Nov. 19, 1968 C. MANN 3,411,673

LIQUID SPRAYING APPARATUS

Filed Nov. 16, 1966 3 Sheets-Sheet 1

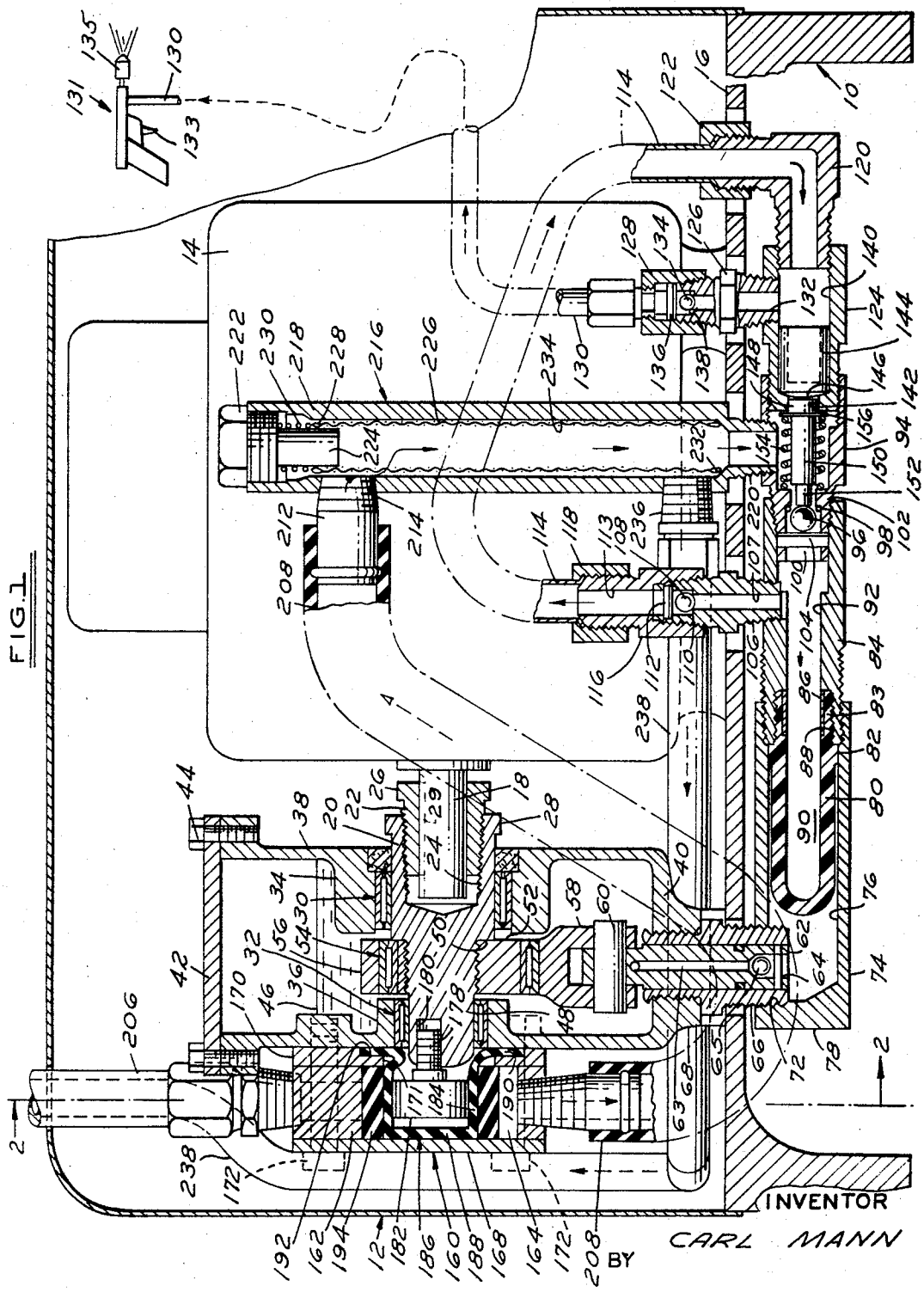


FIG. 1

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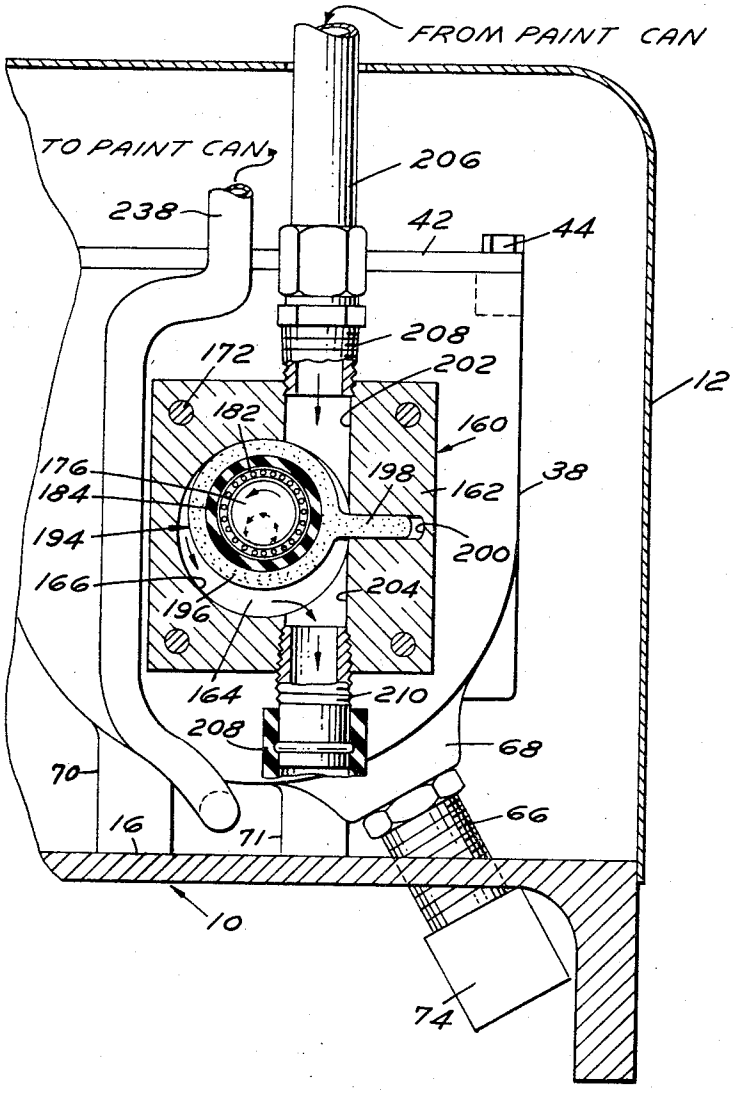
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FIG. 2



