July 3, 1962 S. J. MIKINA 3,042,289

COMPRESSOR LOADERS-UNLOADERS

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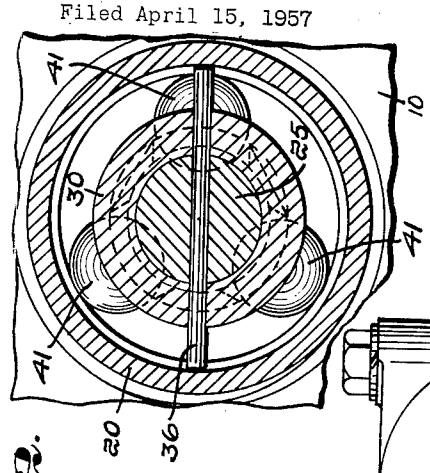


Fig. 2.

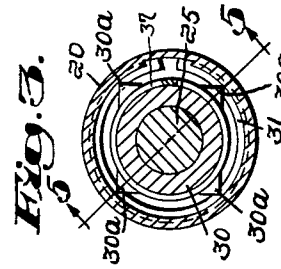


Fig. 3.

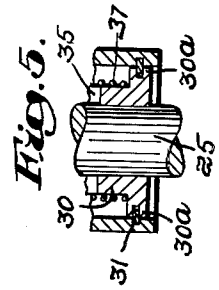


Fig. 5.

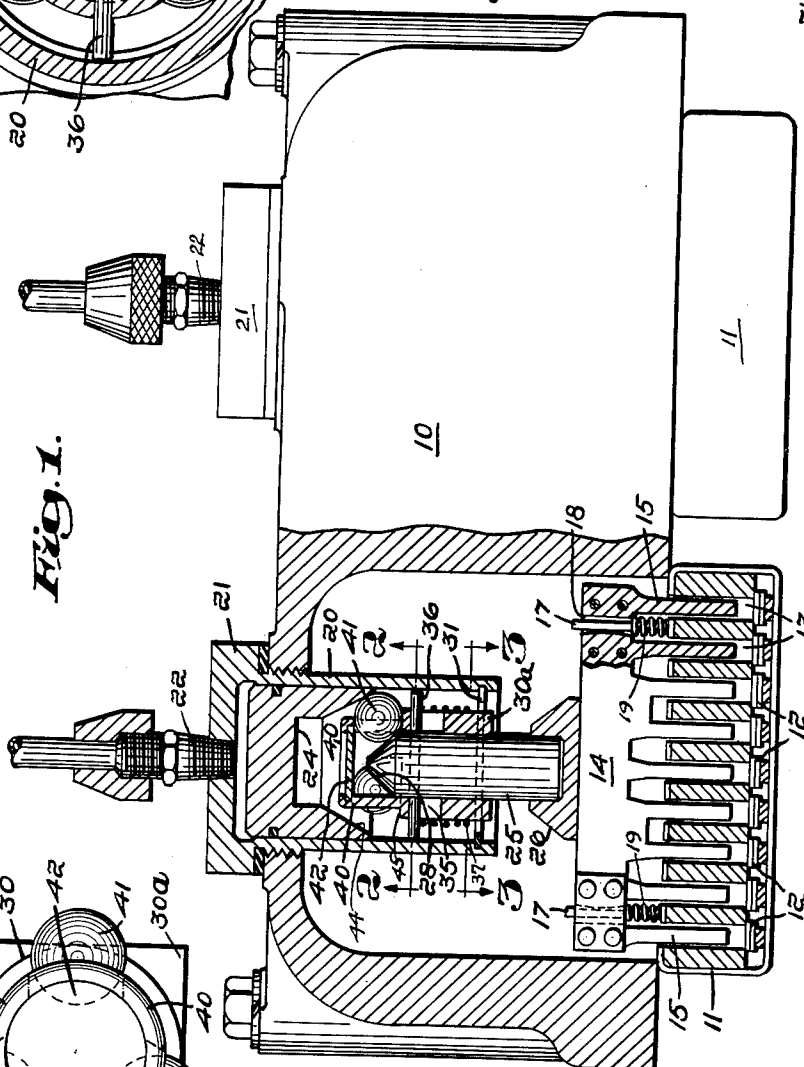


Fig. 1.

