Aug. 23, 1932. W. E. GOLDSBOROUGH 1,873,878

HIGH TEMPERATURE ADIABATIC COMPRESSOR

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Fig. 1.

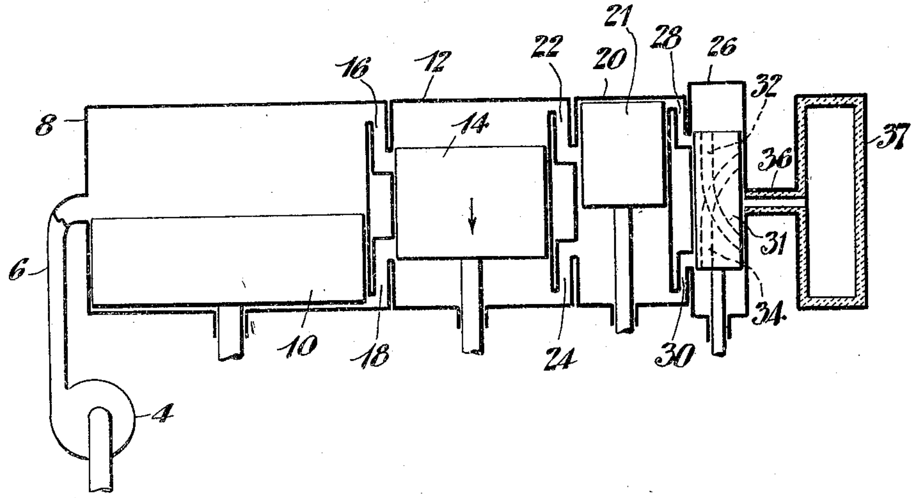

Fig. 2.

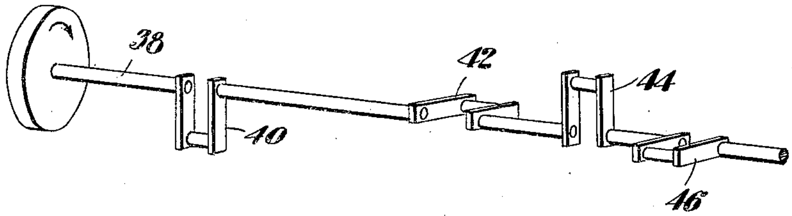

Fig. 4.

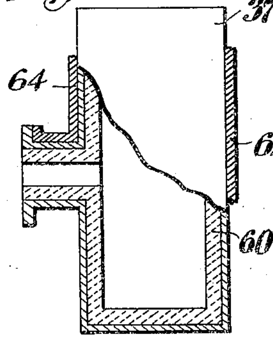

Fig. 5.