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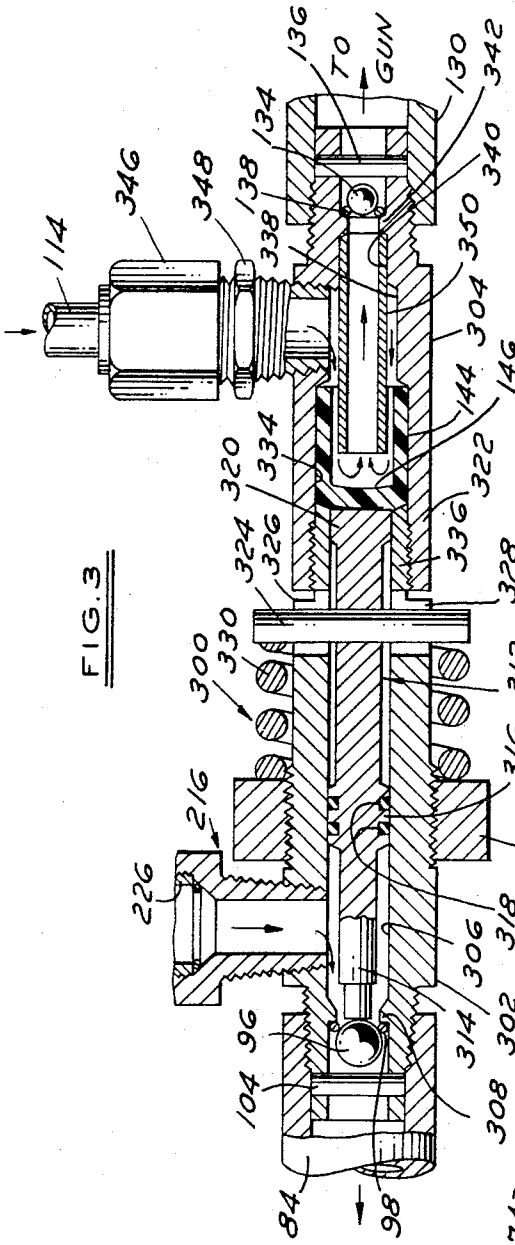


FIG. 3

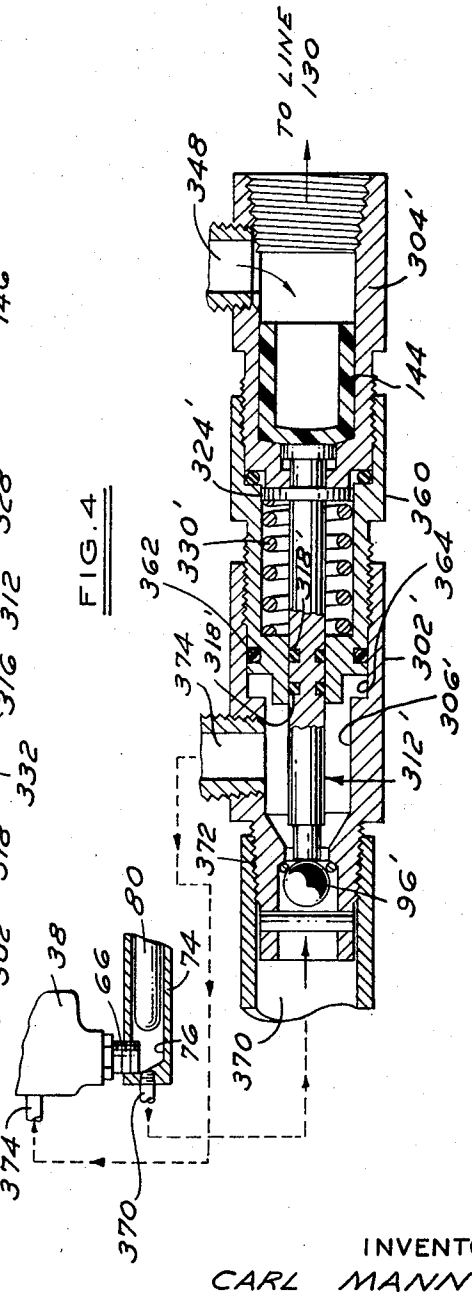


FIG. 4

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3,411,673

LIQUID SPRAYING APPARATUS

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19 Claims. (Cl. 222—189)

ABSTRACT OF THE DISCLOSURE

Improved high pressure airless liquid spraying apparatus incorporating several features including a diaphragm operated plunger which senses output line pressure to unload the high pressure pump in response to a predetermined increase in downstream pressure as when the trigger of the spray gun is released to halt spraying. A high volume, low pressure supply pump is also provided which includes a flexible hat-shaped seal which envelopes the impellor of the pump and isolates the same from the abrasive materials such as paint being pumped to the input side of the high pressure pump. The low pressure side of the system also includes a self-cleaning filter. Modifications of the pump unloader are also disclosed which operate as an adjustable pressure regulator. Further details of these and other features will be found in the description.

This invention relates to improvements in liquid spraying apparatus of the airless type wherein liquid is forced under high pressure through a small orifice to produce a spray by hydraulic atomization, and more particularly to improvements in the airless liquid spray apparatus disclosed in my copending application Ser. No. 406,478, filed Oct. 26, 1964, now United States Patent No. 3,317,141.

It is an object of the present invention to provide an improved airless spraying apparatus which: (1) is lightweight and compact so that it is easily hand transportable; (2) is capable of equal or better performance than preexisting airless spraying equipment but does not require the air compressors, air hoses, air line filters and air pressure regulators of such pre-existing airless equipment; (3) is capable of pumping liquids at high pressures, for example, on the order of 1,500 to 3,000 p.s.i., for subsequent airless spraying of the liquids in a manually controllable and practical fashion; (4) may be used for interior as well as exterior work in locations where only household electrical outlets are available as a power source; (5) may be powered either by a fractional horsepower electrical motor or a small internal combustion engine; (6) is capable of withstanding the wearing action of abrasive liquids such as titanium dioxide paint and the like when being pumped at high pressures for sustained periods; (7) is relatively simple and inexpensive in construction and reliable in operation; and (8) not easily susceptible to clogging or jamming by dirt or solid particles entrained in liquid being sprayed.

Further objects of the present invention are to provide improvements in airless spraying equipment which effect:

(9) reduced wear of the valves and valve seats in the high pressure paint pump of the system;

(10) isolation of the output of the high pressure pump from the downstream pressure expansion chamber effects of the flexible hose or other conduit system connecting the output of the pump to the spray gun;

(11) continuous circulation of the paint or other liquid being sprayed to and from the container in a low pressure system at a relatively high volume so as to maintain the paint in a well mixed condition;

(12) the aforementioned low pressure continuous circulation in an economical and reliable manner by employing a rotary eccentric pump which contains an improved sealing arrangement for the drive member thereof and which is driven by the same drive shaft which drives the reciprocating piston of the high pressure paint pump of the apparatus;

(13) the supply of filtered paint at low pressure to the inlet of the high pressure pump by a self-washing, clog-free filter arrangement disposed in the low pressure side of the system, thereby further reducing pump wear and clogging problems throughout the high pressure side of the system and isolating the filter itself from the high pressure side of the system;

(14) ready substitution of various types of prime movers for driving the low pressure and high pressure pump mechanisms so that the apparatus may be readily converted for use in explosive atmospheres or for various foreign countries operating on different power frequencies and voltages; and

(15) adjustable regulation of the output pressure of the liquid delivered to the spray nozzle.