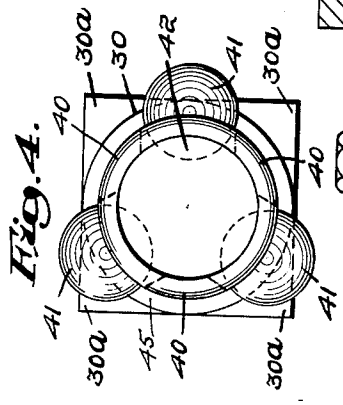


Fig. 4.

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COMPRESSOR LOADERS-UNLOADERS

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Fig. 5.

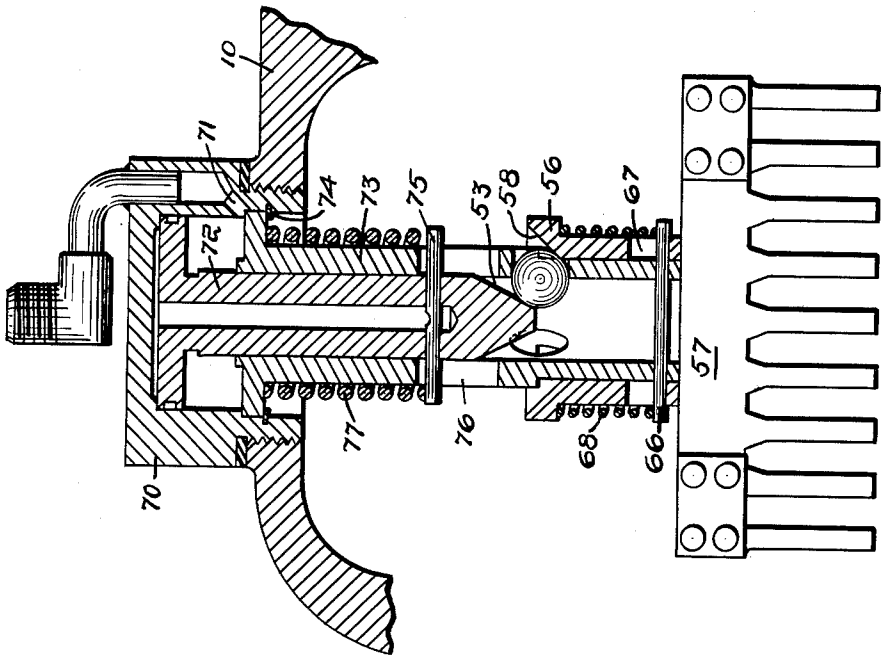
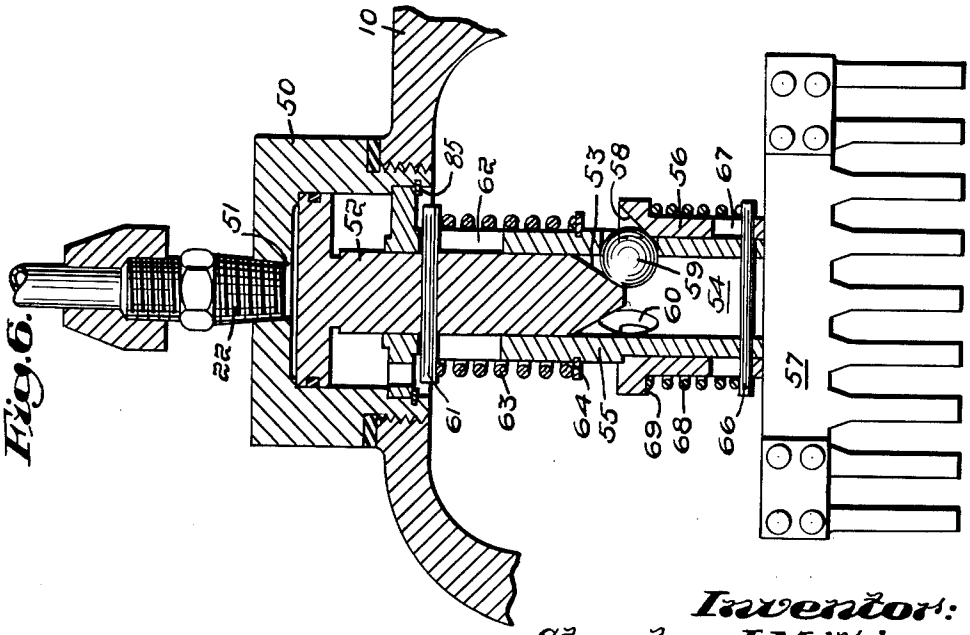


Fig. 6.



