct 54 is connected to the interior of the pump housing and communicates through a member 56 threaded into the lower part of the crank case with the upper part of sump 2. A suitable screen 57 may be disposed on the lower end of member 56 within the sump to prevent foreign matter from entering the inlet duct 54. A ball check valve 59 is disposed in an outlet passage 60 connecting the clearance chamber 53 with the interior of the crank case below the normal level of oil therein, the valve opening when the pressure within the pump chamber is higher than that in the crank case.

A suitable dryer 65, which contains moisture absorbent material such as calcium chloride, phosphoric acid, or phosphorous pentoxide, may be disposed on the exterior of the machine, as shown in Fig. 2, having an air inlet 66 communicating with the outer air, and an air outlet 67 communicating with the upper part of the sump. When the level of oil in the sump is above the mouth of inlet duct 54, the make-up pump is effective in pumping oil, which is emitted through the check valve 59, into the crank case. When the oil level falls below the inlet to the duct 57, the latter communicates with the exterior air through the duct 67 and the dryer 65. Under the latter condition, when the pressure of air within the crank case falls to a predetermined point, depending upon the adjustment of check valve 59, the pump 50 may be effective in drawing air through the dryer 65 and supplying the same to the interior of the machine.

The present invention particularly provides specific improvements in a machine of the general character described above, which permit the more satisfactory and efficient use of the mediating air while avoiding tendency of oil to find its way into the small passages 10 and 10a and between the elements 19, which may readily become clogged with oil due to their small cross sections.

This invention further provides means to aid in the maintenance of the mediating air in a nor-

mally dry condition and also special means to remove moisture, should the moisture content of the air accidentally rise sufficiently to cause the formation of frost in the cold head. To permit these desirable results, I provide, as shown in Fig. 1, an oil separating chamber 70 which communicates with the interior of the crank case through an air passage 71. This separator may conveniently be provided with a plurality of inwardly inclined staggered plates 72 (Fig. 3) which provide a tortuous air passage and which collect oil particles. A drain 73a connects the lower part of the separator 70 with the lower part of the crank case 1, thus permitting the oil separated out of the air which flows into separator 70 to be returned to the crank case.

A duct 73 connects separator 70 with a second dryer 75, which may be similar to the dryer 65. The outlet pipe 77 connects the latter with a radially disposed passage 78 in the wall of the cylinder section 7. Passage 78 in turn communicates with a vertical passage 79. The latter is shown in greater detail in Fig. 3 and is provided with an enlarged upper portion 80 having a ball check valve 81 engaging a seat 82 and normally held in its closed position by a compression spring 84, the upper end of which engages a threaded plug 85 having a slotted end to receive a screw driver and to permit ready variation of the normal distortion of spring 84 when the valve is closed. A vent 86 connects the upper part 80 of passage 79 with the interior of the cylinder.

When the machine is first started the air within the machine may be atmospheric pressure. The make-up pump 50 will then operate to draw air into the dryer 65 and thence into the sump, supplying the same to the interior of the crank case until the pressure therein has risen to a point determined by the relative maximum and minimum displacements of the chamber 55 and the pressure with which the valve 59 is held against its seat. As the machine continues running, the make-up pump tends to maintain the interior pressure at this predetermined point. When air is first supplied to the crank case in this manner by the make-up pump, the mean pressure in the crank case will be higher than that in the compression chamber. Accordingly air flows through passage 71, separator 70, dryer 75, duct 77, passages 79 and 86 each time the piston 8 moves downwardly toward the bottom of its stroke, thus admitting additional air under pressure to the interior of the cylinder. As the air is compressed in the compression chamber and expanded in the crank case due to the upward movement of piston 8, the valve 81 closes. Thus pressure is constantly built up in the cylinder until the mean pressure within the compression chamber is above the mean pressure in the crank case by a definite amount determined by the adjustment of the valve 81. As the machine continues running there is a tendency for air to leak about the piston 8 and the plunger 36 from the compression chamber into the crank case. The arrangement of the by-pass valve 81, however, is effective continuously to compensate for this leakage and to maintain the desired higher pressure within the compression chamber. During temporary idle periods the air at higher pressure in the compression chamber tends to leak into the crank case so that these pressures may become substantially equalized by the time the machine again starts in operation. The arrangement of the valve 81, however, permits the pressure within the cylinder automatically to rise so that the desired differential between the cylinder and crank case pressures is again created. It is thus evident that the arrangement of the valve 81 permits the mean pressure within the cylinder normally to be higher than that within the crank case and that after this pressure differential has been disturbed due to shutting down of the machine the arrangement of the by-pass valve automatically permits the normal pressure conditions to be resumed. Thus the portion of the machine in which the mediating air is actually being used may contain this air at a higher average pressure than the portion of the machine from which any leaks are likely to occur, i. e., the crank case, from which there may be some slight leakage about the ring 150. When leakage thus occurs, the pressure within the crank case falls, so that the make-up pump automatically operates to return the internal pressure of the machine to the desired point.