Other objects, features and advantages of the present invention will become apparent from the following detailed description of an exemplary embodiment of the invention as shown in the accompanying drawings wherein:

FIG. 1 is an elevational view of a portable airless paint spraying unit of the present invention with portions thereof shown in vertical center section to illustrate details thereof, and with a spray gun shown semi-schematically on a reduced scale.

FIG. 2 is a fragmentary end elevational view of the left-hand end of the apparatus as viewed in FIG. 1, with portions thereof shown in vertical center section on line 2—2 of FIG. 1 to illustrate details of the low pressure recirculating pump of the present invention.

FIGS. 3 and 4 are fragmentary axial center sections of modified forms of valve unseaters which also serve as output pressure regulators in accordance with the present invention, FIG. 4 further including a schematic showing of a portion of the high pressure diaphragm pump of FIG. 1 with connections to the modified valve unseater and pressure regulator to illustrate a modified form of pump unloading and pressure regulating system also in accordance with the present invention.

Referring in more detail to FIGS. 1 and 2, the airless liquid spray apparatus of the present invention as exemplified by the illustrated portable embodiment includes a four-legged base **10** on which is suitably mounted a removable cover **12** for enclosing the various components of the apparatus supported on base **10**. An electric motor **14** is removably mounted on the horizontal platform **16** of the base and, by way of example, may be a three-quarter horsepower AC motor rated at 1,725 r.p.m. and operable on 110-volt AC house current. Suitable disconnectable power leads and on-off switch connections (not shown) are provided for motor **14** to facilitate substitution of various types of motors, such as explosion proof and/or foreign power rated, to meet environmental requirements.

Motor **14** has a drive shaft **18** which is removably coupled to a crankshaft **20** by an axially split collet **22** externally threaded for engagement with internal threads of a tapered bore **24** in one end of the crankshaft **20**. Hexagonal flanges **26** and **28** are provided on collet **22** and on crankshaft **20** respectively so that these two members may be coupled or uncoupled with a pair of wrenches. Collet **22** is slidably keyed to shaft **18** as by an internal key **29** received in a keyway in shaft **18**. When collet **22** is threaded into bore **24**, it is radially compressed so that the same frictionally seizes on shaft **18** to thereby supplement the positive driving key connection between shaft **18**

and crankshaft **20**. Preferably, the threads of collet **22** and crankshaft **20** are of the proper hand relative to the direction of rotation of motor **14** so that the parts tend to be driven further into threaded engagement by the driving torque transmitted through this coupling, thereby insuring a secure connection between the motor and crankshaft.

Crankshaft **20** is journalled in a rectangular, boxlike crankcase housing **38** by axially spaced roller bearings **30** and **32** disposed respectively in internal bosses **34** and **36** of housing **38**. The lower end of housing **38** is closed by a bottom wall **40** and the upper end by a cover plate **42** removably secured by bolts **44** to the housing. The hollow interior of housing **38** serves as a reservoir for hydraulic fluid, such as automotive transmission fluid, and is normally filled to the level indicated at **46**. A reduced diameter extension **48** of crankshaft **20** has a threaded portion adjacent a shoulder **50** of the crankshaft which threadably receives a cylindrical crank **52** eccentrically thereon, these parts being properly threaded so that crank **52** is screwed against shoulder **50** by the driving torque transferred from the crankshaft to the crank. Crank **52** thus rotates with crankshaft **20** and is drivingly coupled through an encircling roller bearing **54** to a connecting rod **56** received on bearing **54**. Connecting rod **56** has a bifurcated projection **58** at its lower end which is pivotally connected by a pin **60** to the upper end of a piston **62** which reciprocates in a cylinder **64** of a fitting **66** threadably secured in a boss **68** of housing **38** and disposed (FIG. 2) with its axis inclined from the vertical. Housing **38** is suitably supported on platform **16**, as by legs **70, 71** (FIG. 2), and the externally threaded lower end of fitting **66** projects through and below the platform where it is threaded into a bore **72** in the side of a pump casing **74**.

High pressure side of system

Casing **74** is part of the high pressure side of the system and has a blind bore **76** therein closed at one end by a wall **78** to form a high pressure pulsing chamber. A flexible resilient tubular diaphragm **80** is inserted closed end first into the open end of bore **76** and has a flange **82** which maintains the exterior surface of the diaphragm radially spaced from the wall of bore **76** and which seats and seals against one end of casing **74**. The open end of diaphragm **80** has a reinforcing sleeve **86** received therein, and has a reduced diameter nipple portion **83** threaded into an internally threaded counterbore **88** of casing **84**. This arrangement sealably secures the diaphragm in casings **74** and **84** and also seals the connection of these casings.

The hollow interior **90** of diaphragm **80** communicates at its open end with an axial bore **92** of casing **84** to form therewith a high pressure liquid pumping chamber. The end of casing **84** remote from the diaphragm threadably receives an inlet fitting **94**. A check ball **96** and a ring **98** are disposed in a bore **100** of fitting **94**, ring **98** being fixed against a shoulder of an internal flange **102** to serve as a valve seat for ball **96**. Both of these parts are preferably made of a hard wear resistant material such as tungsten carbide. Ball **96** is held captive between seat **98** and the open end of bore **100** by a retaining pin **104** and operates as an inlet check valve for the high pressure diaphragm pump **80**.

An outlet fitting **106** is screwed into a side opening of casing **84** and contains in a stepped passage **107** thereof an outlet check ball **108**, a ring **110** against which ball **108** seats, both preferably made of tungsten carbide, and a retaining pin **112**. Passage **107** of fitting **106** is connected by a passage **113** of a flare connector **116** to a conduit **114** which is secured at one end by a clamp nut **118** to connector **116**. The other end of tube **114** is similarly plumbed to an elbow **120** by a clamp nut **122**, the other end of elbow **120** being screwed into one end of a piston housing **124**. A double ended male connector **126** is threadably received at one end in a side opening of housing **124** and plumbed at its other end by a coupling **128** to a high pressure output line **130**. Line **130** may be a flexible hose which is connected to a conventional spray gun **131** (FIG. 1) having a usual trigger **133** for operating a discharge valve (not shown) which opens and closes communication between line **130** and an orifice of airless hydraulic atomization spray nozzle **135**. In accordance with one improvement feature of the present invention, connector **126** houses a back check valve **134** to isolate line **114** and housing **124** from the effects of expansion and contraction of line **130**, connector **126** having a stepped bore **132** in which check ball **134** is loosely retained between a pin **136** and a tungsten carbide ring **138** on which ball **134** seats.