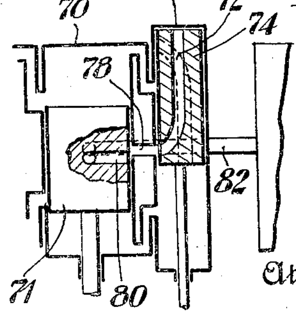

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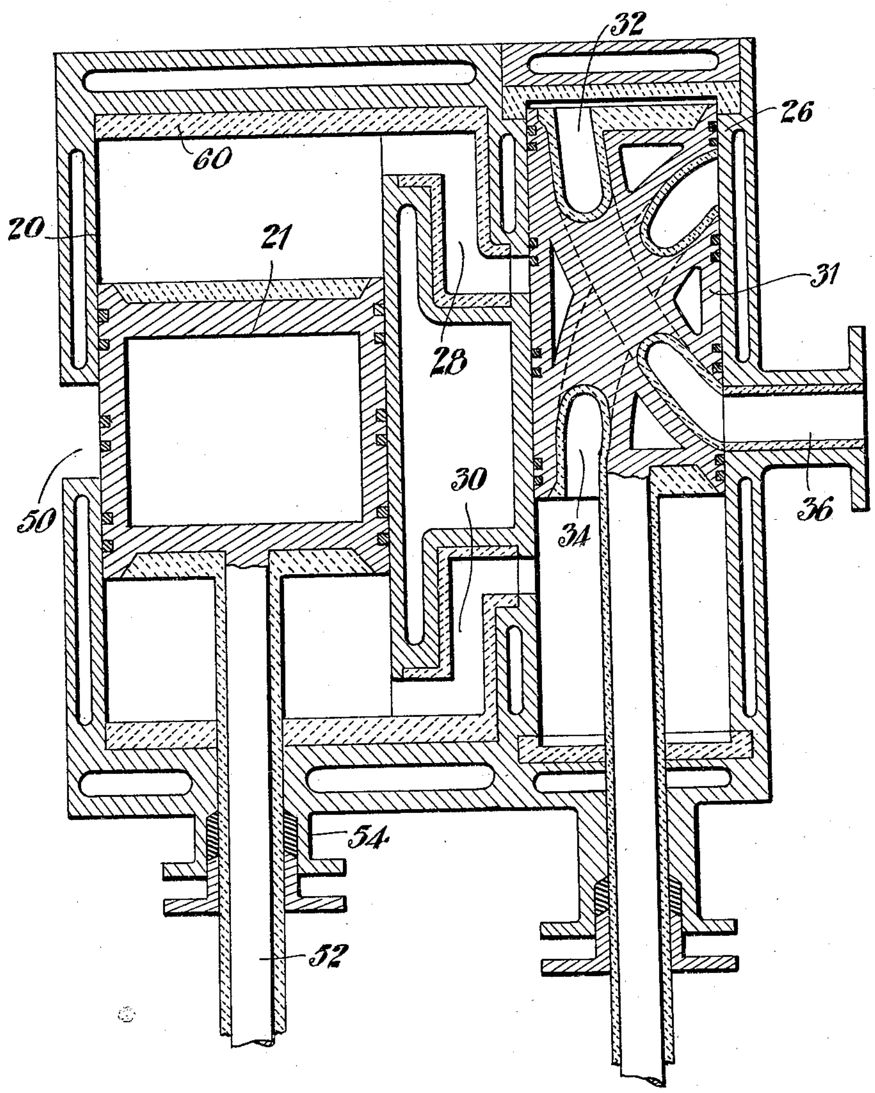
Fig. 3.



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UNITED STATES PATENT OFFICE

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HIGH TEMPERATURE ADIABATIC COMPRESSOR

Application filed August 21, 1928. Serial No. 301,086.

This invention relates to a high temperature adiabatic compressor.

In high pressure compressors heretofore proposed, it has been necessary to perform the compression in a plurality of stages and to provide for intercooling between the stages, in order to avoid the deleterious effect of highly heated air upon the discharge valves and passages. It has also been necessary to provide cooling jackets for the pump cylinders and cylinder heads to prevent them from being warped and scarred due to the high temperatures to which they would otherwise be subjected.

The cooling of the compressor cylinders of high pressure air or gas pumps has also been essential in order to maintain the capacity of the pump after it has been in operation long enough to become heated, it being found that the volumetric efficiency of an air compressor falls off greatly when the walls of the compressors are hot due to the fact that the air or other gas is heated during the suction stroke and its expansion at this time prevents the full capacity of the pump from being realized. In spite of this cooling there is considerable heating of the indrawn air during the suction stroke and the early part of the compression stroke. Later during the compression stroke after the air has become heated due to the combined effect of absorption from the cylinder walls and compression there is a transfer of heat in the opposite direction, that is from the air to the walls of the pump chamber. After a certain temperature difference has been attained the heat lost to the cylinder walls balances the heat added due to compression and a further rise in temperature of the air undergoing compression is impossible. Thus the usual air pump compresses air adiabatically during the first part of the compression stroke while toward the end of the stroke compression becomes practically isothermal.

It is the principal object of this invention to provide an adiabatic compressor which will avoid the difficulties above mentioned.