The upper part of piston 8 is of smaller diameter than the main body portion of the piston, thus providing an annular space 90 between this portion of the piston and the inner surface of the cylinder. Accordingly oil which has not separated from the air received from passage 71 flows under the action of gravity into this annular chamber 90. Due to the fact that the pressure within the cylinder is normally higher than that within the crank case, this oil tends to be forced downwardly between the piston and cylinder and thus be returned to the crank case. The upper part of bushing 37 preferably is provided with a bore of enlarged diameter, designated by numeral 37a, so that it does not directly contact the rod 36. An oil groove 153 is disposed at the lower end of this relieved portion and radial passages 154 communicate with passages 155 in the ribs of the piston 8, that in turn open into the space 90 about the upper part of the piston. Thus oil which is carried upward by the plunger 36 is scraped off from the plunger by the lower edge of the groove 153 and flows downwardly through passages 154 and 155 to the space 90, from which the higher pressure above the piston is effective in returning the oil to the crank case. It therefore is evident that clogging of the air passages in ducts 10 and 10a and those of the regenerator wall is avoided.

Under ordinary operating conditions, the mediating air has substantially all of its moisture removed by the dryers 65 and 75 so that frost will not collect in the cold head 20 despite the low temperature of the latter. Occasionally the dryers 65 and 75 have to be renewed due to the exhaustion of the moisture absorptive property of the material contained therein. If, for example, the material in these dryers is not renewed soon enough and/or a continuous leak develops about the stuffing ring 150, frost may form in the cold head 20. The collection of frost in this region is clearly indicated by a distinct knock, since the clearance between the piston 16 at the top of its stroke and the head of the cylinder normally is quite small. Under these conditions it has heretofore proved difficult to remove the moisture collected in the form of frost in the cylinder head.

The present invention affords special means built into the cylinder wall which cooperates with an auxiliary dryer that may form a part of the service man's equipment to permit the ready performance of the defrosting operation and the removal of the moisture from the interior of the machine. For this purpose, as shown in Figs.

2 and 4, a vertical passage 92 is provided in the wall of the lower section 7 of cylinder 5, this passage having an enlarged upper portion with a check valve 94 therein resting upon a compression coil spring 95 which holds the ball against a seat on the bushing 97 threaded into the upper part of the section 7 and affording communication between the duct 92 and the air passages in the interior of the cylinder wall as well as with the compression chamber. The passage 92 communicates with a threaded opening in the cylinder wall that normally has a threaded plug 94a in engagement therewith. A second threaded plug 100 engages a similar opening 102 below the opening 93 and communicates with a passage 101 extending downwardly in the cylinder wall and communicating with the interior of the crank case 1.

When the defrosting operation and removal of moisture is to be effected, the plugs 94a and 100 are removed and an auxiliary dryer 105 having an inlet duct 107 and an outlet duct 106 is connected to the machine. The ducts 106 and 107 are provided with unions 108 and 109 respectively which are connected to the threaded openings 93 and 102 respectively. Thus the passage 92 is made to communicate with the interior of the dryer 105 and the latter in turn communicates with the crank case.