In accordance with another improvement feature of the invention, housing **124** and **94** house a hydraulically actuated mechanism adapted to unseat ball **96** during the idle periods when motor **14** is running but the spray gun discharge valve is closed. Connector **124** has a cylindrical axial bore **140** which extends from elbow **120** to a counter bore **142** at the other end of the fitting which receives with a close fit a cup-shaped piston like diaphragm **144** made of a flexible high strength elastomer material, such as polyurethane. The open end of diaphragm **144** faces elbow **120** and its outwardly domed end wall **146** abuts the shoulder at the junction of bores **142** and **144**. One end **148** of a cylindrical plunger **150** slides in bore **142** to movably support the plunger axially within fitting **94** between cup **144** and ball **96**. Plunger **150** has a reduced diameter stem **152** adapted to project with a clearance into the reduced passage defined by flange **102**. A compression coil spring **154** encircles plunger **150**, abutting at one end against flange **102** and at the other end against a washer **156** backed up by portion **148** of plunger **150**. Spring **154** biases plunger **150** axially toward diaphragm **144** until washer **154** abuts the end face of fitting **124**, at which point stem **152** is spaced from ball **96** when in its seated position. Spring **154** is selected to yield, and thereby permit movement of plunger **150** axially to the left (as viewed in FIG. 1) into contact with ball **96** and then to push the same off its seat, in response to a predetermined fluid pressure in bore **140** acting on cup wall **146** sufficient to flex it so that it contacts end **148** and drives plunger **150** to this unseating position. It is to be noted that diaphragm **144** thus serves both as a diaphragm, and also as a cup seal between the high and low pressure sides of the system due to presure fluid in bore **140** expanding the skirt portion of the diaphragm **144**.

Low pressure side of system

The liquid such as paint to be sprayed is delivered from the receptacle containing the same, such as a paint can (not shown), by a low pressure pumping system which includes a low-pressure, high volume pump **160** and a filter unit **216** connected in a recirculation circuit so that the liquid undergoes constant recirculation to and from the container in the low pressure side of the apparatus so long as motor **14** is running. Referring to FIGS. 1 and 2, the low pressure pump **160** comprises a body block **162** in which a pumping chamber **164** is defined by a cylindrical bore **166** (FIG. 2) closed at the opposite ends thereof by an outer plate **168** and an inner plate **170** (FIG. 1) having a crankshaft aperture **171**. Plates **168** and **170** are clamped in assembled relation with body **162** by four bolts **172** which also mount the pump assembly against the end face of housing **38** with the axis of bore **166** coincident with the axis of crankshaft **20**.

The pumping mechanism of pump **160** comprises a cylindrical disc **176** (FIG. 2) having a threaded stud **178** extending coaxially therefrom and threadably secured in an eccentric bore **180** (FIG. 1) in end portion **48** of crankshaft **20** so that disc **176** is rotatably driven by shaft **120** and revolves eccentrically within chamber **164**. Disc **176** carries a roller bearing **182** thereon which has its inner race fixed to disc **176** and its outer race

bearing against the inner cylindrical wall of a skirt portion **184** of a cup-like seal **186**. Seal **186** is closed at one end by a radial wall **188** which is axially spaced from disc **176** and disposed in sliding contact with the inner wall of plate **168**, although wall **188** may alternatively be spaced from plate **168**. Seal **186** is open at its other end and has a radially outwardly extending annular flange **190** integrally joined to skirt portion **184** which is received in an annular recess **192** of plate **170** around the margin of opening **171** thereof. The thickness of flange **190** is greater than the depth of recess **192** so that when pump **160** is clamped against housing **38**, plate **170** presses flange **190** tightly against the outer face of housing **38** to thereby form a liquid tight seal therebetween which insures that the paint flowing through pump **160** is not contaminated by oil leakage from the pump in housing **38**. Cup seal **186** is preferably made of a flexible material adapted to withstand continuous flexure caused by the eccentirc motion imparted to skirt portion **184** relative to fixed flange **190**, and for this purpose good results have been obtained with an elastomer such as polyurethane, for example.

The pumping mechanism also includes impeller **194** which has a cylindrical portion **196** (FIG. 2) with an inside diameter adapted to slip closely onto skirt **184** and an outside diameter smaller than that of bore **166**. The axial dimension of impeller **194** is slightly greater than the axial spacing between end plates **168** and **170** so that the end faces of the impeller slide with a slight pressure against the respectively adjacent lates. Impeller **194** has an integral tongue portion **198** which extends radially outwardly from portion **196** for the full axial width thereof. Tongue **198** is slidably received in a mating slot **200** which extends radially in body **200** from the axis of rotation of shaft **20** for a depth sufficient to fully receive tongue **198** therein when portion **196** is moved adjacent to the inlet of slot **200**. Tongue **198** is longer than the eccentric throw imparted by a disc **176** so that it never is withdrawn from the slot. Tongue **198** thus forms a divider in the pump chamber between an inlet passage **202** and an outlet passage **204** (FIG. 2) which communicate with chamber **164** on opposite sides of tongue **198**. Preferably passages **202** and **204** are formed by drilling a bore through body **162** generally tangential to the intersection of bore **166** and slot **200**.

Pump **160** is connected to the source of supply of liquid to be sprayed, such as a paint can filled with paint, by a suitable fluid conductor **206** threadably connected by a male fitting **208** to the threaded inlet **202** of body **162**. Pump **160** is also connected to a fluid conductor, such as a hose **208**, by a male fitting **210** threadably secured in the outlet passage **204** of body **162**. The other end of hose **208** (FIG. 1) is connected by a male inlet fitting **212** to a threaded side port **214** of a casing **218** of filter unit **216** near the upper end thereof. The outlet for filtered liquid from unit **216** comprises a threaded nipple **220** at the lower end of casing **218** which screws into fitting **94**. The open upper end of casing **220** threadably receives a removable closure stud **222** which has a stem **224** on which the upper end of a cylindrical filter screen **226** is piloted. Screen **226** has a grommet **228** at its upper end which is slidably received with a close fit on stem **224** and which abuts a coil compression spring **230** piloted on stem **224**, the screen thus being urged downwardly so that a grommet **232** at its lower end seats against a conical internal shoulder of nipple **220**. The outer surface of screen **226** is spaced radially inwardly of the wall bore **234** of casing **218** to provide an axial flow space along the exterior of the screen running from fitting **212** downwardly to an outlet fitting **236** which is screwed into a side port near the lower end of casing **218**. Fitting **236** is connected to a return line **238** which runs beneath housing **38** (FIGS. 1 and 2), thence upwardly alongside pump **160**, and thence through the top of cabinet **12**, the outlet of return line **238** being adapted for disposition in the paint can or other container for discharging at low pressure spray liquid bypassing the high pressure side of the system.

Operation

To operate the above described embodiment of the improved airless liquid spraying system of the present invention, motor **14** is energized from a suitable source of power, such as a common household 110-volt AC outlet. Considering first the high pressure side of the system, motor **14** is normally operated continuously at a constant speed, for example 1,725 r.p.m. thereby rotating shaft **20** at this speed, and via eccentric **52** and connecting rod **56**, reciprocating piston **64** at the same frequency to produce a pulsating pressure variation in the oil trapped in pulsing chamber **76** of the high pressure casing **74**. Contraction of diaphragm **80** caused by the high pressure phase of the pulsation pressurizes paint or other spray liquid in pumping chamber **90**, **92**, thereby seating inlet check ball **96** and forcing the paint at high pressure past outlet ball **108**, through conduit **114**, fitting **120**, chamber **140** and past check ball **134** into the output line **130** for discharge from the spray gun **131**. Diaphragm **80** expands in the low pressure phase of the pressure pulsation cycle, thereby causing a reduced or negative pressure in chamber **90**, **92** which seats outlet check **108** and opens inlet check **96** to draw filtered paint from the interior of filter **226** via nipple **220** and fitting **94**. This cycle occurs at the pulsation frequency produced by motor **14**, for example 1,725 cycles per minute, and this system is capable of producing very high output pressures in line **130** on the order of 4,000 p.s.i., and even higher.

