MULTI-PLUNGER RECIPROCATING PUMP

Inventors: Frederick W. Buse, Allentown; Warner E. Sensinger, Jr., Emmaus, both of Pa.

Assignee: Ingersoll-Rand Company, Woodcliff Lake, N.J.

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Primary Examiner—William L. Freeh
Attorney, Agent, or Firm—Robert R. Paquin; David W. Tibbott

ABSTRACT
A multi-plunger reciprocating pump having a cylinder head with internal manifolding and valving arrangement that permits removal of valves as units from selected pumps, valve bodies with bias porting, and studs in constant tension. A solenoid actuated rod may be added to unload the compression chambers by inhibiting the inlet or suction valve from seating.

6 Claims, 9 Drawing Figures
MULTI-PLUNGER RECIPROCATING PUMP

DESCRIPTION OF THE INVENTION

This invention relates to reciprocating pumps. More particularly the invention relates to a multi-plunger in-line reciprocating pump which provides economy in manufacture and servicing by internal manifolding and valving arrangement within a cylinder head permitting removal of the suction and exhaust valves as units from selected pumps, and which also includes valve bodies with bias porting providing increased thickness of walls separating high and low pressure areas, and studs in constant tension minimizing stress reversal to reduce this cause of fatigue failure.

Among the disadvantages of high pressure pumps subject to the continuous pulsation and shock inherent in reciprocating pumps is the external manifolding which results in greater assembly cost and more complicated disassembly to the service a single pump unit. In these pumps the inlet ports have generally been holes parallel to discharge ports and subject to failure at great pressure differentials. The studs that hold these assemblies together have been subjected to cyclical stresses with each stroke of the piston, a condition which results in premature failure due to fatigue.

These problems have been resolved in my invention through the use of a cylinder head with internal manifolding and valving arrangement, bias porting of the valve bodies, and an arrangement of the stuffing box-valve bodies and cylinder head which maintains the studs under a relatively constant tension governed by the outlet pressure of the pump.

It is the object of this invention to provide a multi-plunger in-line reciprocating pump with a novel arrangement that affords economy in manufacture and servicing.

Another object is to increase the thickness of the walls separating high and low pressure areas in the valve body.

Another object is to minimize stress reversal in the studs that hold the stuffing box, valve body and cylinder head together.

Still another object is to provide the inlet valve with an integral guide and/or with bias seating to improve sealing.

A further object is to arrange inlet and discharge valves entirely within the valve body to permit servicing them as a subassembly. Another object is to arrange the stuffing box and plunger in a subassembly for convenience in removal and servicing. Yet another object is to provide an unloading means to automatically reduce the pressure within the pump when it is shut off.

A better understanding of the invention will be had by referring to the following description and drawings in which:

FIG. 1 is an elevational view of a vertical in-line pump with three pistons;
FIG. 2 is an elevational cross-section of the cylinder head in FIG. 1;
FIG. 3 is an elevational cross-section of the pump of FIG. 1 taken along line 3—3 showing the piston and valving arrangement;
FIG. 4 is an enlarged fragmentary view of the valves in FIG. 3;
FIG. 5 is a plan view of a horizontal in-line pump with three pistons;
FIG. 6 is a plan view in cross-section of the cylinder head in FIG. 5;
FIG. 7 is a plan cross-section of the pump in FIG. 5 taken along line 7—7 showing the piston and valving arrangement;
FIG. 8 is an enlarged fragmentary view of the valves in FIG. 7;
FIG. 9 is a partial section of a pressure unloader.

In the drawings similar reference characters refer to corresponding parts in the several views. Referring to FIG. 1 a multi-plunger reciprocating pump 10 is seen to comprise a drive unit 12 and a cylinder head 14. FIG. 2 shows that the cylinder head 14 has a plurality of chambers 16, each opening through a common first face 18 of the head 14 and having a large diameter portion 20 and a smaller diameter portion 22. An inlet manifold 24 communicates with the larger diameter portions 20 and terminates in inlet ports 26 at second face 28 and third face 30 of the cylinder head. A discharge manifold 32 similarly communicates with the smaller diameter portions 22 of the chambers 16 and terminates in outlet ports 34 in faces 28 and 30. The manifolds 24, 32 are each generally sealed at one of the faces 28, 30 by an inlet port plug 27 and an outlet port plug 36.

