

July 23, 1935.

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2,009,137

MULTISTAGE PUMP AND PUMPING SYSTEM

Filed April 12, 1932

3 Sheets-Sheet 1

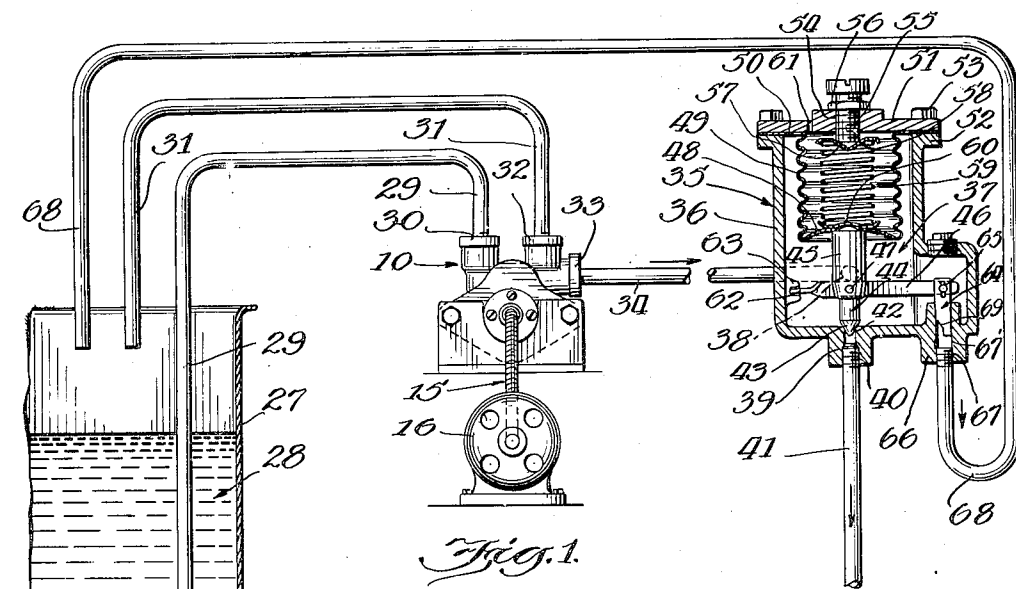
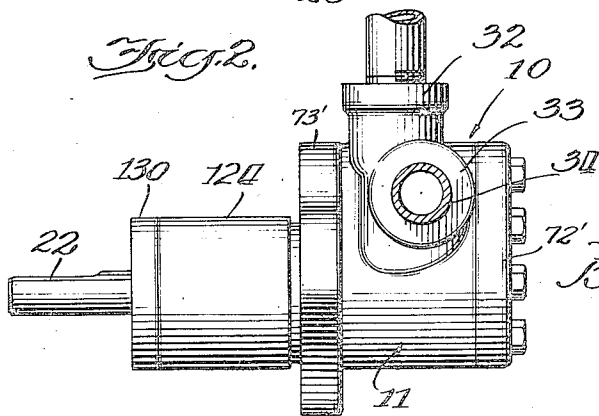
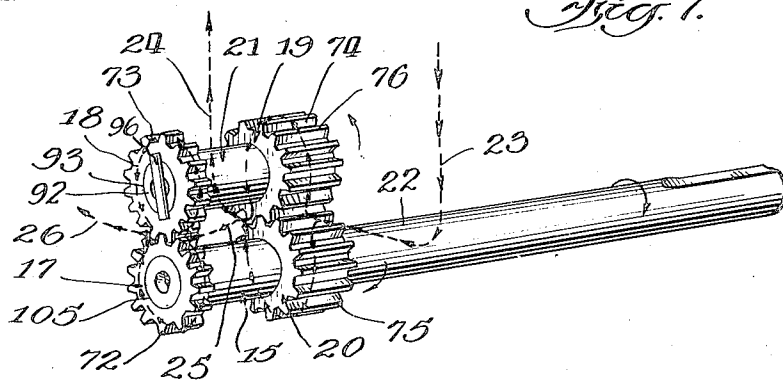


Fig. 7.