When the discharge valve of the spray gun is closed to cease spraying, the pressure in chamber **140** of fitting **124** immediately rises to that available at the pump outlet **113**, this pressure change representing that previously lost due to the pressure drop between outlet **113** and chamber **140** during spraying, normally on the order of 75 p.s.i. This rise in pressure is sufficient to overcome the bias of spring **154** on plunger **150** so that the end wall **146** of diaphragm **144** bulges or flexes against portion **148** and thus drives the plunger toward ball **96** until stem **152** contacts ball **96** and moves the same off its seat. This immediately depressurizes the high pressure pump, allowing the paint in chamber **90**, **92** to course back and forth past ball **96** between chamber **92** and the interior of casing **218** via fitting **94**. Outlet check ball **108** is immediately seated by the pressure differential created when plunger **150** unseated ball **96**, the high pressure liquid in conduit **114** and line **130** thus being trapped between ball **108** and the closed discharge valve of the spray gun. Thus so long as the spray gun is shut off, this trapped body of liquid maintains a constant elevated pressure on piston **144** to hold the inlet check **96** open. When the discharge valve of the spray gun is reopened to resume spraying, the pressure drop between outlet **113** and the spray gun causes a pressure drop in chamber **140** sufficient to permit spring **154** to drive plunger **150** away from ball **96** until stem **152** is spaced from the seated position of ball **96**. Valve ball **96** is thus once again free to open and close in response to the fluctuating pressure in the pump chamber **90**, **92** and hence diaphragm **80** resumes pumping the paint at high pressure from a low pressure source via filter **216**, to the spray gun.

Referring now to the operation of the low pressure side of the system, rotation of crankshaft **20** drives the low pressure rotary eccentric pump **160** at the same rate as the high presure diaphragm pump, e.g., 1,725 r.p.m., thereby imparting eccentric rotation to eccentric **176** which, via the encircling bearing **182** and seal **196**, imparts an eccentric non-rotary motion to impeller **194** so that it sweeps bore **164** and thereby pumps paint at low pressure from inlet **202** to outlet **204** of the pump body at a relatively high flow rate. Thus, so long as motor **14** is running, pump **160** draws paint from the paint can via inlet tube **206** and pumps the same through outlet tube **208** into the

upper end of the filter casing **218**. The paint flows continuously downwardly in the relatively narrow flow space between screen **226** and the wall of bore **234** at a high velocity and is discharged from this flow space in bypass relation to the high pressure side via fitting **236** back to the paint can via return line **238**. Whenever the high pressure diaphragm pump **80** is conditioned to pump paint at high pressure to the spray gun, i.e., when the trigger valve of the spray gun is opened, filtered paint is drawn into the high pressure pump from the interior of screen **226** via fitting **94**, at which time a portion of the unfiltered paint flowing by the exterior of the screen **226** flows radially inwardly through the screen to meet the demand of the high pressure pump.

From the foregoing description, it will now be understood that the present invention provides many improvements in the high pressure airless liquid spraying system as disclosed in my aforesaid copending application. The addition of the valve unseating plunger **150** greatly reduces wear on both the inlet and outlet check balls **96** and **108** and their associated valve seats **98** and **110** since these valves no longer cycle continuously but rather only when the spray liquid is being sprayed from the gun. Moreover, the concurrent unloading of the high pressure pump also reduces wear on diaphragm **80** and in addition reduces the power consumption of motor **14** and the heat developed by the motor. The back and forth circulation of the paint between the chamber **92** and filter casing **218** during the idle period of the spray gun helps prevent clogging in the fitting **94** and also helps dislodge particles from screen **226** so that the same may be carried by the return flow via tube **238** back to the paint can. The check valve **134** isolates any return pressure surges from the output line **130**, which in the case of a flexible and long line can be considerable, thereby preventing hunting of the valve unseating mechanism.

The provision of a low pressure side and a high pressure side, with continuous paint circulation through the low pressure system produced by the low pressure high volume pump **160**, greatly reduces filter clogging and down time, and considerably extends the useful life of screen **226**. The paint flowing rapidly along the exterior surface of the screen **226** produces a constant washing action on the screen so that the same remains clog-free for a much longer period of time. This washing action continues even when paint is being pumped by the high pressure diaphragm pump **80** for discharge from the spray gun since the output of pump **160** exceeds that of pump **80**. The auxiliary low pressure pump **160** thus insures that there is always a supply of paint at the inlet to the high pressure pump, at a slightly elevated pressure, thereby "supercharging" the high pressure pump and insuring very quick response and practically instantaneous achievement of spray pressure so that a high quality spray pattern is developed upon pulling the trigger of the spray gun. In addition, the continuous recirculation of the paint through the low pressure side of the system causes a constant flow of paint in the storage receptacle from which it is being drawn so that the paint is being continuously mixed as long as motor **14** is running.

The construction of the low pressure pump **160** has been found to be highly desirable for pumping abrasive liquids, both impeller **194** and seal **186** being made of polyurethane elastomer material which has shown little evidence of wear even when operated for extended periods in high abrasive fluids. The hat-shaped seal **186** has been found to successfully withstand the continual flexing between the flange **192** and skirt **184** thereof and is very effective in sealing the oil in which the pump drive structure is submerged from the paint pumping chamber of pump **160**, a highly critical area in which it would be disastrous if leakage developed. Seal **186** thus makes it possible to utilize the oil contained in housing **38** not only as a reservoir for the pulse chamber of the high pressure pump (to which makeup oil is supplied via piston passage **63** and check ball **65** (FIG. 1) as described in more detail in my aforementioned copending application) but also as aa lubricant for bearings **30**, **32**, **54** and **182**.

The quick disconnect coupling 22 facilitates interchanging of various prime movers for the spray apparatus, thereby for example enabling economical conversion to explosion proof motors when spraying in explosive atmospheres, or to motors adapted to meet foreign power frequency standards for export. Moreover, all of the components of the spray system, with the exception of the intake line **206**, return line **238** and output line **130**, are located within the confines of cabinet **12** in a compact arrangement where they are protected from damage in handling the portable equipment. Due to the simplicity of the structure of the low pressure pump **160** and the fact that it is driven from the same crankshaft which operates the high pressure pump, the aforementioned benefits of the low pressure continuous flow self washing filter supply to the high pressure side are obtained at a minimum increase in cost over the system described in my aforesaid copending application.