To this end the present invention provides a construction in which there is little loss of the heat of compression to the cylinder walls. This is achieved by coating those portions of the inner walls of the pump which are exposed to the hot gases at high temperature and pressure with a heat insulating refractory material. The coating prevents the loss of heat during that part of the stroke in which there is normally a considerable transfer of heat from the air undergoing compression to the walls of the compression space. While the entire cylinder may also be provided with a heat insulating refractory lining this is usually not necessary except in the final stage of a multi stage compressor since normally there is no transfer of heat from the air to the walls of the compressor during the first part of the compression stroke so that only those parts of the compressor which are exposed to the air after it has attained a pressure and corresponding temperature sufficient to cause an appreciable flow of heat from the air to the walls of the chamber need be coated.

In conjunction with the means for retaining the heat of compression this invention provides a valveless construction whereby the highly heated air or other gases may be discharged from the compressor or transferred from one stage to another without material loss of heat and without coming in contact with valves or other obstructions which would be damaged thereby.

In order to maintain the capacity of the pump after the heat insulating coating becomes hot there is provided a rotary or turbo blower for the first stage of compression so that the volumetric efficiency of the pump may be high regardless of the fact that there are hot surfaces in the pump chamber. To this end the first stage of compression may also be carried out in a low pressure reciprocating pump cylinder which may either form a part of the adiabatic compressor or be separately driven.

These and other objects will more fully appear from a consideration of the accompanying drawings in which:

Fig. 1 is a diagrammatic view of a double-acting multi stage compressor.

Fig. 2 shows the crank shaft in perspective and illustrates the relation of the cranks driving the pistons of the successive compression stages illustrated in Fig. 1.

Fig. 3 is a longitudinal section through the pistons and cylinders of a two stage double-acting compressor showing the disposition of the refractory material upon the walls of the compression spaces, piston heads, piston rods and passageways.

Fig. 4 is a side view of the receiver, parts being shown in section.

Fig. 5 is a longitudinal sectional view with parts shown in side elevation illustrating a modified form of the invention.

Referring to Fig. 1, 4 indicates a rotary or turbo-blower for supplying air through passage 6 which is connected with the side wall of cylinder 8. The cylinder 8 is closed at both ends forming a double acting cylinder and is provided with a double acting piston 10 reciprocative therein. The piston 10 is arranged to uncover the cylinder end of the passage 6 when in its lowermost position to permit air to be forced by the blower into the upper end of cylinder 8. Similarly when the piston 10 is in its uppermost position the passage is again uncovered and air is permitted to pass into the lower part of cylinder 8.

A second double cylinder 12 of less diameter than the cylinder 8 and having a double acting piston 14 reciprocable therein, forms the second stage of compression. Between the upper parts of cylinders 8 and 12 is a passage 16 one end of which opens into the clearance space of cylinder 8 and the other ending in a port in the wall of cylinder 12 which is uncovered by the piston 14 when in about the middle of its downward stroke, as in this figure. A similar passage 18 connects the lower ends of the two cylinders 8 and 12. A cylinder 20 and piston 21 provide a third stage of compression, the cylinder being somewhat smaller than cylinder 12 and having passages 22 and 24 connecting the upper and lower ends thereof with the corresponding ends of cylinder 12 in a manner similar to passages 16 and 18 between cylinders 8 and 12. A final stage of compression is provided by the cylinder 26. This stage resembles the previous stages in that the cylinder 26 is connected with the cylinder of the stage immediately prior thereto by a pair of passages 28 and 30. The double-acting piston 31 of the final stage is provided with a pair of passages 32 and 34 which extend from the upper and lower faces of the piston and terminate in ports in the side wall of the piston, which ports are so positioned as to register with the discharge passage 36 when the piston 31 is in its upper and lower dead center positions. The passage 36 leads to the usual air bottle or tank 37.