When the auxiliary dryer 105 is thus connected to the machine, the direction of rotation of the crank shaft 30 is changed by any means, for example by a suitable arrangement of a twisted belt acting on the flywheel 29 so that the pistons 8 and 16 reciprocate in directions opposite to their normal movements. This results in the compression of mediating fluid above piston 16 and its expansion below the same so that the cold head 20 then becomes a warm compression chamber, its temperature rising so that the frost quickly melts. While the chamber between pistons 8 and 16 then becomes the expansion chamber, the temperature of this portion of the apparatus does not fall unduly, due to the fins 12 which are exposed to the surrounding air. In many installations of a machine of this character, a fan is arranged to blow air at room temperature over these fins. Accordingly the temperature within the chamber between the pistons does not fall sufficiently to cause any formation of frost, when the machine is thus being operated by reversed driving means. Since the check valve 94 opens in response to a higher pressure thereabove, when the piston 8 is in the upper part of its stroke, the air from the interior of the cylinder flows downwardly through the dryer 105 which removes the moisture from the air. The check valve 81 in the passage 79 is effective in permitting the ready return of the dried air from the crank case to the interior of the cylinder, so that as the machine operates in a reversed direction the air is circulated through the dryers 105 and 75, while the frost in the cold head 20 is changing to vapor. Thus the moisture is readily removed from the interior of the cylinder. When the moisture has thus been removed, the auxiliary dryer 105 is disconnected from the machine and the plugs 94a and 100 are replaced. The driving belt is then arranged to cause operation of the machine in its usual manner.

From the foregoing it is evident that I have provided a refrigerating machine employing air or similar gas as a mediating fluid which has a special induction arrangement normally assuring the removal of moisture from the gas which is supplied to the machine to compensate for leakage. This induction means is arranged so that the mean operating pressure within the cylinder is normally higher than that within the crank case from which leakage is more likely to take place. Thus the advantages of employing air at a relatively high working pressure are attained without entailing the necessity of guarding against leakage from such high pressure around the crank shaft.

The induction means is also particularly designed to prevent oil from finding its way into the small passages within the cylinder wall and thus clogging the same to prevent normal flow of air. While this induction arrangement is effective in preventing the collection of an objectionable amount of moisture within the cylinder and consequent formation of frost in the cold head, I have provided means to facilitate the removal of such moisture should the same collect due to abnormal conditions or improper servicing of the dryers 65 and 75. Thus when the auxiliary dryer 105 is arranged to remove moisture under these unusual conditions the induction means cooperates therewith in permitting effective circulation of the air through dryers 105 and 75, thus facilitating the rapid removal of moisture.

It is therefore evident that the present invention is particularly advantageous in permitting the highly efficient employment of air at superatmospheric pressure as a mediating fluid within a refrigerating machine, permitting the air to be maintained in a dry condition or dried if it should become objectionably moist and preventing the interference of lubricating oil with the normal cyclic movement of the air.

It should be understood that the present disclosure is for the purpose of illustration only and that this invention includes all modifications and equivalents which fall within the scope of the appended claims.

I claim:

1. Apparatus of the class described, comprising a crank case, a cylinder, a piston reciprocable in the cylinder, an inlet in the crank case, a duct between the crank case and the interior of the cylinder above said piston, and valve means associated with said duct permitting the flow of fluid from the crank case to the interior of the cylinder in response to an increase in pressure within the crank case and a corresponding decrease in the pressure within the cylinder, said means preventing flow of fluid in the opposite direction.

2. Apparatus of the class described, comprising a crank case, a cylinder, a piston reciprocable in the cylinder, an inlet in the crank case, a duct between the crank case and the interior of the cylinder above said piston, and valve means associated with said duct, said means including a valve and a spring tending to close the valve, the valve means permitting the flow of fluid from the crank case to the interior of the cylinder in response to an increase in pressure within the crank case and a corresponding decrease in the pressure within the cylinder, said means preventing flow of fluid in the opposite direction, and means for adjusting the stress on the spring to vary the pressure at which the valve will open to permit flow through the duct.