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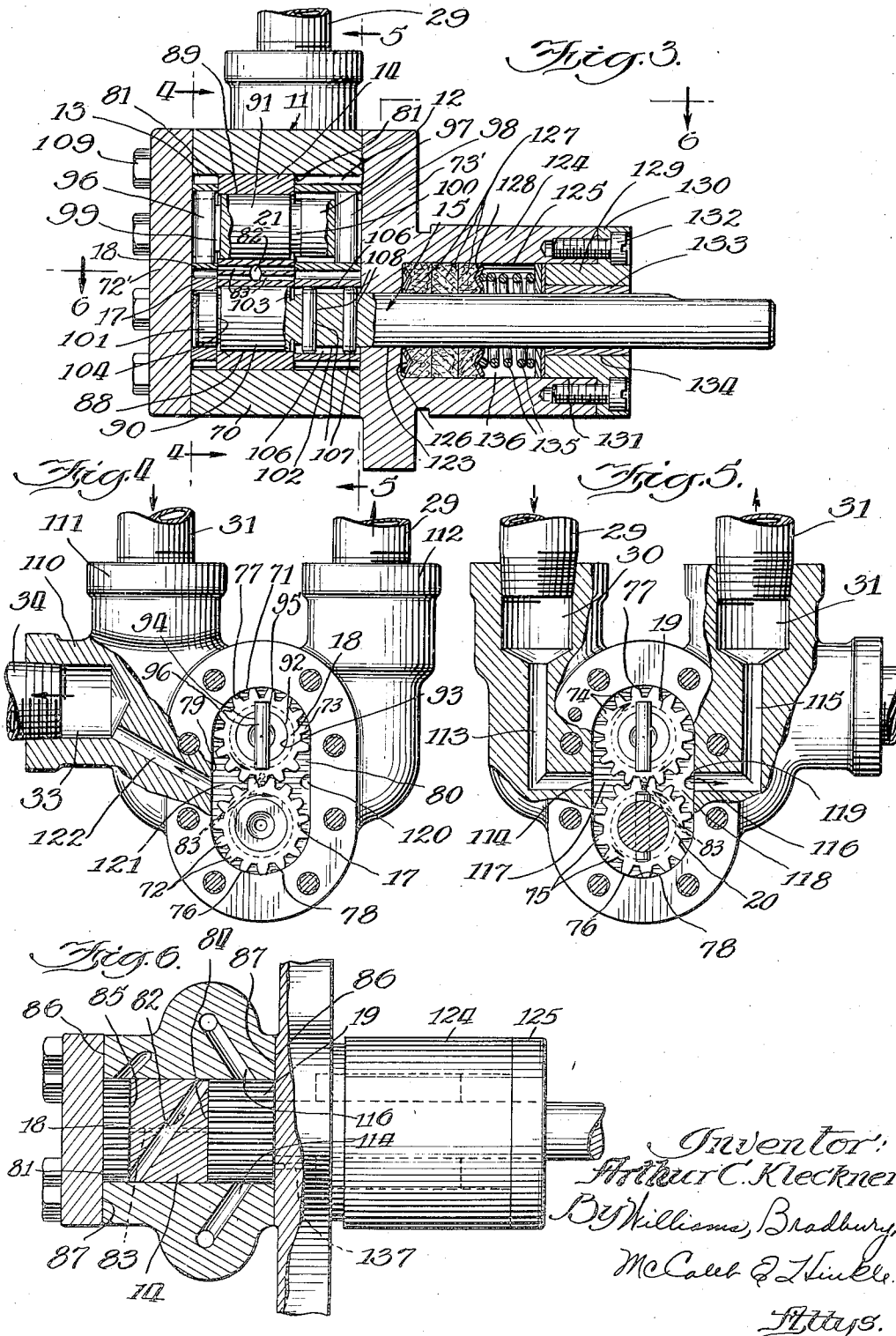
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MULTISTAGE PUMP AND PUMPING SYSTEM

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3 Sheets-Sheet 2



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MULTISTAGE PUMP AND PUMPING SYSTEM

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3 Sheets-Sheet 3

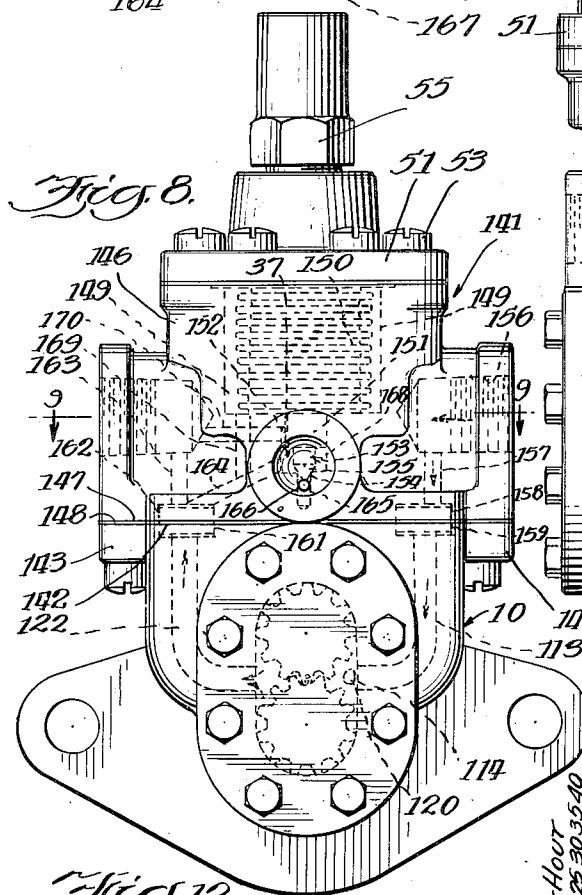
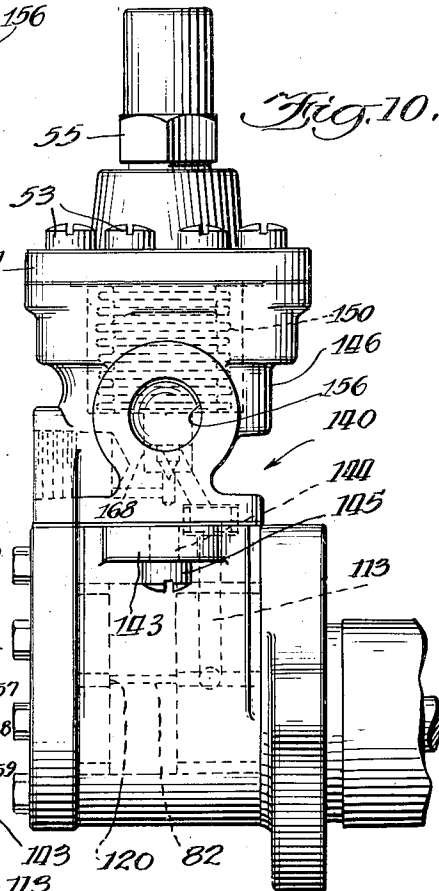
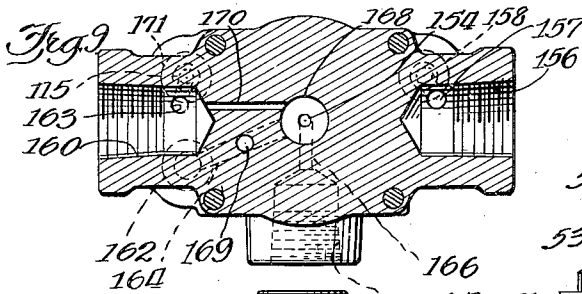