Fig. 2 shows a shaft 38 for driving the pistons 10, 14, 21 and 31 by cranks 40, 42, 44 and 46 which are connected to the pistons in the order stated by means of the usual piston and connecting rods. The cranks are so disposed upon the shaft 38 that when piston 10 is in its lower dead center position as shown, piston 14 will be in the middle of its stroke moving downwardly. Piston 21 will be at the top dead center and piston 31 will be in the middle of its stroke moving upwardly.

The operation of the compressor so far described is as follows:

When the parts are in the position shown in Figs. 1 and 2 air or other gas is forced by blower 4 through passage 6 into the upper end of cylinder 8. As the piston 10 moves upwardly covering passage 6 the piston 14 moves downwardly fully uncovering passage 16. Further upward movement of piston 10 forces the air in the upper end of cylinder 8 through passage 16 into the upper end of cylinder 12. By the time the crank pin of crank 40 which drives piston 10 has passed through 180° the piston 10 will be in its upper dead center position. All of the air from cylinder 8 will have been forced into cylinder 12. The crank pin of crank 42 will also have moved through 180° and the piston 14 driven thereby will be in the middle of its stroke moving upwardly. Thus as the piston 10 reaches its upper dead center forcing the air from cylinder 8 into cylinders 12 and 20, the piston 14 will close the transfer passage 16 preventing backflow of air from the cylinder 12 into cylinder 8 as piston 10 moves downwardly. At this point the piston 21 will be in its lowermost position. As the piston 14 moves upwardly through the remaining half of its upward stroke the air in cylinder 12 will be forced through passage 22 into cylinder 20. When piston 14 reaches upper dead center the piston 21 which lags behind it one half of a stroke, will close passage 22. Further upward movement of piston 21 forces the air from cylinder 20 through passage 28 into cylinder 26. The piston 31 which reciprocates in cylinder 26 closes passage 28 when piston 21 reaches its upper dead center thereby trapping the entire air charge in cylinder 26. On further upward movement of piston 31 the air in cylinder 26 receives its final stage of compression and as the piston approaches its upper dead center position the passage 32 registers with the passage 36 and the air is discharged through this passage into the receiver 37.

A piston valve, one form of which will be hereinafter described in connection with Fig. 5, may be provided in passage 36 to prevent backflow of air from receiver 37 into cylinder 26 during the brief interval in which the piston 31 is moving downwardly and the passage 32 is partially open to passage 36. Such valve is not essential however as a certain time must elapse before a reversal of flow may occur in passage 36 and only a relatively small backflow will occur before the passage 32 is completely out of register with passage 36 when the compressor is being driven at a fair speed.

The operation of the lower ends of the double-acting cylinders is the same as that described in connection with the upper ends as will be readily understood.

It will be seen that any number of intermediate compression stages may be used. In most cases for the best results the crank driving the piston of any stage should be given a lag of about 90° behind the crank of the stage immediately prior thereto. Thus as shown in Fig. 2 crank 42 lags 90° behind crank 40, crank 44 is in turn 90° behind 42 and crank 46 is 90° behind crank 44. The same relation may hold true for any number of cylinders.

While it is to be preferred that the piston lag of each succeeding stage shall be 90° behind that of the immediately preceding stage, it is possible and in some cases desirable to have a different angle of lag by disposing the discharge end of each transfer passage so that it will be closed at the proper moment. For example, if the piston 14 lags behind piston 10 to an extent equivalent to a crank angle of 120°, the piston will reach its upper dead center position when the piston 14 is 120° from top dead center and the passage 16 must accordingly be disposed so that the end opening into cylinder 12 will be closed by piston 14 at this moment. The same principle applies to any other angle of lag.

