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ISOTHERMAL AIR COMPRESSOR

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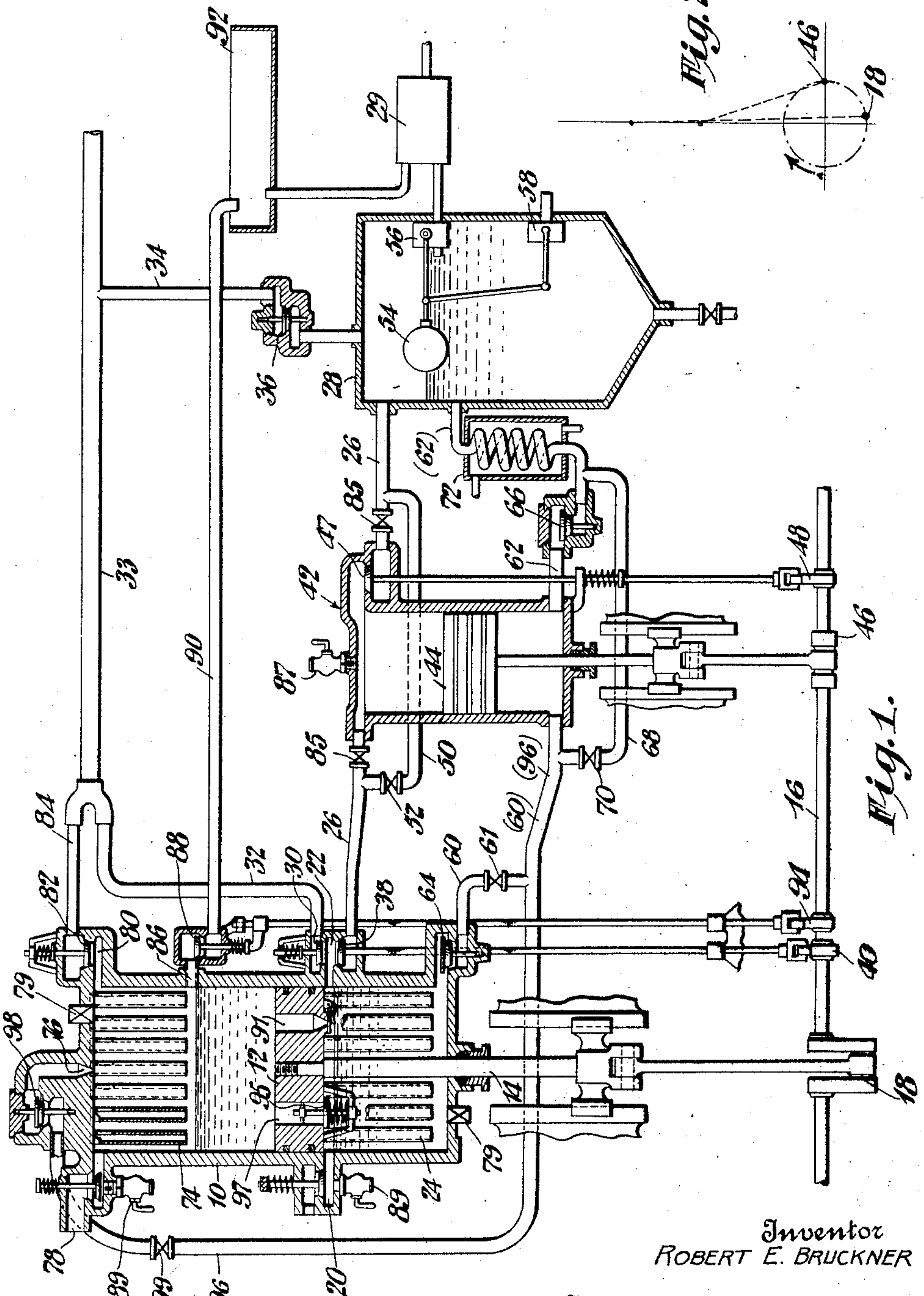

Fig. 2

Fig. 1.

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ISOTHERMAL AIR COMPRESSOR.

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This invention relates to means for compressing air or other gases substantially isothermally and the principal object of the invention is to provide a simple and practical apparatus for cooling the gases during their compression.

The invention will best be understood from the detailed description taken in connection with the accompanying drawing wherein the preferred form of the invention has been shown in a more or less diagrammatic manner.

Referring to the drawings,

Fig. 1 is intended to represent the combinative association of elements of the improved compressor system rather than the actual details of construction thereof, the view as a whole being a vertical section through the improved apparatus, some parts being in elevation.