Fig. 11.

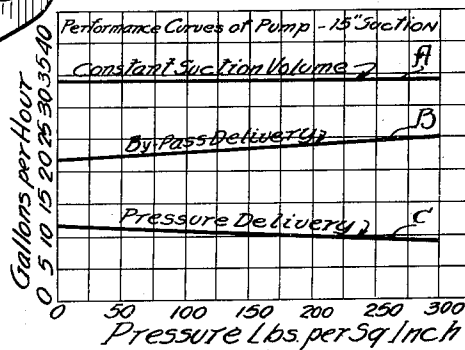
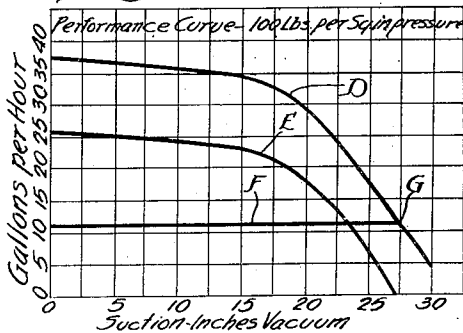


Fig. 12.



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UNITED STATES PATENT OFFICE

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MULTISTAGE PUMP AND PUMPING
SYSTEM

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Application April 12, 1932, Serial No. 604,834

3 Claims. (Cl. 103—126)

The present invention relates to multi-stage pumps and pumping systems particularly adapted to be used in the fuel supply systems for oil burners or the like, but the pump and system are of general application, and may be utilized wherever it is desired to supply liquid at a substantially constant pressure under varying conditions of delivery or supply.

One of the greatest difficulties in the maintenance of the fuel pumps of the prior art has been in the maintenance of a fluid-tight packing surrounding the drive shaft. In order to make some packings fluid-tight or nearly so, such great pressure must be placed upon the packing that a large amount of power is consumed in driving the shaft about which the packing is arranged. Such heavy packing pressure is the cause of excessive wear on the packing and it is, therefore, evident that the use of excessive pressure on the packing itself does not solve the problem and merely leads to greater difficulties.

The fuel pumps of the prior art have also had a relatively poor regulation in that the volume and/or pressure of the liquid delivered from the pump varied greatly with the amount of liquid in the supply tank; that is, the pumps of the prior art delivered the liquid fuel in greater volume when the tank was full than when the tank was empty, and the volume of liquid delivered by the pump also varied greatly with the resistance interposed by the nozzle of the burner or other apparatus.

When an excessive nozzle resistance is encountered in the use of the pumps of the prior art, there is a marked tendency on the part of the delivery volume to fall. The drop in volume delivered which results from leaks in the tank line or in increase in suction resistance is another example of the poor regulation of the pumps of the prior art.

One of the objects of the present invention is the provision of an improved liquid pump which is self-priming by virtue of its improved construction and mode of operation so that the pump will immediately perform its functions on starting, even though the tank and pipe lines had been completely emptied during the last operation of the pump.

Another object of the invention is the provision of an improved rotary pump which is adapted to effect a delivery of fluid at substantially constant volume and pressure throughout a considerable range of variation in the depth, pressure or head of the fluid at the intake end of the pump.

Another object of the invention is the provision of an improved rotary pump having very desirable characteristics from the point of view of regulation so that the delivery requirements at the output and the suction conditions at the input do not materially affect the pressure characteristics of the pump throughout the range of the usual operating conditions.

Another object of the invention is the provision of an improved pumping system by means of which liquid may be supplied to the high pressure side of a multi-stage pump at a substantially constant volume and pressure so that the high pressure side of the pump may operate under substantially constant pressure conditions at its intake port and thereby effect a better regulation at the delivery end of the rotary pump.