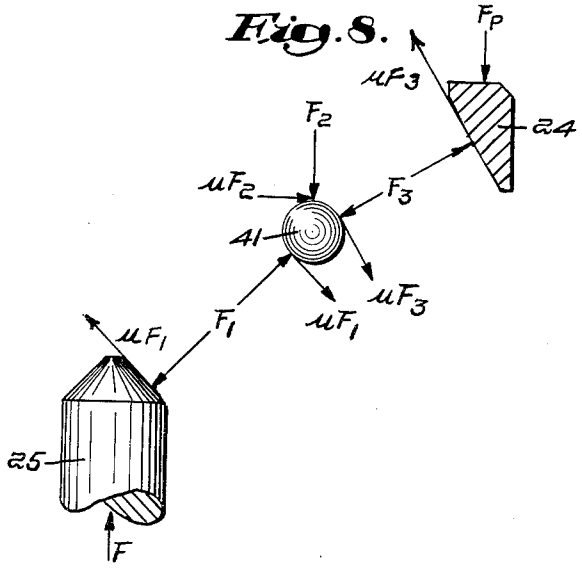
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COMPRESSOR LOADERS-UNLOADERS

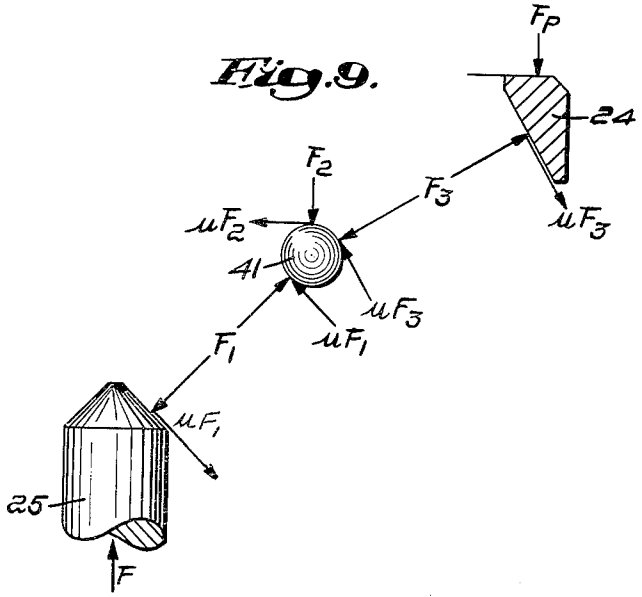
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Fig. 8.



UNLOADER EQUILIBRIUM FOR DOWNWARD MOTION OF PISTON 24

Fig. 9.



UNLOADER EQUILIBIUM FOR UPWARD MOTION OF PUSH-ROD 25

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COMPRESSOR LOADERS-UNLOADERS

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Filed Apr. 15, 1957, Ser. No. 652,771
14 Claims. (Cl. 230—30)

This invention relates to loaders-unloaders for compressors, and relates more particularly to loader-unloaders for refrigerant compressors.

In many refrigerant compressors, loading-unloading mechanisms are used for reducing the starting power, and for reducing the output when load reductions take place. The E. R. Wolfert, U.S. Patent No. 2,296,304 discloses a widely used form of loader-unloader in which unloading is accomplished by depressing suction valve reeds so that they do not act as check valves during the compression strokes of the pistons in their associated cylinders, as they usually do. A narrow toothed bar called a "comb" is used to hold a set of suction reeds down, the comb being forced down against the reeds by refrigerant discharge gas pressure acting on a piston in an unloader cylinder located over the comb. When loading is required, the gas pressure on the piston in the auxiliary cylinder is removed so that the suction valve reeds can seat when the discharge strokes of the piston in their associated cylinder take place. Guide pins extending through straight sided openings in the comb adjacent its ends are used for causing the teeth of the comb to line-up with the suction reeds.

Such a loader-unloader has been found defective in that due to the wide spaces between the guide pins as compared to the lengths of the guide holes in the comb, the comb sticks or binds on its guide pins similar to a "sticking drawer" effect. Such a loader-unloader has also been found defective in that it exhibits a fluttering, clattering vibration when refrigerant pressure is applied to the unloader piston for holding open the suction valves. This clatter is particularly pronounced at low unloader differential actuating pressures. The occasional binding of the comb on its guide pins, and the vibration, result in guide pin breakage, and in hammering of the valve plate by the comb.