Fig. 2 is a diagrammatic view showing the relative position of the cranks which reciprocate the compressor and pump pistons.

In accordance with the present invention the compressor cylinder is required to be of greater length than the working stroke of the piston in order to accommodate the means hereinafter described for absorbing the heat of compression. The compressor cylinder is generally indicated at 10, its piston at 12, and the piston rod for the latter at 14. The piston may be reciprocated by any suitable means as, for example, by a crank shaft 16 having a crank 18 coupled to the piston rod 14 in a conventional manner.

The compressor is preferably of the double acting type but as will hereinafter more fully appear, the construction is such that one side or the other of the compressor may be operated alone. The constructional features of the lower or crank-end side of the compressor will first be described. The piston rod 14 extends from the cylinder through any suitable type of stuffing box. The air enters and leaves the space below the piston through valve controlled ports both of which open on the cylinder wall at or near the lower limit reached by the piston. The air inlet port is indicated at 20 and the air outlet port at 22.

Depending from the underside of the piston are a plurality of elongated heat-absorbing members 24 which are adapted to absorb the heat of compression and transfer it to a cooling liquid maintained within the cylinder in the space below the lower limit reached by the piston. The heat-absorbing members dip into the cooling liquid as the piston reciprocates and are preferably of such length that their lower ends remain below the upper surface of the liquid at all times. Agitation or splashing of the liquid is thereby reduced to a minimum. The depth of the liquid and length of said members are of course such as to allow rapid transfer of heat from said members to the liquid. The upper maximum level of the liquid, when the piston is at the bottom of its stroke, is such that the clearance volume between the piston and liquid is as little as possible.

Various expedients may be resorted to for maintaining the cooling liquid at or below a given temperature. However, in view of the fact that fresh liquid must be added in order to compensate for the liquid unavoidably passing off with the compressed air, it is preferred to accomplish both requirements by continuously circulating a properly cooled liquid through the cylinder. In order to prevent collisioned impact between the piston and upper level of the liquid it is necessary to provide for the withdrawal of excess liquid. According to my invention this is accomplished by providing a valved port in the cylinder wall adjacent the point reached by the piston on its down stroke. For illustrative purposes, this port has been shown as part of port 22 but in actual practice the two ports will preferably be independent of each other. The bottom of this port is sufficiently below the lowermost point reached by the piston to insure its being well covered by liquid prior to the withdrawal of the excess liquid. The purpose of this arrangement will presently appear. The liquid entering this port is withdrawn through a conduit 26 leading from the bottom of said port and is subsequently recirculated as will presently appear.

In accordance with the present invention, the liquid withdrawn through the port 22 by way of conduit 26 is discharged into a closed tank 28 wherein the pressure is substantially the same as that of the compressed gas. The air outlet valve opening on the port 22 is indicated at 30. Leading from the discharge side of this valve is a conduit 32 through which the compressed air is led to a main line conduit 33. Between conduit 33 and tank 28 is a conduit 34 through which air which has entered the tank with the cooling liquid may pass into the compressed air line. Conduit 34 is preferably provided with a non-return valve 36 to prevent the flow of compressed air from the main line to the tank.

It is preferred that the liquid outflow conduit 26 be controlled by a valve 38 located in as close proximity as possible to the overflow port 22 in order to prevent back flow of liquid or air from the tank 28 on the upstroke of the piston. This valve is so synchronized with the piston 12 that it will be in open position when the piston is approaching the lower limit of its stroke and will close as the piston begins its upstroke. The opening and closing of the valve are preferably controlled by a cam 40 mounted on the driving shaft 16,—suitable power transmitting mechanism not necessary to be described being interposed between said valve and cam.

It is desirable that the excess cooling liquid be positively withdrawn from below the piston in order the more effectually to prevent danger of collisioned impact between the piston and cooling liquid. To this end there is interposed in the liquid outflow conduit 26 a pump generally indicated at 42. This pump is preferably of the reciprocating piston type and more particularly of the double acting type though only one side of the pump is utilized for liquid withdrawal purposes, the other side being utilized for introducing cooling liquid into the compressor as will presently appear. The piston is indicated at 44 and is reciprocated in synchronism with the compressor piston 12 by any suitable means as by a crank 46 on the main driving shaft 16 operatively connected with the piston in a conventional manner. The pump piston is so synchronized with the compressor piston that when the latter is at the lower limit of its stroke the pump piston is at the middle of its downstroke. This is accomplished by positioning the pump-piston crank 46 ninety degrees behind the compressor-piston crank 18. On the down stroke of the pump piston the excess liquid will therefore be positively drawn into the pump cylinder space above the piston and on the upstroke will be discharged to the tank 28. Valve 38 obviously serves as the inlet valve to the pump. The outlet valve is indicated at 47 and is shown as controlled by a cam 48 on the driving shaft 16.