Another object of the invention is the provision of an improved rotary pump which is so constructed and arranged that the difficulties caused by the necessity for using a packing about the drive shaft are substantially eliminated and so that any leakage which occurs along the drive shaft from the high pressure end of the pump is collected and conveyed back into useful channels, and it is not absolutely necessary to endeavor to prevent leakage from the high pressure chamber.

Another object of the invention is the provision of an improved rotary pump having an improved packing arrangement and low pressure supply so that the packing is not subjected to high fluid pressures and it is not necessary to subject the packing to excessive packing pressure to seal the shaft at the fluid pressures used, thereby maintaining an effective seal without the necessity for excessive wear on the packing or the use of much power for overcoming packing resistance.

Another object of the invention is the provision of an improved pump of the class described which is sturdy, efficient, capable of economical manufacture and sale, and adapted to perform its functions for long periods of time without necessity for repair or replacement of its various parts.

Another object of the invention is the provision of an improved method of providing fuel supply for oil burners and the like and the provision of an improved system, including an improved pressure regulator.

Other objects and advantages of the invention will be apparent from the following description and from the accompanying drawings, in which similar characters of reference indicate similar parts throughout the several views.

Referring to the drawings, of which there are three sheets,

Fig. 1 is a diagrammatic elevational view in partial section, showing a pumping system constructed according to the present invention;

Fig. 2 is a side elevational view of the pump unit;

Fig. 3 is a medial sectional view of the pump unit taken on a vertical plane, passing through the axis of the drive shaft, with the shafts in partial section;

Fig. 4 is a vertical elevational view in partial section, taken on the plane of the line 4—4 of Fig. 3, looking in the direction of the arrows, showing the mechanism in the high pressure side of the pump;

Fig. 5 is a similar view, in partial section, taken on the plane of the line 5—5 of Fig. 3, showing the arrangement of the low pressure side of the pump;

Fig. 6 is a plan view of the pump, with the pump in partial section on the plane of the line 6—6 of Fig. 3, looking in the direction of the arrows, showing the various conduits;

Fig. 7 is a diagrammatic view in perspective, showing the rotary pump gears and the course of the liquid during the operation of the pump;

Fig. 8 is a side elevational view of a combined pump and regulator unit constructed according to the present invention;

Fig. 9 is a sectional view taken on the plane of the line 9—9 of Fig. 8 looking in the direction of the arrows;

Fig. 10 is a side elevational view of the combined pump and regulator unit taken from the right in Fig. 8;

Fig. 11 is a reproduction of the performance curves of the pump, showing the gallons per hour and pressure in pounds per square inch, to show the relation of volume and output pressure; and

Fig. 12 is a reproduction of the performance curves at fixed output pressure, showing the gallons per hour and suction in inches of vacuum, to show the relation of the suction resistance to volume output.

Referring to Figs. 2, 3 and 7, the pump unit, which is indicated in its entirety by the numeral 10, preferably includes a pump casing 11, with a low pressure chamber 12 and a high pressure chamber 13, separated by a partition 14.

The mechanism of the pump preferably comprises a drive shaft 15, an appropriate electric motor or other source of power 16, a pair of high pressure gears 17, 18, and a pair of low pressure gears 19—20.

Referring to Fig. 7, it will be noted that the two gears 17 and 20 are mounted on the drive shaft 15, while the gears 18 and 19 are mounted on the stub shaft 21. It should also be noted that the projecting end 22 of the drive shaft 15 is located so as to project from the low pressure side of the pump so that the drive shaft need only be provided with packing adequate to take care of a relatively low pressure.

The course of the liquid through the pump is diagrammatically illustrated in Fig. 7 by the dotted line 23 and the arrows which show that the liquid passes into the chamber at the front of the gears 19 and 20 in Fig. 7. The clockwise rotation of the shaft 22 and gear 20 and the counterclockwise rotation of the shaft 21 and gear 19, as indicated, tends to produce a liquid pressure at the opposite side or the rear side of the gears 19 and 20 in Fig. 7.

The line 24 and its arrows indicate the overflow or output of excess liquid from the low

pressure side of the pump, and the line 25 with its arrows describes the course of the liquid which is fed from the low pressure output to the high pressure input.

The line 26 and arrow drawn from the rear side of the gears 17 and 18 in Fig. 7 indicate the direction of the high pressure output and the general location of the output conduit for the high pressure side of the pump.

It will thus be observed that liquid is pumped into the low pressure chamber by means of the mechanism on the low pressure side of the pump and transferred from the output of the low pressure side to the input of the high pressure side. The low pressure pumping mechanism supplies an excess of liquid for the input to the high pressure side of the pump, and the excess is permitted to flow back to the tank. The high pressure pump stage is thus provided with a supply of liquid at a substantially constant pressure, and the capacity of the low pressure stage may be made such that there is always an excess of liquid to be returned to the tank, and consequently the pressure of the supply to the high pressure stage will not vary greatly.

Referring to Fig. 1, 27 is a diagrammatic illustration of a tank of any kind which is provided with a supply 28 of liquid fuel, such as oil, and adapted to be pumped by the pump unit 10.