An object of my invention is to prevent a loader-unloader for a refrigerant compressor from vibrating.

Another object of my invention is to prevent a loader-unloader comb of a refrigerant compressor from binding on its guide pins.

My invention will now be described with reference to the annexed drawings, of which:

FIG. 1 is a side elevation, in section, of a loader-unloader embodying my invention, a compressor head also being shown;

FIG. 2 is an enlarged section along the line 2—2 of FIG. 1;

FIG. 3 is a section along the line 3—3 of FIG. 1;

FIG. 4 is an enlarged plan view of the ball retainer and the balls used,

FIG. 5 is a section along the line 5—5 of FIG. 3;

FIG. 6 is a sectional view of another form of loader-unloader embodying my invention;

FIG. 7 is a sectional view of still another form of loader-unloader embodying my invention;

FIG. 8 is an unloader equilibrium diagram for downward motion of the unloader piston, and

FIG. 9 is an unloader equilibrium diagram for upward motion of the unloader push-rod.

A compressor head 10 common to two cylinders of a refrigerant compressor, has similar loader-unloaders for the two cylinders, the details of the loader-unloader of the left cylinder being shown. A conventional valve plate 11

has suction valve reeds 12 which extend across suction valve slots 13. The reeds 12 would be flexed downwardly by suction pressure to uncover the slots 13, and upwardly by discharge pressure to cover the slots. A comb 14 has downwardly extending teeth 15 which contact the upper surfaces of the reeds 12 and move the reeds downwardly for uncovering the slots 13 when the associated compressor cylinder is to be unloaded. The comb has guide pins 17 within guide holes 18, the lower ends of the pins contacting the upper surface of the valve plate 11, the pins having coiled springs 19 therearound between the upper surface of the plate 11 and the lower surface of the comb 14. The springs 19 are compressed when the comb is moved downwardly during unloading, and act to restore the comb to its neutral position when the unloading pressure against it is removed.

The inner sides of the guide pin holes 18 are curved in arcs of a circle which has a diameter equal to the distance between the guide pins. Whatever the inclination of the comb is in the plane of the guide pins, its clearance relative to the pins is constant, and no binding can occur. In prior comb constructions, the corresponding inner sides of the guide pin holes were straight, and when such combs were inclined in the planes of their guide pins, there was binding similar to the so-called "sticking drawer" effect.

Located centrally above the comb 14 is an unloader cylinder 20 which is threaded into the top of the cylinder 10. The cylinder 20 has a nut-shaped head 21 into which is threaded a fitting 22 through which discharge gas is supplied when unloading is desired. The unloader cylinder 20 has a piston 24 against the head of which the discharge gas acts. A push-rod 25 has its lower end within a plate 26 which is attached to the top of the comb 14. The upper end of the push-rod 25 has a conical, hardened-steel surface 28 which has a bevel at an angle which may be 45° to the vertical.

The push-rod 25 extends through a bore in a ball retainer which has a square base 30*a*, which has a cylindrical intermediate portion 30 above the base 30*a* with an outer diameter equal to the length of a side of the base, and which has a top consisting of a cylindrical wall 40 having three circular holes drilled therethrough to receive steel balls 41. The corners of the base 30*a* contact the inner surface of the cylinder 20 as best shown by FIG. 3. A snap-ring 31 extends in a recess in the wall of the cylinder 20, and in recesses in the corners of the base 30*a*, and holds the retainer in place within the cylinder 20.

The push-rod 25 has a pin 36 extending therethrough near its top, and the ball retainer has a slot 35 within which both ends of the pin 36 extend. A coiled spring 37 extends around the cylindrical portion 30 of the retainer between its base 30*a*, and the ends of the pin 36. The push-rod 25 thus is adapted to be moved downwardly against the resistance of the spring 37.

The bottoms of the three holes drilled through the wall 40 form seats for the balls 41 which have portions extending outwardly through the holes in the walls 40. The inner surface of the upper end of the wall 40 is recessed to receive a circular steel reaction disc 42 which has a diameter equal to the diameter of the recess in the wall 40. The upper portion of the wall 40 is crimped over the disc 42 after the latter has been placed in the recess in the wall 40.