Combined valve unseater and pressure regulator

Referring to FIG. 3, a modified form of valve unseating mechanism **300** is shown in accordance with the present invention with parts corresponding to those previously described given like reference numerals. Unit **300** includes an inlet fitting **302** which is substituted for fitting **94** and an associated piston fitting **304** which is substituted for fitting **124**. Fitting **302** has an axial cylindrical through-bore **306** with an internal shoulder **308** therein backing up seat ring **98**. Filter unit **216** is theradably mounted in a side port of fitting **302** for communication with bore **306**. A plunger **312** is disposed for axial movement in bore **306** and has a reduced diameter stem portion **314** adapted for engagement with ball **96** in the manner of plunger **150**. Plunger **312** has an enlarged diameter guide portion **316** which carries a pair of O-ring seals **318** adapted to slidably and sealably mount the plunger in bore **306**. The right hand end (as viewed in FIG. 3) of plunger **312** is also enlarged to provide a guide portion **320** for the plunger. The shank **322** of plunger **312** between guide portions **316** and **320** is slightly reduced in diameter and is cross drilled to receive a pin **324** the opposite ends of which project through axially extending slots **326** and **328** disposed diametrically opposite one another in fitting **302**. A coil compression spring **330** encircles fitting **302** and abuts at its ends against pin **324** and an adjusting nut **332** is threadably received on fitting **302** to thereby bias plunger **312** away from ball **96**.

Fitting **304** has an axial bore **334** which is internally threaded at one end to screw onto nipple **336** of fitting **302**, and which receives diaphragm **144** inwardly of the threaded portion with end wall **146** abutting end **320** of the plunger. Bore **334** opens to a smaller counterbore **338** which in turn opens to a still smaller counterbore **340**. An internal shoulder **342** in counterbore **340** backs up seat **138** for isolation check ball **134**, and output line **130** is secured to the nipple at the right hand end of fitting **304**. The high pressure output line **114** is plumbed by a fitting **346** and connector **348** to a side port of fitting **304** for communication with bores **338** and the interior of diaphragm **144**. Preferably, a hollow tube **350** has one end thereof inserted with a press fit in counterbore **340** and extends axially with a radial clearance partially into the interior of diaphragm **144** so that liquid flowing into bore **338** from line **114** must flow into the interior of the piston before reaching the outlet line **130**, thereby insuring that paint or other material does not collect and deposit within diaphragm **144** when the passageways are flushed with water or solvent in a cleanup operation.

The modified valve unseating unit **300** operates to unseat the inlet check ball **96** of the high pressure paint pump in response to diaphragm **144** sensing the full output pressure of the pump when the discharge valve of

the spray gun is closed in the same manner as the previously described valve unseater **150**. However, by providing means such as nut **332** for adjusting the biasing force of spring **330** acting on plunger **312**, the pressure required to drive plunger **312** to the valve unseating position may be adjusted as desired over a wide range by the operator. In the previous embodiment, spring **154** is selected to permit valve unseating action only at the maximum pressure developed by the pump, which occurs only when discharge from the gun is blocked by closure of the gun trigger valve. With unit **300** the output pressure at the spray gun may be regulated within a wide range as desired by screwing nut **332** to the left (as viewed in FIG. 3) to reduce the spring biasing force so that diaphragm **144** drives plunger **312** to unseat ball **96** in response to a correspondingly reduced liquid pressure in fitting **304**. Preferably, spring **330** and nut **332** are designed so that a quarter turn of nut **332** is effective to vary the unseating pressure from a minimum of for example about 500 p.s.i. up to the maximum output pressure capacity of the high pressure diaphragm pump. It has been found that with plunger **312** so adjusted below maximum pump pressure the same will unseat ball **96** and thereby partially unload the diaphragm paint pump whenever the output pressure exceeds the preselected adjusted value. As soon as the pressure falls in fitting **304** to a point where the fluid force acting on diaphragm **144** is overbalanced by spring **330**, plunger **312** is retracted by spring **330** to permit ball **96** to operate freely in its normal cycle as an inlet check valve, whereupon pump output pressure climbs once more to the pre-set regulated value. This action occurs rapidly, the unloading phase of the cycle being much shorter in duration than the pressure buildup phase of the cycle. Accordingly, unit **300** permits the output pressure to be controlled at a selected maximum value, within relatively narrow limits, which does not alter the spray pattern.

Although the exemplary embodiment shown in FIG. 3 utilizes a spring **330** mounted exteriorly of the plunger casing **302**, it is to be understood that an interior spring may also be used as shown in the further modified valve unseater unit illustrated in FIG. 4. In this embodiment a spring **330'** is inside a casing **360** interposed between modified fittings **302'** and **304'**. Spring **330'** abuts at one end against an internal pin or flange **324'** connected to a modified valve unseating plunger **312'** and at the other end against the inner end wall of casing **360**. Casing **360** is threadably connected to fittings **302'** and **304'** as shown in FIG. 4 and is accessible from the exterior of the unit for adjusting the biasing force of spring **330'** by screwing casing **360** further toward or away from fitting **304'**. The change to an internal spring arrangement requires an additional seal **362** carried in a groove of casing **360** to seal the counterbore **364** of fitting **302'** which receives the male end of casing **360**.

FIG. 4 also illustrates a modified automatic pressure unloading system, also in accordance with the present invention, which may be substituted for the valve unseating-unloader mechanism **150** of FIG. 1 and/or the pressure regulator-unloader mechanism of FIG. 3. As illustrated schematically in FIG. 4, the pulse chamber 76 in the high pressure pump casing **74** is connected by a line **370** to nipple **372** of fitting **302'**. Bore **306'** of fitting **302'** is connected by a line **374** to the oil reservoir in crankcase housing **38**, preferably at a point submerged below fill level **46**. Fitting **304'** is connected in the same manner as fitting **304** described previously.

With this arrangement, whenever the output pressure of the high pressure pump rises above a predetermined value, determined by the adjustment of the biasing force of spring **330'** as set by adjusting casing **360**, plunger **312'** will be driven by piston **144** toward ball **96'** to unseat the same. This opens a return connection from pulse chamber **76** back to the reservoir in housing **38** via lines **370** and **374**, thereby unloading the pulse chamber so that the continuous reciprocation of piston **62** and the associated replenisher valve **65** now pumps oil at low pressure in a recirculation path from housing **38** via piston passage **63**, past valve **65**, into pulse chamber **76**, out line **370**, past valve ball **96'** into bore **306'** and thence via line **374** back to the reservoir in housing **38**. Hence the magnitude of the pressure pulsations in chamber **76** is reduced to an insignificant value and consequently diaphragm **80** is essentially relieved of flexing stress. Consequently the paint or other liquid in pump chamber **90**, **92** is no longer pressurized by diaphragm **80** and therefore the pressure of this liquid drops to the low side pressure at the inlet **220** to the high pressure pump. Hence, valve balls **96** and **108** in the high pressure diaphragm pump cease movement during the unloaded condition which occurs when the discharge valve of spray gun **131** is closed and/or when the pressure in line **130** rises above the maximum regulated value determined by adjustment of casing **360**.

The system of FIG. 4 thus can be employed as the high pressure diaphragm pump unloader in place of plunger **150** of FIG. 1 to thereby prevent wear of the valve balls during the non-spraying periods, and to prevent excessive pressure build-up in the high pressure side of the system as motor **14** continues to run. In addition, the system of FIG. 4 can be used in place of the adjustable pressure regulator unloader of FIG. 3 to accomplish a regulated output of the high pressure diaphragm pump. By thus unloading pulse chamber **76** to thereby indirectly unload pump chamber **90**, **92**, an additional advantage is obtained in that oil in the pulse chamber is recirculated during the unloading phase back to the reservoir which serves to cool the pulse chamber and diaphragm **80** by heat transfer from the oil via housing **38** to atmosphere. Also, when spraying certain liquid vinyl materials it has been found desirable to minimize turbulence of such material which tends to cause foaming of the same. Therefore the system of FIG. 4 is advantageous in handling such material since it avoids the back and forth surging action obtained with the unloading plunger **150** in the system of FIG. 1 since diaphragm flexure ceases in the unloaded phase and hence the material in the pump chamber is quiescent in this phase.