The intake conduit 29 from the intake 30 of the pump leads to the bottom of the tank or receptacle 27 so as to render practically all of the liquid in the tank available for pumping, and an overflow conduit 31 leads from the low pressure outlet 32 of the pump 10 back to the tank.

The high pressure outlet 33 of the pump is connected with a pipe or conduit 34, which may be directly connected to the nozzle of the oil burner or other device which is to be supplied with liquid under pressure.

In the preferred embodiment of the invention, however, the system will be provided with a pressure regulator, indicated in its entirety by the numeral 35, and comprising a casing 36 having a liquid chamber 37. The conduit 34 communicates with the interior of the liquid chamber 37 at the inlet port 38.

The casing 36 may be formed with an outwardly projecting lug 39, formed with a threaded bore 40 for receiving the threaded end of a conduit 41 leading to the burner nozzle. At the inner end of the bore 40 it may be provided with a frusto-conical seat 42 for seating the complementary end 43 of a needle valve 44. The needle valve may have its body 45 provided with a slot or aperture for receiving a transverse lever 46, which is pivoted by a pin 47. The upper end of the needle valve body may be secured by a rivet, bolt, or other convenient means to the closed end 48 of an expansible sheet metal bellows 49.

The bellows 49 is preferably provided with a radially extending attaching flange 50 at its open end, and the flange 50 may be clamped between a cover 51 and an attaching flange 52, by means of a multiplicity of screw bolts 53 which pass through the cover and are threaded into the flange 52.

The cover 51 is also preferably provided with a threaded bore 54 for receiving a screw bolt 55 having a lock nut 56. The inner end of the screw bolt 55 engages a spring plate 57 which is formed with an annular depression or groove 58 providing a seat for the helical compression spring 59. A similar spring plate 60 provides a seat for the compression spring 59 at its opposite end and engages the closed end 48 of the bellows 49. The

spring 59 tends to maintain the needle valve 44 in closed position until a predetermined liquid pressure is built up in the regulator chamber 37 so as to compress the bellows 49. The interior of the bellows 49 communicates with the atmosphere through one or more air holes 61 in the cover 51. The pressure at which the valve 44 will be actuated or opened may be regulated or predetermined by adjustment of the screw bolt 55 which is adapted to adjust the spring pressure inside the bellows 49.

The lever 46 is preferably provided with a twisted end 62, which may be pivoted in a groove 63 formed in one side of the casing 36. The opposite end of the lever 46 is pivoted to a piston valve 64 by means of a pin 65. The casing 36 is also preferably provided with a projecting lug 66, which may be provided with a threaded bore 67 for receiving the threaded end of the overflow conduit 68 leading from the pressure regulator 35 back to the tank 27.

The bore 67' is adapted to slidably receive the cylindrical body of the piston valve 64 to effect a closure of the bore until the bellows 49 is compressed to a predetermined degree. The piston valve 64 is also provided with a tapered throttling surface 69 which effects a gradual opening of the piston valve when the piston 64 is raised a predetermined amount by the lever 46.

It will be observed that the piston valve is located at the end of lever 46, where it will have a much greater movement than the needle valve 44, and the contour of the surface 69 may be made such as to accomplish a very close regulation of the pressure in the regulator chamber 37, so that the nozzle 41 will be supplied with liquid at a substantially constant pressure.

The operation of the pressure regulator is as follows: When the pump 10 is not operating, the pressure of the spring 59 closes the needle valve 44 and the piston valve 64. As soon as the pressure generated by the pump 10 builds up the pressure in the regulator chamber 37 to the proper amount the liquid pressure will cause the bellows 49 to collapse against the compression of spring 59 and needle valve 44 will be opened to supply liquid under pressure to the nozzle.

The pump 10 is adapted to supply more liquid under high pressure than is necessary for the ordinary operation of the nozzle or other device in order to assure the maintenance of the proper pressure at the nozzle, but as soon as the pressure builds up above a predetermined amount, the bellows 49 will collapse still further, and the piston valve 64 will be opened to permit the excess liquid to flow back to the tank through the conduit 68.

The multiplying mechanism which actuates the piston valve 64 makes the piston valve quite sensitive and decreases the range of pressure variation of the device.

It should be understood, however, that the pressure regulator 35 need only be used in the system whenever extremely close regulation of pressure is required, and in some embodiments of the invention the pump unit 10 is adapted to provide a supply of liquid under sufficiently constant pressure so that no pressure regulator need be employed.

Referring to Fig. 3, the casing 11 of the pump unit is preferably formed of a substantially oblong metal member 70 having an oblong chamber 71 and having both of its ends open. The ends of the casing are closed by cover plate 72' and cover plate 73'.

In order to provide an efficient rotary pump,

the parts of the casing and pump mechanism must be very accurately machined, and should preferably be constructed of the best steel or any suitable steel alloy suitable for accurate machining and long wear.