In order that positive withdrawal of excess liquid may be the more readily effected as the pump piston moves downward, the inlet end of the conduit 26 leads from the bottom of the port 22 and the latter is preferably dished as indicated to form as it were a shallow reservoir for the liquid. Immediately after the accumulated excess liquid has been withdrawn, compressed air will also rush into the pump but this is of no particular consequence since it is eventually returned to the main line from tank 28. When pump 42 is interposed in the conduit 26 it is not of any great importance whether the discharge end of the conduit 26 is above or below the level of outlet port 22 or whether it is above or below the upper level of the liquid in the tank 28. It is, however, preferred that the outlet end of the conduit 26 enter the tank 28 at a point above the liquid level in the tank and that such point be not above the outflow port 22. In other words, it is preferred that the arrangement be such that if the pump is not functioning whether designedly or not the excess liquid will flow from the overflow port 22 to the tank 28 by gravity after valve 38 is opened. In order to pass the excess liquid directly to the tank without the necessity of passing through the pump cylinder, a shunt line or by-pass 50 is provided around the pump. This by-pass has a valve 52 therein which will be kept closed when liquid withdrawal by the pump is desired. It will now be appreciated that the excess liquid may be withdrawn by gravity independently of the pump or by the positive action of the pump as may be desired.

In order to keep the liquid in the tank from rising above the level of the outflow port 22 or more properly speaking above the discharge end of the conduit 26 and thereby interfering with the gravity flow of the excess liquid, the tank is provided with a float 54 which controls a liquid inlet valve 56 and a vent valve 58. If there is an excess of liquid in the tank the float on rising will open the vent valve. Inasmuch as the liquid circulating system is a closed system only enough fresh cooling liquid need be introduced thereinto to compensate for such liquid as is carried out by the compressed air into the main line.

As previously indicated the pump 42 is preferably of the double acting type. Inasmuch as positive circulation of the cooling liquid is preferred, the crank-end or lower side of the pump is utilized for this purpose. The pump receives its supply of cooling liquid from the tank 28 and delivers it into the compressor cylinder at some appropriate point as near the lower end of the cylinder. The liquid delivery conduit between the pump and compressor cylinder is indicated at 60 and that between the tank and pump at 62. Instead of providing the pump outlet non-return valve in the pump proper it is preferred to place such valve in close proximity to the compressor cylinder as indicated at 64. The pump inlet non-return valve may be positioned in the pump proper as usual or in the inlet side of the conduit 62 as indicated at 66. In order to regulate the amount of cooling liquid flowing from the pump to the compressor a shunt or by-pass 68 having a regulating valve 70 therein may be provided around the pump whereby some of the liquid may be returned to the tank 28 or the conduit 62 as shown. A regulating valve 61 may also be provided in the conduit 60.

In order to bring the cooling liquid to the proper temperature before introducing it into the compressor, suitable means are provided for cooling the liquid. As shown in the drawings, the conduit 62 between the tank and pump is passed through a cooling tank generally indicated at 72.

The mode of operation of the mechanism thus far described will be readily understood without further explanation. Attention should, however, be called to an important relation between the means for supplying the cooling liquid to the compressor and the means for withdrawing the excess liquid from the latter. It will be noted that the piston rod side of the pump is utilized for entering the cooling liquid to the compressor. This side of the pump has obviously a less volumetric capacity than the piston head side of the pump due to the space taken up by the piston rod. The arrangement therefore provides a means permitting the withdrawal from the lower end of the compressor cylinder of more liquid than is directly introduced thereinto by the pump. Danger of collisioned impact between the compressor piston and the liquid therebeneath is therefore reduced to a minimum. Another advantage of said relation will more fully appear in connection with the description of the upper part of the compressor.