FIG. 3 is an elevational cross-section showing the cylindrical valve body 38 positioned in one of the chambers 16 of the cylinder head 14. The valve body 38 has an inlet face 40 and a discharge face 42 which bears against a step in the cylinder head. As shown in FIG. 5, the valve body 38 has a stepped bore 44, which includes a bore step 46, a conical valve seat 48, and a valve seat annulus 50. The bore 44 further comprises an enlarged diameter portion 52, a discharge valve seat 54, a chamber or recess 56, and an outlet valve cavity 62. The valve body 38 has a suction annulus 57 in the outer periphery and inlet passages 58 providing communication between the suction annulus 57 and the bore 44. O-ring annuli 60 are provided in the cylindrical periphery and the discharge face 42 of the cylindrical valve body.

A funnel-shaped inlet valve 64 is slidably located at the inlet end of the valve body bore 44. It comprises a cylindrical portion 66 having a first annular recess 68, and a conical portion 70 having a second annular recess 72. An inlet valve bore 74 communicates with the first annular recess through ports 76, and the wide end of the conical portion is provided with inlet valve slots 78. When the valve is in the closed position, the second annular recess 72 mates with the valve seat annulus 50 of the valve body.

A stuffing box 80, having a step bore 82, mates along a first face 84 with the valve body inlet face 40. At the first face the bore has an enlarged diameter defining a chamber and step for a valve stop 104. A second face 88 of the stuffing box has an annular projection 90 which locates gland ring 130. Within the stuffing box bore 82 are packing 92 and a sleeve 94. The sleeve bore 96 partially defines a cylinder or compression chamber 98. An end face of the sleeve 100 provides a bearing surface for the inlet valve spring 110 and the valve stop 104. A piston 102 is slidable and coaxially positioned in the cylinder head 98.

The cyndrical stop 104 comprises a stepped bore 106 which retains inlet valve spring 110 and a step face 108 which provides a bearing surface that limits the
axial movement of the inlet valve 64 during the suction stroke of the piston. A discharge valve 112 rests in the closed position on the valve seat 54, and is guided by discharge valve plug 114. The plug has a stepped bore 116 which includes discharge valve retainer cup 118 at one end and a cavity for the discharge valve spring 120 at the other end. The plug is slidable positioned in the discharge valve spring retainer 122 and is coaxial with it and all the cylindrical elements described hereto.

The discharge valve spring retainer 122 has a threaded diameter 124 which engages the outlet valve cavity of the valve body 62. A sealing flange 126 partially defines an O-ring recess with the annulus 60 in the valve body discharge face 42. Studs 132 threadedly engage cylinder head 14 and gland ring 130 thereby compressively binding the gland ring, stuffing box, valve body and cylinder head.

An unloader system may be provided as shown in FIG. 9 comprising an unloader rod 140, actuated by a solenoid to control diaphragm cylinder 142 to move axially through an unloader port 144 in the cylinder head, the suction annulus 57, and one of the inlet passages 58 to valve seat annulus 50. A seal 146 in the unloader port 144 prevents leakage to the atmosphere.

In the horizontal modification shown in FIGS. 5 through 8, the cylinder head chambers 16 also communicate with a fourth face 31 of the cylinder head as shown in FIG. 6. This opening is sealed with a cylinder head plug 138 which has an O-ring annulus in the surface that interfaces with the fourth face of the cylinder head. Instead of a funnel configuration, the cylindrical valve body has a flat inlet valve seat 47 and a valve seat recess 49 which provides clearance and reduces the amount of lapping that is required. It is further provided with discharge passages 59 which are biased to increase material thickness in the guide portion and facilitate machining. The discharge valve spring retainers described in the vertical pump is eliminated. The inlet valve is cylindrical, its body serving as a guide, and has a flat seal 77. As the valve stop has been eliminated, face 5 of the stuffing box serves as a spring abutment and inlet valve stop.

OPERATION OF THE INVENTION

In the operation of the pump of FIGS. 1 through 4, when the driving means retracts piston 102 in the stuffing box 80, the volumetric increase of compression chamber 98, decreases the pressure therein sufficiently to overcome the force of the inlet valve spring 110, so that inlet valve 64 moves axially toward the piston until it bears against step face 108 of valve stop 104. Fluid is drawn into the system through inlet port 26, inlet manifold 24, and the annular chamber defined by the annular recess 57 in cylinder valve body 38. From there the fluid moves through inlet passages 58 around the conical surface 70 of the inlet valve 64. Part of the fluid flows towards the second annular recess 52 in the valve through the inlet valve ports 76 to fill the inlet valve bore 74, while a greater volume is diverted around the conical portion 70 through the slots 78 in the end face of the inlet valve and fills the compression chamber 98. As the inlet pressure is lower than the pressure in the discharge manifold 32, discharge valve 112 is urged to its closed position against discharge valve seat 54 by the greater fluid pressure in the discharge manifold and by the discharge valve spring. The spring urges the discharge valve plug 114 axially toward the piston 102 within the stepped bore 128 of the discharge valve spring retainer 122. As the discharge valve 112 is carried in the discharge valve retainer cup 118 of the discharge valve plug 114, proper seating of the valve on discharge valve seat 54 is assured.