Referring to Fig. 3, it will be observed that the oblong chamber 71 is adapted to receive the gears 17 to 20. The gears 17—20 may be provided with a multiplicity of teeth 72—75, which are preferably of the same number and shape on each gear. The side surfaces of the teeth 72—74 may be formed according to the best practice for providing a rolling contact between the adjacent surfaces and for eliminating noise and leakage between the teeth at the center of the pump. The periphery of each of the gears 17—20 or the outside edges of the teeth are provided with curved surfaces 76, forming portions of a cylinder, the surfaces being substantially complementary to the cylindrically curved walls 77, 78 located within oblong chambers 71 at each end. The side walls 79 and 80 of the oblong chamber 71 are preferably substantially plane and located tangent to the semi-circular or cylindrical walls 77, 78 at each end.

In order to form the low pressure chamber 12 and the high pressure chamber 13 in the oblong chamber 71, the casing is provided with partition 14. It would be extremely difficult, if not impossible, to form the corners 81 at the inner ends of the chambers 12 and 13 with a sharp right angle on account of the tendency for tools to become dull at the point or apex of two blades which are disposed at an angle to each other. This would be the cause of an inaccurate fit between the end surfaces of the gears and the partition 14 and therefore I prefer to form the partition 14 of a separate piece of metal which has an external surface substantially complementary to the surface of the oblong chamber 77. The partition 14 may then be provided with its transverse conduit 82 without any difficulty before the partition is put in place, and also with the bleeder conduits 83, the purposes of which will be described in detail hereinafter.

The partition 14 is made sufficiently large and fits the oblong chamber 77 in such a manner that there is a close frictional engagement between the external surface of the partition 14 and the internal walls of the chamber 77. The parts may be heated, prior to their assembly by means of a press and the casing 70 may be permitted to contract about the partition 14 to secure it in place.

It will be noted that the partition 14 is so located that the high pressure chamber 13 is relatively small, while the low pressure chamber 12 is relatively large. The low pressure chamber 12 is made larger in order to accommodate larger gears and to provide an excess supply of liquid under low pressure for the intake side of the high pressure stage.

Each end of the partition 14 is machined to a substantially plane surface 85 and the adjacent ends of the gears are also machined to a substantially plane surface to engage the surface of the partition. The thickness of the gears is such that the outer end surfaces of the gears, which are also machined to a substantially plane surface, are flush with the flat end surfaces 86 of the casing, and when the cover plates 72 and 73 are secured on the casing, the inner surfaces 87 of the cover plates are in close sliding engagement with the ends of the gears.

In other words, the gears 17—20 fit accurately in the gear chambers 12, 13, and the peripheral

surfaces 76 of the gears are in sliding engagement with the curved walls 78.

The partition 14 is preferably provided with a pair of substantially cylindrical bores 88—89 adapted to receive the complementary cylindrical portions 90, 91 of the shafts 15 and 21. The shaft 21 is provided with a reduced cylindrical portion 92 which is adapted to be received in the complementary cylindrical bore 93 in gear 18. A transverse slot 94 is formed in the end of shaft 21 and extends into the side walls of the bore 93 in gear 18. A transverse pin 96 is located in the slots 94, 95, and the pin causes the gear 18 to be driven by shaft 91.

In a similar manner gear 19 is rotatably mounted on the reduced cylindrical end 97 at the right end of stud shaft 21 and the gear 19 is keyed to shaft 21 by a pin 98.

In order to facilitate the accurate machining of the cylindrical surfaces 92, 91 and 97 on the shaft 21, the shaft is formed with grooves 99, 100 between these cylindrical surfaces respectively so that the tools in grinding one surface may not overlap on the adjacent surface which is of a different diameter. The same is true of the left end of shaft 15 which is formed with cylindrical surfaces 90, 101 and 102 separated by grooves 103, 104. The cylindrical surface 101 is rotatably received in the bore 105 in gear 17, and cylindrical surface 102 is received in a complementary bore in gear 20. Since gear 20 drives all of the other gears in the embodiment illustrated, it is provided with longitudinally extending slots 106 for receiving a pair of pins 107 which are located in transverse bores 108 in the drive shaft 15.

In some embodiments of the invention the gears may be splined to the shafts in many other different ways, but it is found that when the gears are arranged as a train so that they are driven one by the other from one end of the train to the other, all of the backlash is taken up when the gears are being driven and there is no possibility of noise due to backlash. The splining of the gears, as shown in Fig. 3, is found to reduce the amount of noise caused by the gears quite materially.

The cover plates 72', 73' may be secured to the casing 70 by means of a plurality of screw bolts 109 which pass through apertures in the cover 72' and through registering bores in the casing 70, and are threaded into threaded bores in the end plate 73'. The oblong casing 11 is preferably formed with integral projections 110, 111, 112, provided with threaded bores 33, 32 and 30 respectively, which form the inlet and outlet ports and are adapted to receive the threaded ends of the pipes 34, 31 and 29 respectively.

Referring to Fig. 5, the inlet port or bore 30 communicates with a conduit 113 which leads to an inlet port 114 located at the low pressure end of the pump in chamber 12 on the side toward which the gears 19 and 20 are rotating. The overflow outlet port 32 communicates through a conduit 115 with an overflow port 116 which is located in the opposite wall of the low pressure chamber 12 on the side from which the gears rotate, with reference to the interengaging parts of the gears.