The hardened, lower, inner surface of the piston 24 is tapered at 44 to have an angle which may be 30° to the vertical, which surface is in contact with and tangential to the adjacent surfaces of the balls 41. The conical top of the push-rod 25 is in contact with and tangential to the adjacent surfaces of the balls 41 opposite where they contact the piston surface 44. The two inclined planes where the balls contact the surfaces 28 and 44,

and the balls, form a leverage system of which the ball retainer is a fulcrum.

In operation, when discharge gas is applied to the head of the piston **24** when unloading is desired, the piston acts on the push-rod **25** through the balls **41** that transmit the piston force from the inclined surface **44** of the piston to the inclined surface **28** of the top of the push-rod. In the embodiment shown by FIG. 1, the piston surface **44** has a slope of 2. Thus, a ¼" downward movement of the piston will move the balls horizontally ⅛". Since the push-rod end has a bevel of 45°, the horizontal displacement of the balls results in ⅛" downward displacement of the push-rod and the comb **14**. A part of the ball reaction is provided by the reaction disc **42**. The action of the inclined planes, the balls, and the friction forces is such as to make the unloader capable of holding an upward comb force equal to 3.57 times the downward piston force of the unloader. This can be shown as follows by considering the equilibrium relations between the leverage system elements.

Let the coefficient of friction between the balls **41** and the surfaces **28** and **44** be designated by μ. Then the static equilibrium of the unloader for downward movement of the piston **24** can be written as follows. Push-rod equilibrium requires that

$$F+.707\mu F_1=.707F_1$$

that is

$$F_1=\frac{1.414F}{1-\mu}$$

in which

F=upward force from comb to push-rod, and
F_1=normal reaction force between balls and push-rod, and
.707 is the sine and cosine of 45°, the bevel of the upper end of the push-rod.

In the following equilibrium relations, the three balls are treated as one ball. The horizontal equilibrium of the ball is expressed by

$$.707F_1+.707\mu F_1+\mu F_2+.4472\mu F_4=.8944F_3$$

Here

F_2=reaction force between ball and disc **42**,
F_3=force between ball and piston,
.4472=sine of piston angle $\tan^{-1}$ .5,
.8944=cosine of piston angle $\tan^{-1}$ .5.

The vertical equilibrium of the ball is given by

$$.707F_1=.707\mu F_1+.8944\mu F_3+.4472F_3$$

The vertical equilibrium of the unloader piston is given by

$$F_p=.4472F_3+.8944\mu F_3$$

Solving these equations for

$$F_p=\frac{F(1+2\mu-\mu^2)(.4472+8944\mu)}{.8944(1-\mu)(1+\mu^2)}$$

Letting μ=.1, F_p=.777F, or F=1.28F_p.

This shows that for the downward motion of the unloader piston, the leverage system has increased the downward force on the unloader comb by only 28%. If this were the only effect of the leverage system, it might not be worth using. However, while only a moderate increase in force is provided for downward motion of the comb, a reaction force equal to 3.57 times the piston force is provided whenever the comb forces tend to move it upward. This reaction force results from the increased friction on and binding of the balls when the comb push-rod is pushed upwardly. When gas is flowing into the compressor cylinder to be unloaded, the gas forces on the suction reeds and unloader comb are in a direction to aid an unloading displacement of the unloader system. The F=1.28F_p during this phase is able to displace the unloader system downward into the position required for adequate unloading. Then, subsequently, when the compressor piston is discharging gas out of the compressor cylinder, and this gas flow tends to shove the suction valve reeds and unloader comb back upwards, the unloader F=3.57F_p is able to resist this shove and to hold the reeds in the open position. The force equilibrium relations for the unloader leverage system during this phase of the cycle are as follows.

Push-rod equilibrium requires that

$$.707F_1+.707\mu F_1=F$$

$$F_1=\frac{1.414F}{1+\mu}$$

The horizontal equilibrium of the ball is expressed by

$$.707F_1=.707\mu F_1+\mu F_2+.4472\mu F_3+.8944F_2$$

The vertical equilibrium of the ball is expressed by

$$.707F_1+.707\mu F_1+.8944\mu F_3=F_2+.4472F_3$$

The equilibrium of unloader piston forces is given by

$$F_p=.4472F_3-.8944\mu F_3$$

Solving these equations for F_p in terms of F, we obtain

$$F_p=\frac{F(1-2\mu-\mu^2)(.4472-.8944\mu)}{.8944(1+\mu)(1+\mu^2)}$$

Letting μ=.1, the last equation gives

$$F_p=.28F \text{ or } F=3.57F_p$$

Thus, a 3.57 fold increase in comb holding force is realized during the part of the unloading cycle when the discharge gas pressure tends to move the suction reeds closed in opposition to the action of the unloader. This has proven to be sufficient to eliminate unloader vibration.