Figure 3 shows in detail the application of the refractory heat insulating material 60 to the cylinder and piston heads and to the transfer and piston passages. In this figure two stages of compression are shown which correspond to the last two stages in Fig. 1. In this case the piston 21 reciprocating in cylinder 20 controls the inlet port 50 which may lead to a rotary blower or turbo-blower or directly to the atmosphere. The head of the piston 21 is coated with a heat insulating refractory material and the same is also applied to the inner wall of the cylinder head. On the lower portion of the piston 21 the heat insulating material is also applied to the piston rod 52. As shown in the drawings the material is applied for the entire length of the rod which passes through the packing gland 54. It will be readily understood that the insulation of the piston rod may be limited to that portion which is exposed in the clearance space of the cylinder when the gases are at high pressure. The insulating material is also applied to the transfer passages 28 and 30 and to the passages 32 and 34 in the piston 31. The side walls of the cylinders 20 and 26 against which the piston rings contact are metal as in the usual construction. These side walls are not exposed to the compressed gases while they are at sufficiently high temperature for material heat transfer to occur during the time available, and therefore need not be protected like the portions of the compression chamber which are exposed to the gases when the piston 31 approaches its upper dead center position as shown in this figure. The discharge passage 36 with which the passages 32 and 34 register when piston 31 is in its upper and lower dead center positions, respectively, is also coated with a heat insulating refractory material to prevent its destruction by the highly heated gases passing therethrough. The passages 32 and 34 end in the side walls of piston 31 at points between two sets of piston rings which prevent the loss of compressions to the opposite ends of the cylinder.

Refractory material may be applied to the inner wall of tank or air bottle 37, as shown at 60 in Figure 4. An exterior lagging 64 may also be applied on the outside of the tank to further retard any loss of heat therefrom. This structure permits of a temperature of the gas or air in the tank of 3,000° or more since the interior coating keeps the gases from contact with the metallic walls thereof and causes a temperature drop between the gas and the metal of 2,000° to 2,500°. The metal is therefore subjected to a temperature of between 500° and 1,000°, a temperature range which it can readily stand. The lagging 64 prevents rapid radiation from the metal wall to the atmosphere.

Figure 5 illustrates a slightly modified structure in which a piston 71 which corresponds to piston 21 in Figure 1 acts as a piston valve between the last stage of compression and the air receiver. In this construction a passage 72 in a piston 74 registers with a passage 78 leading from the side wall of cylinder 76 to the side wall of cylinder 70. The piston 71 is provided with a passage 80 which is adapted to register simultaneously with passage 78 and with a passage 82 leading to the air tank when the piston 71 is in the middle of its stroke.

In the operation of this form of the invention the piston 74 is given a lag which is slightly more than 90°. When the piston 74 approaches its upper dead center position the piston 71 is in the middle of its stroke moving downwardly and the passage 80 is in full registry with passage 82. The passage 72 is at this point being moved into registry with passage 78 and air compressed in the upper compression space of cylinder 76 passes through passages 72, 78, 80 and 82 into the air receiver. As the piston 74 reaches its upper dead center position the passage 80 in piston 71 is moved out of registry with passage 78, the position of the parts at this point being shown in the figure. Communication between cylinder 76 and the air receiver is now cut off so that upon the downward movement of piston 74 a reversal of flow of the air will be impossible. The operation of the lower ends of the double-acting cylinders 70 and 76 will be readily understood from the description of the operation of the upper ends.

It will be understood that in either of the above constructions that unless the air compressed in the air receivers is to be immediately used, that suitable means will be provided to cut off communication between the tank and the compressor during periods when the compressor is not in operation, for the purpose of preventing losses around the pistons of the compressor and to avoid the possibility of the air driving the compressor as a motor.

By the provision of means whereby the heat of compression will be conserved thereby obtaining substantially adiabatic compression, in conjunction with means capable of transferring and discharging the compressed gases while at the high temperature resulting from such adiabatic compression, this invention provides a compressor capable of generating and delivering a blast of highly heated air.

It will be seen that compressors constructed in accordance with the above disclosure will have numerous uses. It is particularly advantageous in connection with internal combustion engines of the type in which compressed air is used in starting. By the use of a compressor of the type disclosed herein, the refrigeration of the engine cylinders by the expansion of cold compressed air during the starting period will be avoided. It is also particularly desirable for use in connection with engines operating in conjunction with a recuperator which must be heated before the engine can be started, and in many other places where a blast of highly heated air is needed as in certain chemical processes.