I claim:

1. Apparatus for high pressure airless spraying of liquid including in combination a pump having a pump chamber, inlet means connected to said pump chamber and adapted for connection to a source of the liquid to be sprayed. outlet means connected to said pump chamber, inlet and outlet check valve members movably disposed respectively in said inlet means and said outlet means and being cooperable with said pump to cyclically open and close said inlet and outlet means to effect pumping of the spray liquid from said inlet to said outlet means, an output line connected to said outlet means of said pump and pump unloading means including a movable plunger, means for yieldably biasing said plunger toward a first position spaced from the closed position of one of said valve members and movable means exposed to the liquid in said output line downstream from said outlet means of said pump and operably connected to said plunger for biasing said plunger into engagement with said one valve member to unseat the same in response to a predetermined pressure of said liquid acting on said movable means, said movable means comprising a diaphragm having one side exposed to the liquid in said output line and rigid force transmitting means operably interconnecting the side of said diaphragm opposite said one side thereof with said plunger.

2. The combination set forth in claim **1** wherein said yieldable biasing means includes a spring operably connected to said plunger for biasing said plunger away from said inlet check valve member and means for adjusting the biasing force exerted by said spring on said plunger.

3. The combination set forth in claim **2** wherein said

plunger has guide means in slidable sealed engagement with said bore intermediate said inlet check valve member and said movable means, a pin secured to said plunger between said guide means and said movable means projecting transversely therefrom exteriorly of the casing, said spring encircling said casing exteriorly thereof and abutting at one end against said pin, and wherein said means for adjusting the biasing force of said spring comprises a rotatable member threadably received on the exterior of said casing and having an operable connection with the other end of said spring.

4. Apparatus for high pressure airless spraying of liquid including in combination a pump having a pump chamber, inlet means connected to said pump chamber and adapted for connection to a source of the liquid to be sprayed, outlet means connected to said pump chamber, inlet and outlet check valve members movably disposed respectively in said inlet means and said outlet means and being cooperable with said pump to cyclically open and close said inlet and outlet means to effect pumping of the spray liquid from said inlet to said outlet means, an output line connected to said outlet means of said pump and pump unloading means including a movable plunger, means for yieldably biasing said plunger toward a first position spaced from the closed position of one of said valve members and movable means exposed to the liquid in said output line downstream from said outlet means of said pump and operably connected to said plunger for biasing said plunger into engagement with said one valve member to unseat the same in response to a predetermined pressure of said liquid acting on said movable means, said pump unloading means including a casing having a bore therein communicating with said output line downstream of said outlet means of said pump, said movable means comprising a flexible cup-shaped diaphragm disposed in said bore having one end open and in communication with the liquid in said bore, said diaphragm having a transverse wall closing the other end thereof and a skirt portion integral with said wall, said plunger being disposed in abutting relation with said end wall of said diaphragm whereby the pressure of said liquid acting on said diaphragm from the interior thereof flexes said wall to move said plunger toward said inlet check valve member and said interior pressure also expands the skirt portion of said diaphragm into tight sealing relation with the wall of said bore.

5. Apparatus for spraying liquids under high pressure comprising a prime mover having a rotary output shaft, a crankcase disposed adjacent said prime mover with said shaft extending through said crankcase, a cylinder connected to said crankcase and having a piston reciprocable therein with one end of said piston extending into said crankcase, means operably connecting said shaft to said piston to convert rotary motion of the shaft to reciprocating motion of the piston, high pressure pump means having a pulse chamber, said piston having an end remote from said one end thereof defining a movable wall in said pulse chamber, said high pressure pump means including a diaphragm disposed in said pulse chamber and flow passage means having inlet means and outlet means and inlet and outlet valve associated respectively therewith cooperable with said diaphragm in response to expansion and contraction of said diaphragm produced by fluid pressure pulsations in said pulse chamber to pump liquid from said inlet means to said outlet means, an output line connected to said outlet means adapted for connection to a spray gun, a low pressure pump mounted on said crankcase on the side thereof remote from said prime mover and having an impellor operably connected to said shaft, an input line connected to said low pressure pump, an output line connected to the output of said low pressure pump, a filter unit connected between said output line and said inlet means, a return line connected to said filter unit in bypass relation to said inlet means and including a portion disposed for returning the liquid pumped from said low pressure pump to a source of the liquid.

6. The combination set forth in claim 5 wherein said filter unit comprises a casing having a liquid chamber therein, a filter extending within said chamber and having one surface thereof spaced from a wall of said chamber to define a flow space therebetween extending along said one surface of said filter, the surface of said filter opposite said one surface defining with said chamber a filtered liquid space in said chamber, an inlet in said casing communicating with said flow space adjacent one end of said filter and connected to said output line of said low pressure pump, means connecting the filtered liquid space in said chamber to said inlet means of said high pressure pump means, and an outlet in said casing communicating with said flow space at a point spaced axially from said casing inlet, said return line being connected to said casing outlet for conducting unfiltered liquid from said flow space in bypass relation to said inlet means to thereby cause a flow of low pressure liquid along said one surface of said filter to effect a washing action thereof.

7. The combination set forth in claim 6 wherein said low pressure pump is operable to pump the liquid to said filter unit at a rate in excess of the intake rate of said high pressure pump to thereby supercharge said high pressure pump and also effect a continuous washing action on said filter.

8. The combination set forth in claim 6 wherein said low pressure pump comprises a pump body with oppositely disposed sides, a cylindrical bore extending through said body and opening at said sides, a cover plate disposed against one of said sides remote from said crankcase and forming an end wall of said bore, a second cover plate disposed against the other of said sides between said body and crankcase and having an aperture therein axially aligned with said shaft, inlet and outlet passages communicating with said bore, a slot extending radially in said body from the axis of said bore, an impellor ring disposed in said bore with its axially opposite end faces in sliding contact with the respectively adjacent cover plates and having a radial tongue slidably received in said slot, a hat-shaped flexible seal having a cylindrical skirt portion received within said aperture of said second plate and within said impellor ring, an end wall closing one end of said skirt portion and an annular radially outwardly extending flange at the open end of said skirt portion clamped between said second cover plate and said crankcase in sealed relation therewith, an eccentric crank means extending into the open end of said seal and operable for imparting eccentric motion to said skirt portion of said seal to move said impellor in eccentric pumping relation to said inlet and outlet passages.

9. The combination set forth in claim 8 wherein said crankcase has a liquid lubricant reservoir therein, said piston being submerged in said reservoir and having a passage and check valve therein cooperable with said piston for replenishing said pulse chamber with liquid from said reservoir, said crankcase having bearing means in said sides thereof journalling said shaft therein and exposed to the liquid in said reservoir, the interior of said skirt portion of said seal communicating with said reservoir via the adjacent shaft bearing means.