By making the base **30***a* of the ball retainer square, gas passages between its corners are provided for permitting gas escaping past the unloader piston to flow into the compressor cylinder. This eliminates the necessity for drilling a gas passage through the body of the retainer.

Except for the leverage system, and the feature of preventing the unloader comb from binding on its guide pins, the unloader of FIGS. 1–5 would operate in the usual manner.

FIG. 6 illustrates another embodiment of my invention which is kinematically inverted from the design shown by FIG. 1 in that the cone tapers are interchanged. An unloader cylinder **50** having a discharge gas inlet **51**, has a piston **52** with a lower end having a conical surface **53**. The piston **52** is slidable within a circular bore **54** in a ball retainer **55**. The upper end of the retainer is held against a flanged surface in the inner surface of the cylinder **50** by a snap-ring **85**. The lower portion of the retainer **55** has a cylindrical outer surface around which extends a slidable sleeve **56**, the lower end of which is adapted to contact the upper surface of a comb **57** which is similar to the comb **14** of FIG. 1.

The upper end of the sleeve **56** has a tapered surface **58**. Three steel balls **59**, only one of which is shown by FIG. 6, similar to the balls **41** of FIG. 1, are in tangential contact with the surfaces **53** and **58**. The balls **59** are held in circular holes **60** which extend through the wall of the retainer **55**. A pin **61** extends through the piston **52**, and its ends extend through a slot **62** in the retainer **55**. A coiled spring **63** extends around the retainer **55** between the pin **61** and a snap-ring **64** in a recess in the outer surface of the retainer **55**, and acts to cause the piston **52** to retract when discharge gas pressure against its head is removed.

Another pin **66** extends through the retainer **55**, and its ends extend into a slot **67** in the sleeve **56**. A coiled spring **68** extends around the sleeve **56** between the pin **66** and a flanged surface **69** of the sleeve, and acts to retract the sleeve when the discharge gas acting against the head of the piston **52** is removed.

In the operation of the embodiment of FIG. 6, when

the piston **52** is forced downwardly by gas pressure when unloading is desired, the downward motion of the piston is transmitted through the balls **59** to the sleeve **56** which depresses the comb **57**. The piston surface **53** has the 2:1 slope which the piston surface **44** of FIG. 1 has, and the sleeve surface **58** has the 45° slope the push-rod surface **28** of FIG. 1 has.

The embodiment of FIG. 6 provides the same leverage action the embodiment of FIG. 1 does, and has the advantage over the latter that a crimped over reaction disc is not required.

Some loader-unloaders are spring unloaded at the start, and require discharge gas for loading. The G. L. Biehn U.S. Patent No. 2,751,143 discloses such a loader-unloader. FIG. 7 illustrates another embodiment of my invention which is spring unloaded at the start, and in which loading is provided by discharge gas pressure. FIG. 7 is similar to FIG. 6 in many repsects, and in the following description, components of FIG. 7 which are similar to corresponding components of FIG. 6 are given the same reference numerals.

FIG. 7 has a loading cylinder **70** with a discharge gas inlet **71** which connects with the interior of the cylinder **70** below the head of its piston **72**, the lower end of which has a conical surface **53**. A retainer **73** has an upper portion held against a flanged portion of the inner surface of the cylinder **70** by a snap-ring **74**. The piston **72** has a pin **75** extending therethrough with its ends extending into a slot **76** in the retainer **73**. A coiled spring **77** extends around the retainer **73** between the pin **75** and the top of the retainer, and serves to force the piston normally downwardly for depressing through the balls **59** and sleeve **56**, the combs **57** for unloading. When loading is desired, discharge gas supplied through the inlet **71** against the bottom of the head of the piston **72** overcomes the action of the spring **77** permitting the combs **57** to move upwardly, and the associated suction valve reeds to seat.

The balls **59** and the bevelled surfaces **53** and **58** provide the same leverage action as in the embodiment of FIG. 6.