The counterclockwise rotation of the gear 19 and clockwise rotation of the gear 20 in Fig. 5 tends to carry liquid from the point 117 about the outer periphery of the gears adjacent the curved walls 77 and 78 and creates a pressure at the point 118 at the right hand side of the chamber 12 in Fig. 5.

The space in chamber 12 at the point 118 thus constitutes a source of liquid under reduced pressure for supply to the high pressure stage of the pump, and the excess liquid is carried off by the conduits 115, 32, 31 back to the tank. The liquid under reduced pressure is supplied to the high pressure chamber 13 through the diagonal conduit 82 (Fig. 6) which is so located as to form a port 119 adjacent the overflow port 116.

When the pump is operating, liquid flows in the direction of the arrow shown in Fig. 6 through the diagonal conduit 82 and the opposite end 120 of the conduit 82 forms an inlet port for a high pressure chamber at the right side of Fig. 4.

Since Fig. 4 is a view looking at the other end of the pump, the gear 17 will rotate in a clockwise direction and the gear 18 will rotate in a counterclockwise direction.

The operation of the gears 17 and 18 in their high pressure chamber 13 is substantially the same as described with respect to the low pressure side.

The liquid is engaged by the teeth as it issues from the intake port 120 and is entrained by the teeth about the periphery and carried along the periphery of the gears and along the curved walls 77, 78 to the space 121 at the left side of the high pressure chamber 13 in Fig. 4, tending to cause a high pressure in the liquid within the space 121. The space 121 communicates with the outlet port 33 through the conduit 122 and port 33 is the high pressure outlet of the pump.

On account of the formation of the teeth 74 there is some tendency toward the squeezing or compression of the liquid at the points between the gears as the tooth rolls or slides down into the space between two adjacent teeth. This compression between the teeth results in a slight noise and should preferably be relieved in such manner as will not affect the efficiency of the teeth in their pumping action when they are in engagement with the curved walls 77, 78.

In order to relieve this pressure between the engaging teeth, the partition 14 is preferably provided with a plurality of bleeder conduits 83, which are located to permit the liquid under pressure from the high pressure side to flow out sidewise from between the teeth as they come into engagement with each other. One of the conduits 83 is located in Fig. 4 to register with the base of the groove between the teeth of gear 17, and the other conduit 83 is located to register with the base of the grooves between the teeth of the gear 18.

This effect is present to some extent in both the high pressure and low pressure chambers, but it is found that the noise and resistance to rotation which is caused by this effect are relieved by permitting the liquid between the high pressure teeth to flow back to the low pressure side.

The end plate 73' is provided with an accurately machined circular bore 123 which is adapted to rotatably receive the projecting end 22 of shaft 15. The end plate 73' is also preferably provided with a tubular formation 124 surrounding shaft 15 and formed with a counterbore 125. The base of counterbore 125 is provided with an expansion ring 126 which may consist of an annular sheet metal member of substantially V shape in cross section and a plurality of packings 127 are compressed between expansion ring 126 and a similar expansion ring 128.

The tubular formation 124 is provided with a gland having an attaching flange 130 and hav-

ing a cylindrical formation 131 adapted to be received in counterbore 125. The gland may be secured to the member 124 by a plurality of screw bolts 132 passing through the attaching flange 130 and threaded into the member 124. The gland 129 is provided with a bearing 133 formed of suitable bearing metal and located in a bore 134 and a helical packing spring 135 is compressed between the end of the gland 129 and expansion ring 128. The packing is thus automatically taken up as fast as it wears, and is maintained under a relatively low pressure by means of the compression spring 135.

Since the projecting end 22 of the drive shaft 15 leads into the low pressure chamber, it is not necessary to pack the drive shaft 22 so securely as would be necessary if a high pressure were generated in chamber 12. As a matter of fact, the packing chamber 136 may actually be at a pressure which is slightly sub-atmospheric so that any leakage past the packing 127 may be drawn back into the low pressure chamber 12.

For this purpose the plate 73' may be formed with an aperture 137 leading from the packing chamber 35 to the intake side 117 of the low pressure chamber.

It might be supposed that since the gears 17-20 are all driven from the same shaft at the same speed the pressures generated by the two stages of the pump might be substantially the same or that the pressure generated by the larger gears might be greater than that generated by the smaller gears. These pressures, however, depend not only upon the rate of rotation of the gears, but upon the relative sizes of the supply and outlet ports, and particularly upon the resistance to discharge from the pump which is encountered at the outlet side of the pump. The pressure builds up as the outlet resistance is increased. The pressure on the low pressure side is extremely low or sub-atmospheric because of the free return of liquid to the tank from that side. The sizes of the gears 19 and 20 on the low pressure side are such that the low pressure stage is adapted to pump or to suck about fifty gallons of liquid per hour and supply it to the high pressure side at a pressure which may be slightly sub-atmospheric or slightly above atmospheric.

Referring to Figs. 8, 9 and 10, these are views of a combined pump and regulator unit, which has great advantages over the devices of the prior art and the separate pump and regulator units by reason of a saving in cost of material and labor in the installation.