During the discharge stroke the piston 102 is driven into the compression chamber 98 guided by stuffing box sleeve 94. Compression of the fluid impels inlet valve 64 axially. The cylindrical portion 66 is guided by the bore 44 of cylinder valve body 38. The conical portion 70 mates with conical valve seat 48, closing the inlet passages 58. Although the inlet manifold 24 is sealed off from this piston during the compression stroke the intake fluid may flow around annular recess 57 in the cylinder valve body 38 and be diverted to another pump in-line and undergoing suction stroke. When the fluid pressure in the compression chamber 98 exceeds the combined force of the fluid in the discharge manifold 32 and the discharge valve spring 120 upon the discharge valve 112, the discharge valve plug 114 will move axially away from the piston 102 carrying the discharge valve with it and thereby allowing the fluid in the compression chamber 98 to discharge through the discharge manifold 32.

O-rings effectively seal the fluid from leakage at the interfaces of the various components, and packing 92 prevents leakage of the fluid from the compression chamber 98 past the piston. A gland ring 130 and studs 132 compressively mate the stuffing box, the cylinder head, and the cylinder valve body. Because the studs 132 are constantly in tension, fatigue failure due to cyclic reversal of stress is avoided, and therefore smaller diameter studs may be used than with conventional pumps. At the beginning of the intake stroke inlet fluid pressure upon inlet valve 64 is distributed evenly around the conical portion 70 because second annular recess 72 and conjoining valve seat annulus 50 provide communication between inlet passages 58. This prevents mis-alignment and uneven wear of the inlet valve. For servicing, the stuffing box and piston may be removed as a unit and worked on at a bench. Similarly the valves and valve body may be taken out as a unit to be worked upon separately. Leaving the cylinder head in place thereby avoids complicated disconnecting of manifolds.

When the pump is shut off for emergency or operational reasons the pressure built up in compression chambers 98 will continue to exhaust fluid into the discharge manifold until the internal pressure is reduced to that at outlet port 30. Where it is necessary to provide for immediate dumping of this pressure, the unloading system projects an unloader rod 140 a predetermined distance beyond valve seat annulus 50 thereby preventing the seating of inlet valve 64. As communication between compression chamber 98 and suction annulus 57 is open, the internal pressure is prevented from rising above inlet pressure. During normal operation of the pump, solenoid 142 retracts rod 140 sufficiently to allow proper seating and sealing of valve 64. At all times seal 146 prevents leakage of the fluid to atmosphere through the cylinder head unloader port 144.

In reciprocating pumps with conventional manifolding, the studs join the stuffing box to a working barrel which contains the compression chamber. Thus, the force transmitted through the box to the gland
studs fluctuates as the pressure in accordance with the chambers fluctuates. In this invention, the force transmitted to the gland 130 through the stuffing box 80 is the relatively constant force of the discharge fluid working to separate valve body block 38 from cylinder head 14. This force places studs 132 in fairly constant tension, reducing the cyclical reversals that cause fatigue failure and thereby permitting the use of smaller diameter studs.

In the horizontal modification of the pump the cylinder head plug 138 may be removed providing ready access to the discharge valve and valve plug assembly. The operation of this modification differs in the fluid flow within the valve body because of the modified inlet valve and discharge passage structure. On the intake stroke of the piston the inlet valve is opened by the pressure differential between the inlet manifold 24 and compression chamber 98. The cylindrical portion of the valve 66 guides its axial movement in the enlarged diameter 62 of the valve body. Bearing face 100 in the stuffing box which serves as an abutment surface for this modification with the valve in the open position inlet fluid flows through inlet passages 58 partially diverting around inlet valve seat 77 to the inlet valve bore 74 and to valve body bore 44, and partially through annular recess 56 in the valve body through inlet valve ports 76 to the compression chamber 98. During the compression stroke of the piston the inlet valve is axially moved to close upon the flat valve seat 47 in the valve body. The valve seat recess 49 and the recess 56 prevent binding of the valve in its closed position. The compressed fluid is forced through bore 44, opening discharge valve 112, and flows through discharge passages 59 to the discharge manifold 32.