What I claim is:

1. In a loader-unloader for a cylinder of a gas compressor having suction valve reeds, a comb for depressing said reeds, and an auxiliary cylinder having an inlet for receiving discharge gas, the combination therewith of a piston in said auxiliary cylinder having a tapered surface, a plurality of balls in contact with said surface, a comb contacting member having one end adjacent to said comb and having a tapered surface at its other end in contact with said balls opposite said first mentioned tapered surface, and a retainer for said balls attached to said auxiliary cylinder, said surface of said piston diverging towards said member, said surface of said member converging towards said piston.

2. A loader-unloader as claimed in claim 1 in which means is provided for resiliently connecting said retainer to said member.

3. A loader-unloader as claimed in claim 2 in which means is provided for resiliently connecting said piston to said retainer.

4. In a loader-unloader for a cylinder of a gas compressor having suction valve reeds, a comb for depressing said reeds, and an unloader cylinder having an inlet for receiving discharge gas, the combination therewith of a push-rod having one end adjacent to said comb and having its other end extending centrally into said unloader cylinder, said other end having a conical surface, a piston in said unloader cylinder having a tapered inner surface opposite said conical surface, a plurality of balls between and in contact with said surfaces, and a retainer for said balls extending around said push-rod and secured to said unloader cylinder, said tapered surface diverging towards said push-rod, said conical surface converging towards said piston.

5. A loader-unloader as claimed in claim 4 in which means is provided for resiliently connecting said retainer to said push-rod.

6. A loader-unloader as claimed in claim 5 in which said retainer has a cylindrical wall with circular holes therein in which said balls are located.

7. A loader-unloader as claimed in claim 6 in which a reaction disc is secured to said wall in contact with said balls opposite said other end of said push-rod.

8. A loader-unloader as claimed in claim 7 in which said retainer has portions in contact with the inner surface of said unloader cylinder and has other portions spaced from said inner surface of said unloader cylinder for providing gas passages.

9. A loader-unloader as claimed in claim 4 in which said push-rod is slidable within said retainer towards said comb, and in which spring means is provided for opposing the slidable movement within said retainer towards said comb of said push-rod.

10. A loader-unloader as claimed in claim 4 in which said comb has holes extending therethrough adjacent its ends for receiving guide pins, the adjacent sides of said holes being curved in circular arcs the diameter of which is approximately equal to the distance between said adjacent sides.

11. In a loader-unloader for a refrigerant compressor having a valve plate with suction valve reeds, a comb for depressing said reeds, and an unloader cylinder having an inlet for discharge gas, the combination therewith of a push-rod having one end adjacent to said comb and having its other end extending centrally within said unloader cylinder, said other end having a conical surface, a plurality of balls in contact with said surface, a piston in said unloader cylinder having a tapered surface in contact with said balls opposite to said conical surface, a ball retainer secured to said unloader cylinder, said retainer having a central bore within which said push-rod is slidable towards and from said comb, said retainer having a cylindrical wall with circular holes in which said balls are located, a retainer disc clamped to said wall in contact with said balls opposite to said other end of said push-rod, said retainer having a slot extending diametrically therethrough and having a depth extending longitudinally of said retainer, said push-rod having a pin secured thereto and extending therethrough and having ends extending beyond said push-rod into said slot, said retainer having a base portion and having an intermediate portion between said base portion and said slot, said base portion having portions extending outwardly beyond said intermediate portion, and a spring around said intermediate portion with its ends in contact with said portions of said base portion and with said pin.

12. In a loader-unloader for a cylinder of a gas compressor having a valve plate with suction valve reeds, a comb for depressing said reeds, and an auxiliary cylinder having an inlet for discharge gas, the combination therewith of a piston in said auxiliary cylinder having a head at one end and having a tapered surface at its other end, a plurality of balls in contact with said surface, a retainer for said balls secured at one end to said auxiliary cylinder, a comb contacting sleeve around the other end of said retainer, said sleeve having one end adjacent to said comb and having a tapered surface at the other end in contact with said balls opposite said first mentioned surface, means for resiliently connecting said sleeve to said retainer, and means for resiliently connecting said piston to said retainer.

13. A loader-unloader as claimed in claim 12 in which said means for resiliently connecting said piston to said retainer comprises spring means which biases said piston away from said sleeve, and in which said inlet is arranged to project discharge gas against the top of said piston head for moving said piston towards said sleeve.

14. A loader-unloader as claimed in claim 12 in which said means for resiliently connecting said piston to said

retainer comprises spring means which biases said piston towards said sleeve, and in which said inlet is arranged to project discharge gas against the bottom of said piston head for moving said piston away from said sleeve.

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