3. Apparatus of the class described, comprising a crank case, a cylinder, a piston reciprocable in the cylinder, an inlet in the crank case, a duct between the crank case and the interior of the

cylinder above said piston, and valve means associated with said duct permitting the flow of gas from the crank case to the interior of the cylinder in response to an increase in pressure within the crank case and a corresponding decrease in the pressure within the cylinder, said means preventing flow of gas in the opposite direction, and an oil separator associated with said duct to prevent the passage of oil through the duct to the interior of the cylinder.

4. Apparatus of the class described, comprising a crank case, a cylinder, a piston reciprocable in the cylinder, an inlet in the crank case, a duct between the crank case and the interior of the cylinder above said piston, and valve means associated with said duct permitting the flow of gas from the crank case to the interior of the cylinder in response to an increase in pressure within the crank case, and a corresponding decrease in the pressure within the cylinder, said means preventing flow of gas in the opposite direction, and a dryer associated with said duct to remove moisture from the gas passing through said duct.

5. Apparatus of the class described, comprising a crank case, a cylinder, a piston reciprocable in the cylinder, an inlet in the crank case, a duct between the crank case and the interior of the cylinder above said piston, and valve means associated with said duct permitting the flow of fluid from the crank case to the interior of the cylinder in response to an increase in the pressure within the crank case and a corresponding decrease in the pressure within the cylinder, said means preventing flow of gas in the opposite direction, a dryer associated with said inlet to remove moisture from gas entering the crank case, and a second dryer associated with said duct to remove moisture received from the oil in the crank case.

6. Apparatus of the class described comprising a crank case, a cylinder, a piston reciprocating in the cylinder, a pump in the lower part of the crank case, said pump being arranged automatically to feed air into the crank case when the internal pressure in said case falls below a predetermined point, said pump having an outlet normally immersed in an oil body in the lower part of the case, a duct communicating with the upper part of the case and with the interior of the cylinder, a check valve adapted to prevent flow through said duct from the cylinder to the crank case, and permitting flow from the case to the duct as the piston moves downwardly and increases the pressure in the case to a point above that in the cylinder.

7. Apparatus of the class described comprising a crank case, a cylinder, a piston reciprocating in the cylinder, a pump in the lower part of the crank case, said pump being arranged automatically to feed air into the crank case when the internal pressure in said case falls below a predetermined point, said pump having an outlet normally immersed in an oil body in the lower part of the case, a duct communicating with the upper part of the case and with the interior of the cylinder, a check valve adapted to prevent flow through said duct from the cylinder to the crank case, and permitting flow from the case to the duct as the piston moves downwardly and increases the pressure in the case to a point above that in the cylinder, and an oil separator associated with the inlet end of said duct to prevent oil passing therethrough into the cylinder, whereby the average pressure in the cylinder is higher than that in the case to prevent oil from passing between the cylinder wall and piston into the chamber above the piston.

8. Apparatus of the class described comprising a crank case, a cylinder, a piston reciprocating in the cylinder, a pump in the lower part of the crank case, said pump being arranged automatically to feed air into the crank case when the internal pressure in said case falls below a predetermined point, said pump having an outlet normally immersed in an oil body in the lower part of the case, a duct communicating with the upper part of the case and with the interior of the cylinder, a check valve adapted to prevent flow through said duct from the cylinder to the crank case, and permitting flow from the case to the duct as the piston moves downwardly and increases the pressure in the case to a point above that in the cylinder, and an oil separator associated with the inlet end of said duct to prevent oil passing therethrough into the cylinder, whereby the average pressure in the cylinder is higher than that in the case preventing oil passing between the cylinder and piston, said piston having an upper portion of reduced diameter to provide an oil collection space, wherein any oil passing through the duct may be pocketed.