From the foregoing description and the drawings, it can be seen that the objects of the invention have been achieved. While the preferred embodiments have been described with particularity, the details of construction presented here should not be regarded as limiting the scope of the claims which follow.

We claim:
1. A reciprocating pump comprising
   a. a cylinder head having
   b. a plurality of cylindrical chambers with
      1. a larger diameter portion communicating with
         and axially normal to the first face, and
      2. a smaller diameter portion coaxial with the
         larger diameter portion;
   c. an inlet manifold serially connecting the larger
      diameter portions of the chambers; and
   d. a discharge manifold providing communication
      between the smaller diameter portions; and for
      each said chamber
   2. a cylindrical valve body coaxially positioned in the
      chamber having
   a. an inlet face and a discharge face;
      b. a bore coaxial with the chamber terminating in
         a conical valve seat at the inlet face and an en-
         larged diameter at the discharge face, and having
         a second valve seat where the bore diameter
         changes;
   c. an annular recess aligned with the inlet manifold; and
   d. a plurality of inlet passages communicating between
      the annular recess and the conical valve seat;
   3. a funnel shaped inlet valve having
      a. a cylindrical portion dimensioned to permit reci-
         rocating movement of the inlet valve in the
         valve body bore;
      b. a conical portion with an annular recess that
         conjoins with the inlet passages of the conical
         valve seat when the inlet valve is seated;
      c. a bore coaxial with the valve body bore;
      d. a plurality of ports communicating between the
         bore and the cylindrical face of the inlet valve;
   and
   e. at least one slot in the base of the cone;
   4. a stuffing box with first and second faces adapted to
      matably bear the first face against the inlet face
      of the valve body and having
      a. a stepped bore extending between the first face
         and the second face, coaxial with the cylinder
         head chamber and an enlarged diameter at the
         first face; and
      b. a sleeve positioned against a step in the bore de-
         fining a compression chamber coaxial with the
         bore;
   5. a piston adapted to reciprocate axially in the stuff-
      ing box;
   6. packing means adapted to prevent fluid leakage
      between the piston and stuffing box at the second
      face of the stuffing box;
 7. a cylindrical inlet valve stop coaxial with and posi-
   tioned within the larger diameter bore of the stuff-
   ing box having a stepped bore adapted to receive the
   inlet valve;
 8. a discharge valve; and
 9. a cylindrical discharge valve plug slidedly posi-
   tioned in the valve body having a stepped bore adap-
   ted to receive the discharge valve; whereby a reci-
   rocating motion imparted to a piston when the
   inlet manifold is connected to an external source of
   fluid will produce axial motion of the inlet valve
   and discharge valve plug in the same direction and
   seating of the inlet and the discharge valve in alter-
   nate strokes, thereby resulting in fluid flow from
   the inlet to the outlet manifold and permitting flow
   of inlet fluid through said annular recess around
   the valve body of a piston in the discharge stroke
   to the valve body of a piston in the suction stroke.

2. The reciprocating pump of claim 1 wherein the inlet
   and outlet manifolds each have ports at second
   and third faces of the cylinder head, and the pump fur-
   ther comprises plug means whereby an inlet and an out-
   let port may be selectively sealed.
3. The reciprocating pump of claim 2 further com-
   prising
   an inlet valve spring positioned in the valve stop,
   bearing against the stuffing box sleeve and inlet
   valve so as to urge the inlet valve to seat in the
   closed position on its conical portion,
   a discharge valve spring, and
   a cylindrical discharge valve spring retainer having a
   stepped bore coaxial with the valve body bore and
   positioned in the enlarged diameter of the valve
   body bore with the cylindrical discharge valve plug
   slidedly positioned in the spring retainer bore and
   the discharge valve spring positioned in the valve
plug bore urging the plug and discharge valve to the closed position in which the discharge valve blocks the bore, whereby both valves are closed when the pump is not operating.

4. The reciprocating pump of claim 3, further comprising O-rings and a plurality of annuli in the cylindrical valve body adapted to receive O-rings in the peripheral surface and inlet and discharge faces thereby sealing the suction manifold from the inlet and discharge faces of the valve body.

5. The pump of claim 4, further comprising gland ring and stud means compressively mating said stuffing box and valve block.

6. A reciprocating pump according to claim 5, wherein said gland ring and valve block are at opposite ends of said stuffing box, and said stud means are external to said stuffing box and connected at opposite ends to said gland ring and said valve block.

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