10. The combination set forth in claim 5 wherein said rotary output shaft comprises a disconnectable shaft assembly including a cylindrical shaft directly connected to said prime mover, a crank shaft journalled in said crankcase and having a bore in the end thereof adjacent said prime mover shaft, said prime mover shaft being coaxially received in said bore, a connector sleeve having a through bore slidably received on said prime mover shaft, and means keying said sleeve to said prime mover shaft, said crank shaft bore having internal tapered threads and said connector having external tapered threads mating with said bore threads whereby said connector is slidable on said prime mover shaft into threaded

engagement with said bore threads and is radially compressed as the same is screwed into said bore to thereby frictionally lock on said prime mover shaft to couple the same to said crank shaft.

11. Apparatus for spraying liquid including in combination pump means including a pump chamber, a diaphragm having one side exposed to and forming a movable wall of said pump chamber, inlet means connected to said pump chamber and adapted for connection to a source of the liquid to be sprayed, outlet means connected to said pump chamber, inlet and outlet check valve members disposed respectively in said inlet means and said outlet means and being cooperable with alternating flexure of said diaphragm to pump the spray liquid via said inlet and outlet means, a closed pressure chamber filled with liquid and communicating with at least a portion of said diaphragm on a side thereof opposite said one side thereof, pulse means adapted to generate a pulsating pressure on the body of liquid in said pressure chamber to produce said alternating flexure of said diaphragm, liquid spray means connected to said outlet means of said pump including an output line, an isolation valve serially connected with said output line adjacent but downstream of said outlet means of said pump, said valve including a valve seat and a movable valve member adapted to close on said seat to block flow from said output line toward said outlet means in response to a reversal of the normal pressure drop in said output line downstream from said outlet means and means responsive to a predetermined pressure in said output line between said outlet means and said isolation valve operable to open one of said valve members.

12. A pump comprising a pump body having a pumping chamber therein, means forming a transverse wall at one end of said pumping chamber, means defining an opening at the other end of said pump chamber axially opposite said one end thereof, means forming inlet and outlet passages communicating with said pumping chamber, an impellor disposed in said pumping chamber and cooperable with said passages to pump fluid from said inlet passage to said outlet passage in response to pumping motion of said impellor around the interior of said pumping chamber, a hollow tubular seal member disposed with a first portion thereof extending into driving engagement with said impellor, said seal member having a second portion extending axially through said opening, first means sealing said second portion of said seal member in fixed relation with said pump to said opening, second means disposed adjacent said transverse wall sealing the interior of said seal member from said pumping chamber, said seal member between said first and second portions thereof being flexible in a plane radially of the axis of said seal member and drive means extending axially within said seal member and having rotor means engaging the interior of said first portion of said seal member to impart said pumping motion to said impellor.

13. The combination set forth in claim **12** wherein said tubular seal member comprises a hat-shaped urethane plastic member, said first portion comprising a tubular body portion of said hat-shaped member, said second means sealing the interior of said tubular seal member comprising a flat end wall integrally joined to one end of said tubular body portion of said hat-shaped member and said second portion comprises a flange of said hat-shaped member integrally joined to and extending radially outwardly from said tubular body portion at the open end thereof, and wherein said first means clamps said seal member to said pump and comprises a wall of a housing containing an oil reservoir adapted to lubricate said drive means.

14. In combination, a tubular seal member having a wall closing one end thereof and being open at the other end thereof axially opposite said one end thereof, a body having a chamber therein encircling said tubular seal member with a radial clearance therebetween, means clamping the open end of said tubular seal member in fixed sealed relation with said body, and motion transmitting means extending axially into said tubular seal member via the open end thereof and having means adapted to engage said tubular seal member adjacent said closed end thereof and to move with an eccentric motion in conjunction with such motion of said tubular seal member in the vicinity of said one end thereof, said tubular seal member being made of a material adapted to permit flexure thereof radially of the axis of said tubular member between said fixed and closed ends of said tubular member.

15. The combination set forth in claim **14** where said member comprises a tubular portion, said end wall being integrally joined to said tubular portion and closing one end thereof, a flange portion integrally joined to said tubular portion at said open end thereof disposed axially opposite said closed end thereof, said flange portion extending radially outwardly from said tubular portion, said member being made of material impervious to fluid and being flexible radially in said tubular portion between said ends thereof.

16. Apparatus for spraying liquid including in combination pump means including a pump chamber, a diaphragm having one side exposed to and forming a movable wall of said pump chamber, inlet means connected to said pump chamber and adapted for connection to a source of liquid to be sprayed, outlet means connected to said pump chamber, inlet and outlet check valve members disposed respectively in said inlet and outlet means and being cooperable with alternating flexure of said diaphragm to pump the spray liquid from said inlet to said outlet means, a pulsing chamber filled with liquid, at least a portion of said diaphragm on a side thereof opposite said one side thereof being exposed to the liquid in said pulsing chamber, pulse means adapted to generate a pulsating pressure on the body of liquid in said pulsing chamber to produce said alternating flexure of said diaphragm, means forming a reservoir liquid for receiving liquid from said pulsing chamber, first passage means connecting said reservoir to said pulsing chamber, valve means in said passage means for opening and closing communication between said pulsing chamber and said reservoir via said passage means, an output line connected to said outlet means of said pump, and means for unloading said pump comprising means associated with said valve means operable to open said valve means in response to a predetermined pressure in said output line.

17. The combination set forth in claim **16** further including replenisher means cooperable with said pulse means including a second passage for admitting pulsing liquid from said reservoir to said pulsing chamber whereby the pulsing liquid recirculates via said pulsing chamber, said first passage means, said reservoir and said second passage means when said valve means is open.

18. The combination set forth in claim **16** wherein said unloading means includes means forming a pressure chamber communicating with said output line downstream of said outlet check valve member, a movable member disposed in said pressure chamber and movable in response to pressure of the liquid in said output line, a plunger operably connected for movement by said movable means and means biasing said plunger toward said pressure chamber, said biasing means yielding when said movable member is subjected to said predetermined pressure to thereby cause said plunger to open said valve means.

19. Means for reducing pressure in a fluid pressure system having a chamber containing liquid under pressure comprising casing means having a first bore extending therein and communicating with one end of said casing means, a valve seat in said first bore, a check ball disposed in said first bore between said valve seat and said one end thereof, means fixed to said casing means between said check ball and said one end thereof adapted to limit movement of said check ball away from said seat, a

plunger slidably mounted in said casing means and having one end thereof projecting axially in said first bore toward said check ball, said plunger being axially movable in said casing means such that said one end of said plunger is engageable with said check ball to hold the same off said seat and is disengageable from said check ball to permit the same to seat against said seat, said casing means having a second bore adjacent the opposite end of said casing means, means sealing communication between said bores, a movable member disposed in said second bore and operably connected to said plunger, spring means connected between said casing means and said plunger for biasing said plunger toward said movable member, means adapted to connect said first bore between said second bore and said check valve with said pressure chamber, and means adapted to connect said second bore between said movable member and said opposite end of said casing means with a source of liquid under pressure whereby the pressure of the source liquid acts on said movable member to control movement of said plunger to thereby release liquid from said pressure chamber via said check ball in response to a given pressure of the source liquid.

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