While I have shown a double-acting multi-stage compressor it may be seen that single-acting construction may be obtained by obvious omissions from the construction shown, and that while the coating of parts of the compressor with refractory material has particular advantages in connection with the valveless compressor shown it may also be used in other types of compressors.

Other modifications within the scope of the following claims will readily suggest themselves to those skilled in the art.

Having described the invention what is claimed as new is:

1. In a high temperature compressor, a cylinder, a piston reciprocative therein, valveless means for the admission and discharge of gases to said cylinder, means for heat-insulating the cylinder and piston walls which are exposed to the compressed gases at high temperature and pressure for conserving the heat of compression and protecting said walls.

2. In a high temperature compressor, a cylinder, a piston reciprocative therein, an inlet passage leading to said cylinder and a discharge passage leading therefrom, a passage through said piston having one end opening into the interior of said cylinder and the other end adapted to register with said discharge passage toward the end of the compression stroke of said piston, means for heat-insulating the walls of said cylinder, piston and passages which are exposed to the compressed gases at high temperature and pressure for conserving the heat of compression and protecting said walls.

3. In a high temperature compressor a cylinder, a piston therein and forming a compression space therewith, means composed of a heat-insulating refractory material for protecting the metallic walls of said compression space of said cylinder from highly heated gases, and means for maintaining the volumetric efficiency of the compressor when the refractory material becomes hot during the course of operation.

4. In a multi-stage compressor, a high pressure cylinder and a low pressure cylinder each providing a compression space in the interior thereof, a piston reciprocative in said low pressure cylinder, an air admission passage leading into the low pressure cylinder and having a port adapted to be uncovered by said piston when the same is at the end of its suction stroke, a discharge passage leading from the compression space of said low pressure cylinder and terminating in a port in the wall of said high pressure cylinder, a piston in said high pressure cylinder adapted to cover and uncover said port in the middle of its compression and suction strokes respectively.

5. In a multi-stage compressor, the combination of a plurality of cylinders, pistons reciprocative in said cylinders, valveless passages connecting said cylinders, cranks driving said pistons, the crank of any piston having an advance of 90° ahead of the crank of the piston of the next succeeding cylinder.

6. In a multi-stage compressor, the combination of a plurality of cylinders, pistons reciprocative therein and forming therewith a plurality of successive compression stages, valveless passages between each cylinder and the cylinder of the next succeeding stage, and means for heat-insulating the walls of the cylinders of the higher stages of compression.

7. In a multi-stage adiabatic compressor, the combination of a plurality of cylinders, pistons reciprocative therein and forming therewith a plurality of successive compression stages, a valveless passage extending from each compression space of each cylin-

der, except the last, through the side wall of the cylinder of the next succeeding stage and terminating in ports controlled by the pistons in said cylinders, passages in the piston of the last stage, one end of each of which opens into a compression space of said last stage and the other end of each of which is adapted to register with a passage in the side wall of the cylinder when the piston is at an end of the compression stroke.

8. In a high pressure air compressor, a cylinder, a piston therein, a coating of heat-insulating refractory material upon the surfaces of said cylinder and piston which are exposed to the air after the same has been compressed to a high pressure and corresponding temperature.

9. In a system for the compression and storage of a gaseous fluid, the combination of an adiabatic compressor, a receptacle for storing gas, a passage between said compressor and said receptacle and a coating of heat insulating refractory material upon the inner walls of said passage and receptacle.

10. In a system for the compression and storage of a gaseous fluid, the combination of a compressor, a receptacle for storing gas, a passage between said compressor and said receptacle, and a coating of heat-insulating refractory material upon the inner walls of said compressor, of said passage and of said receptacle.

In testimony whereof I affix my signature.

WINDER E. GOLDSBOROUGH.