The upper side of the compressor will now be described. Depending from the upper cylinder head of the compressor cylinder are a plurality of heat-absorbing members 74. A body of cooling liquid is maintained above the compressor piston 12. As the piston rises these members become immersed in the cooling liquid. The heat of compression of the gas is therefore taken up by the cooling liquid. The depth of the cooling liquid at the time the piston reaches the upper limit of its stroke is such that there is a minimum clearance volume between the cylinder head and the upper surface of the liquid above the piston. Cooling liquid is introduced through the cylinder head preferably in the form of a spray, the point of entry being indicated at 76. The air to be compressed enters the cylinder through a valved port 78 and after compression is discharged therefrom through a valved port 80 from above the valve 82 of which leads a conduit 84 through which the air is conducted to the main line 33.

In the cylinder wall at a point a little below that reached by the piston on its upstroke is a valved port 86 through which liquid above the level of said port is withdrawn when the piston is at the lower part of its stroke. The excess liquid flows out by gravity when a valve 88 which controls said port is open. A conduit 90 leads from the discharge side of said valve to an open tank 92 from which it may be taken by a booster pump 29 and delivered into the tank 28 when the float controlled inlet valve 56 is open.

The outflow port 86 is positioned somewhat lower than the upper point reached by the compressor piston to compensate for the cooling liquid which is introduced above the piston during its upstroke. The amount of liquid thus introduced will be enough to increase the depth of the liquid above the piston sufficiently to reduce the clearance volume between the cylinder head and upper level of the liquid to a minimum at the time the piston is at the upper limit of its stroke.

The valve 88 for port 86 is controlled as to opening and closing as by means of a cam 94 on the driving shaft 16. The cam is so constructed that the valve will be kept closed on the up compression stroke of the piston and will open when the piston moves toward the lower limit of its stroke.

Cooling liquid is delivered to the upper end of the cylinder through a conduit 96 leading from the lower side of the pump 42. A non-return valve 98 for this conduit is placed in as close proximity to the point of entry of the liquid into the cylinder as possible. A regulating valve 99 is also provided at a suitable point in said conduit to permit control of the amount of liquid delivered to the cylinder.

Inasmuch as there is no positive withdrawal of cooling liquid from above the compressor piston at the time it is completing is upward compression stroke, it is desirable to provide means for quickly venting from above the piston any excess liquid existing therein at the time the piston is at the upper limit of its stroke in order to prevent damage to the compressor by collisional impact between the upper cylinder head and upper surface of the cooling liquid. Such means preferably take the form of a plurality of valved-controlled piston passages 97. The valves for controlling these passages are conveniently placed at the under side of the piston as indicated at 95. Stiff springs beneath the valves keep them closed at normal pressures. It is preferred that the springs be so tensioned that the valves will open one after the other under progressively increasing pressures. This arrangement provides a simple and effective means for relieving the upper compression space of such excess liquid as would cause collisional impact.

The compressor piston is also preferably provided with a plurality of passages 91 with restricted bottom openings. These passages will hold liquid and hence will effectually seal the passages against the passage of compressed air on the upstroke of the piston but will nevertheless permit liquid to continually pass through the restricted openings in the form of fine jets or spray. The air drawn by the lower side of the compressor on the upstroke of the piston will therefore be appreciably cooled by the spray jets. On the down compression stroke of the piston some air will pass through the restricted openings but in such negligible quantity as to be of no particular moment. In order to obviate this minor objective non-return valves such as flap valves may be positioned below the passages 91 but at some sacrifice to satisfactory spraying of the liquid.

In view of the fact that liquid above the piston passes continuously through the restricted passages 91 in the piston and that liquid may under certain circumstances pass through the valved passages 97, the advantage of having a pump 42 of greater volumetric liquid withdrawal capacity than liquid input capacity will be readily appreciated. It will of course be understood that separate pumps one for withdrawing the excess liquid and one for introducing it into the compressor may be provided and that the relative volumetric capacities of the pumps may be varied as desired to obtain the end in view.

It will now also be clear that the one side or the other of the compressor may be operated alone. When one side of the compressor is to be idle, air should be allowed free ingress and egress as for example through a cock 89 opening on the proper air inlet port. As previously mentioned, instead of using the liquid withdrawal-side of pump 42 for positive withdrawal of excess liquid, the liquid may be shunted around the pump. In such event air should be allowed ingress and egress into the liquid withdrawal side of the pump as through a cock 87 in the top-cylinder head. Shut-off valves 85 on both sides of pump should then also be closed for obvious reasons.

The heat absorbing members 74 and 24 have been shown as tubes open at their lower ends and perforated at their upper ends to permit free flow of fluid therethrough. The invention is however not limited to any particular form of heat absorbing members. For example they may take the form of solid rods or concentric tubes of sheet material or other equivalent arrangement. Safety valves 79 may be provided in the compressor cylinder heads for obvious reasons.