9. Apparatus of the class described comprising a crank case, a cylinder, a piston reciprocating in the cylinder, a pump in the lower part of the crank case, said pump being arranged automatically to feed air into the crank case when the internal pressure in said case falls below a predetermined point, said pump having an outlet normally immersed in an oil body in the lower part of the case, a duct communicating with the upper part of the case and with the interior of the cylinder, a check valve adapted to prevent flow through said duct from the cylinder to the crank case, and permitting flow from the case to the duct as the piston moves downwardly and increases the pressure in the case to a point above that in the cylinder, and a dryer associated with pump inlet to remove moisture from air entering the crank case.

10. Apparatus of the class described comprising a crank case, a cylinder, a piston reciprocating in the cylinder, a pump in the lower part of the crank case, said pump being arranged automatically to feed air into the crank case when the internal pressure in said case falls below a predetermined point, said pump having an outlet normally immersed in an oil body in the lower part of the case, a duct communicating with the upper part of the case and with the interior of the cylinder, a check valve adapted to prevent flow through said duct from the cylinder to the crank case and permitting flow from the case to the duct as the piston moves downwardly and increases the pressure in the case to a point above that in the cylinder, a dryer associated with pump inlet to remove moisture from air entering the crank case, and another dryer in said duct between the separator and valve to collect moisture received from the oil.

11. Apparatus of the class described comprising a crank case, a cylinder having a head, a pair of pistons in the cylinder, and means for causing relative movement between the pistons, a duct connecting a chamber between the pistons to a chamber between the outer piston and the cylinder head, a passage in the cylinder wall communicating with said duct, a check valve in said passage to permit flow away from the cylinder, a closure member normally threaded into the end

of said passage remote from the duct, whereby the check valve is normally inoperative, a passage communicating with the crank case, and a closure normally closing the last-named passage but removable therefrom, said closures being removable to permit the connection of drying means to the opening normally occupied by the closures, whereby air may flow through the passage from the cylinder and thus through the dryer into the crank case.

12. Apparatus of the class described comprising a crank case, a cylinder having a head, a pair of pistons in the cylinder, and means for causing relative movement between the pistons, a duct connecting a chamber between the pistons to a chamber between the outer piston and the cylinder head, a passage in the cylinder wall communicating with said duct, a check valve in said passage to permit flow away from the cylinder, a closure member normally threaded into the end of said passage remote from the duct, whereby the check valve is normally inoperative, a passage communicating with the crank case, and a closure normally closing the last-named passage but removable therefrom, said closures being removable to permit the connection of drying means to the opening normally occupied by the closures, whereby air may flow through the passage from the cylinder and thus through the dryer into the crank case, an induction duct between the interior of the crank case and the interior of the cylinder, a check valve associated with said duct to permit air flow to the cylinder, and a dryer associated with said induction duct, whereby air passing through said drying means to the crank case may pass through the dryer and return to the cylinder.

13. Apparatus of the class described, comprising a crank case, a cylinder having a head, a pair of pistons reciprocable therein and providing a compression chamber between the pistons and an expansion chamber between one of the piston and cylinder heads, passages between said chambers, a duct between the first-named chamber and the interior of the crank case, and a check valve in said duct permitting fluid flow from the crank case to said first-named chamber.

14. Apparatus of the class described, comprising a crank case, a cylinder having a head, a pair of pistons reciprocable therein and providing a compression chamber between the pistons and an expansion chamber between one of the piston and the cylinder heads, passages between said chambers, a duct between the first-named chamber and the interior of the crank case, a pump connected to the crank case and arranged to maintain air therein at a predetermined mean superatmospheric pressure, and means associated with said duct to maintain air within the cylinder at a predetermined mean pressure higher than the near pressure in the crank case.

15. Apparatus of the class described comprising a crank case, a cylinder secured to the crank case and having a head, a pair of pistons in the cylinder, and means for causing relative movement between the pistons, a duct connecting the chamber between the pistons with the chamber between the outer piston and the cylinder head, whereby relative movement of the pistons causes the movement of fluid through said duct between said chambers, a passage in the cylinder wall communicating with the interior of the cylinder including said chambers and said duct, a check valve in said passage to permit fluid flow away from the interior of the cylinder, and means normally closing the outer end of the passage but movable to open the same so that fluid may flow out of said chambers and duct to the exterior of the cylinder.

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