The mode of operation of the compressor may be briefly reviewed as follows. It will be observed that the compressor piston has been shown as at the lower limit of its downward compression stroke. Inasmuch as the pump piston 44 is descending, cooling liquid is forced into the lower compression space and is also being withdrawn therefrom by the upper side of the pump, it being remembered that the valve 38 at the bottom of the outflow port 22 is open when the compressor piston is at the lower limit of its stroke as shown. Cooling liquid is also being introduced into the upper side of the compressor at this time as will be readily understood from the connections shown and is also being withdrawn from the upper compression space through the outflow port 86, it being remembered that the valve 88 which controls this port is open when the compressor piston is at the lower limit of its stroke. If it is desired to operate only the lower side of the compressor, the valve 99 in the conduit 96 through which liquid is supplied to the upper compression space of the compressor is closed and the cock 89 associated with the air inlet 78 opened. On the other hand, if it is desired to operate only the upper side of the compressor, the valve 61 in the conduit 60 is closed and the cock 89 associated with the air inlet conduit 20 is opened. The cock 87 on the upper side of the pump 42 is also opened and the valves 85 in the conduit 26 preferably closed as is also the valve 52 in the shunt 50. It is believed that the mode of operation of the compressor system will now be fully understood without any further labored explanation.

Various changes in details of construction may obviously be made without departing from the spirit of the invention. No limitations as to details of construction are therefore intended except as may be defined in the appended claims.

What is claimed is:

1. In a gas compressor, the combination with an upright cylinder and a reciprocable piston therein, of heat absorbers depending from the piston and adapted to transfer the heat of compression directly to a body of cooling liquid maintained within the cylinder below the piston.

2. In a gas compressor, the combination with an upright cylinder and a reciprocable piston therein, of heat absorbers depending from the piston and adapted to transfer the heat of compression directly to a body of cooling liquid maintained within the cylinder below the piston, and means for venting cooling liquid above a predetermined maximum amount from the cylinder.

3. In a gas compressor, the combination with an upright cylinder and a reciprocable piston therein, of heat absorbers depending from the piston and adapted to transfer the heat of compression directly to a body of cooling liquid maintained within the cylinder below the piston, and means for venting cooling liquid above a predetermined maximum amount from the cylinder, said means including a liquid outflow passage in the cylinder wall at a point adjacent the lowest point reached by the piston on its down stroke.

4. In a gas compressor, the combination with an upright cylinder and a reciprocable piston therein, of heat absorbers depending from the piston and adapted to transfer the heat of compression directly to a body of cooling liquid maintained within the cylinder below the piston, and means for maintaining the cooling liquid at a predetermined temperature.

5. In a gas compressor, the combination with an upright cylinder and a reciprocable piston therein, of heat absorbers depending from the piston and adapted to transfer the heat of compression directly to a body of cooling liquid maintained within the cylinder below the piston, and means for passing the cooling liquid through the cylinder.

6. In a gas compressor, the combination with an upright cylinder and a reciprocable piston therein, of heat absorbers relatively movable with respect to a body of cooling liquid maintained within the cylinder, said absorbers adapted to transfer the heat of compression directly to the liquid, and means for controlling the amount of said liquid within the cylinder.

7. In a gas compressor, the combination with an upright cylinder and a piston reciprocable therein, of means for maintaining within the cylinder a body of cooling liquid below the lowermost point reached by the piston, and means carried by the piston for transferring the heat of compression directly to the liquid.

8. In the gas compressor, the combination with an upright cylinder and a piston reciprocable therein, of means for maintaining within the cylinder a body of cooling liquid below the lowermost point reached by the piston, a port in the cylinder wall through which liquid above a predetermined amount may flow from the cylinder, a valve synchronized with the piston movement for controlling the outflow of liquid through said port, and means movable with the piston for transferring the heat of compression directly to the liquid.

9. In a gas compressor, the combination with an upright cylinder and a reciprocable piston therein, of means for maintaining within the cylinder at a level short of that reached by the piston on its downstroke a body of cooling liquid for receiving the heat of compression, and means movable with the piston adapted to absorb the heat of compression and transfer it to the cooling liquid.

10. In a gas compressor, the combination with an upright cylinder and a reciprocable piston therein, of means for maintaining a body of cooling liquid below the piston, a liquid outflow port in the cylinder wall, means for withdrawing through said port all liquid above a predetermined level, and means for transferring the heat of compression directly into the body of the liquid.

11. In a gas compressor, the combination with an upright cylinder and a piston reciprocable therein, of heat absorbing members carried by the underside of the piston and adapted to dip into a cooling liquid maintained below the piston to transfer the heat of compression to said liquid, a closed tank, means for transferring cooling liquid above a predetermined level in the cylinder to said tank, and means for withdrawing liquid from said tank and delivering it to the body of liquid within the cylinder.

12. In a gas compressor, the combination with an upright cylinder and a reciprocable piston therein, of means for introducing cooling liquid into the cylinder, means acting during a portion of the stroke of said piston and capable of withdrawing liquid from the cylinder at a higher rate than it is supplied thereto by said means, means for maintaining a predetermined liquid level in the cylinder, and means carried by the piston and adapted to transfer the heat of compression to the cooling liquid by direct contact therewith.

13. In a gas compressor, the combination with an upright cylinder and a reciprocable piston therein, of heat absorbers depending from the piston and adapted for immersion in a cooling liquid when the piston is at the bottom of its stroke, and means for maintaining a predetermined maximum amount of said liquid in the cylinder.

14. In a gas compressor, the combination with an upright cylinder and a reciprocable piston therein, of heat absorbers depending from the upper cylinder head and adapted for immersion in a cooling liquid when the piston is at the upper limit of its stroke, means for maintaining a body of cooling liquid of a predetermined depth above the piston and means for reducing the depth of said liquid on the down stroke of the piston.

15. In a gas compressor, the combination with an upright cylinder and a reciprocable piston therein, of heat absorbers depending from the upper cylinder head and adapted for immersion in a cooling liquid when the piston is at the upper limit of its stroke, means for maintaining a body of cooling

liquid of a predetermined depth above the piston, and a liquid outflow port in the cylinder wall adjacent the point reached by the piston on its upstroke for reducing the depth of the liquid at a predetermined time.

16. In a gas compressor, the combination with an upright cylinder and a reciprocable piston therein, of heat absorbing means depending from the upper cylinder head and adapted for immersion in a cooling liquid when the piston is at the upper limit of its stroke, heat absorbing means depending from the underside of the piston and adapted for immersion in a cooling liquid when the piston is at the lower limit of its stroke, passages in the piston through which liquid from above the piston may pass in restricted amount to the compression space below the piston, and means for maintaining a predetermined amount of cooling liquid on both sides of the piston.

17. In a gas compressor, the combination with an upright cylinder and a piston reciprocable therein, of heat absorbing members in the compression spaces on both sides of the piston, said members being relatively movable with respect to bodies of cooling liquid maintained in said spaces on both sides of the piston and adapted to be immersed in the liquid bodies with respect to which they are relatively movable at the given positions of the piston, means providing for a given depth of said liquid bodies at the completion of each compression stroke of the piston, and means for decreasing the depth of said liquids when the piston is at a given point.

18. In a gas compressor, the combination with a double acting cylinder and a reciprocable piston therein, means including a cooling liquid for receiving the heat of compression, and passages in the piston through which cooling liquid in one compression end of the cylinder continually passes into the opposite compression end of the cylinder.

19. In a gas compressor, the combination with a cylinder and a reciprocable piston therein, means including a cooling liquid for receiving the heat of compression, and passages in the piston through which cooling liquid in one compression end of the cylinder continually passes into the opposite compression end of the cylinder, said passages having discharge outlets of less cross-sectioned area than the inlet ends thereof.

20. In a gas compressor, the combination with a cylinder and a reciprocable piston therein, means including a cooling liquid for receiving the heat of compression, passages in the piston through which cooling liquid in one compression end of the cylinder continually passes into the opposite compression end of the cylinder, and means for supplying cooling liquid to both compression ends of the cylinder from a source of supply outside of the cylinder.

21. In a gas compressor, the combination with a cylinder and a reciprocable piston therein, means including a cooling liquid for receiving the heat of compression developed in both compression ends of the cylinder, means for supplying cooling liquid to both of said compression ends at the same time, and means for withdrawing excess cooling liquid from both of said compression ends at the same time.

22. In a gas compressor, the combination with a cylinder and a reciprocable piston therein, means including a cooling liquid for receiving the heat of compression developed in both compression ends of the cylinder, means for supplying cooling liquid to both of said compression ends at the same time, and means for withdrawing excess cooling liquid from both of said compression ends at the same time that cooling liquid is being supplied thereto.

In testimony whereof I affix my signature.

ROBERT EARLL BRUCKNER.