The combined unit is more easy to install because there is no necessity for a number of different pipes which are otherwise required where the units are separate. The combined pump and regulator unit is indicated in its entirety by the numeral 140, and it preferably consists of a pump indicated by the numeral 10 and a regulator 141. The pump 10 may be substantially similar in construction to that previously described except that it is not provided with the customary pipe fittings 110, 111 and 112 for attachment of the pipes, but the conduits leading from the pump all extend to the upper flat surface 142 of the pump casing. The pump casing is provided with attaching flanges 143 having apertures 144 for receiving the screw bolts 145 which are threaded into the body of the regulator casing 146 to secure the parts of the unit together. The base of the regulator casing 146 is likewise provided with a flat surface 147 or a surface complemen-

tary to the surface 142 on the pump casing, and the conduits of the regulator casing 146, which are intended to communicate with the conduits of the pump 10, lead to the surface 147 and register with appropriate conduits of the pump 10. An appropriate gasket 148 having suitable apertures is interposed between the surfaces 147 and 142, if deemed necessary to insure a fluid tight joint.

The regulator unit shown in Fig. 8 is of a more simple construction than that shown in Fig. 1, but its casing 146 is likewise provided with a substantially cylindrical chamber 149 for housing the pressure bellows 150. The bellows 150 is provided with an outwardly extending flange which is clamped between the cover 51 and the casing 146 by means of screw bolts 53, and the cover is provided with an adjustment screw bolt 55 for adjusting the pressure on the spring, as shown in detail in Fig. 1.

The closed end of the bellows 150 supports a piston valve 151 for controlling an overflow port 152, and the piston valve may support a needle valve 153 for controlling an output port 154. The needle valve 153 is preferably provided with a frusto-conical end surface 155 for engaging a complementary seat. The length of the piston valve 151 is such that it does not uncover the overflow port 152, until the needle valve 153 is already opened, and the pressure on the bellows 150 has been increased to an amount more than that required for the burner.

The regulator of Figs. 8 to 10 is thus adapted to operate substantially the same as the regulator previously described, but the extremely flexible bellows 150 gives the device a range of movement which permits it to control two valves 151, 153 successively by movement in the same direction.

It is not necessary, therefore, to describe in detail all of the parts of the pump and regulator, but the course of the liquid through the pump and regulator will be described in order to show the connection between the various conduits and the elimination of pipes which have been rendered unnecessary by the use of a combined unit.

Referring to Fig. 9, the regulator casing 146 is provided with a threaded bore 156 which forms the inlet for the pipe from the tank and corresponds to the inlet 30 of Fig. 1 connected with pipe 29. A conduit 157 leads from the inner end of the bore 156 downward to a counterbore 158, which registers with a counterbore 159 formed in the surface 142 of the pump. The counterbore 159 communicates with a bore or conduit 113 leading to the port 114 at the input of the low pressure side of the pump. A diagonally extending conduit 82 (Fig. 10) conducts liquid from the output of the low pressure side to the input of the high pressure side, and is omitted in Fig. 8 for the purpose of clarity. The outlet 120 of this diagonal conduit is indicated in Figs. 8 and 10.

Referring to Fig. 9, a conduit 115 leads upward from the low pressure output and communicates with the threaded bore 160, which is adapted to receive a single overflow pipe leading back to the tank. A conduit 122 leads from the output of the high pressure side of the pump and communicates with a counterbore 161 in the surface 142. Counterbore 161 registers with the counterbore 162 in the surface 147 of the regulator casing 146, and the regulator casing is provided with a conduit 164, communicating with counterbore 162. Conduit 164 conducts fluid from the high pressure side of the pump to the pressure chamber 37 of the

regulator unit. The liquid under pressure first forces the bellows 150, piston valve 151 and needle valve 153 upward to open the port 154. Port 154 communicates with a downwardly extending conduit 165 which communicates with a laterally extending conduit 166. The laterally extending conduit 166 (Fig. 9) communicates with a threaded bore 167, which is adapted to receive a pipe leading to the burner.

The piston valve is slidably mounted in a bore 168 to control the flow of liquid through the overflow port 152. The conduit 164, which leads liquid under high pressure to the pressure chamber 37, also communicates through a conduit 169 with the cylindrical chamber 149 in which the bellows 150 is located. The bellows 150 is thus always subjected to the same pressure that exists in the pressure chamber 37, and the chamber 149 may be considered a part of the pressure chamber 37 for certain purposes.

When the pressure in the pressure chamber 37 rises above a predetermined value, the upward movement of the piston valve 151 with the bellows 150 causes the piston valve 151 to uncover port 152, which is the overflow port. Port 152 communicates by conduit 170 with the bore 160. The conduit 163, which is observed in Fig. 8, does not communicate with the counterbore 162, but with a counterbore 171 disposed on the other side of the unit. Conduit 162 thus communicates with the low pressure output conduit 115 from the low pressure side of the pump and is adapted to carry back to the tank the excess liquid from the low pressure side of the pump. Conduit 170 conveys back to the tank through the bore 160 and an appropriate pipe the excess liquid from the pressure chamber 37 of the regulator.

It will thus be observed that a single overflow conduit may be used to carry back excess liquid from the regulator unit and from the low pressure stage of the pump when the combined unit is used. Furthermore, there is no necessity for the interconnecting pipe 34 of Fig. 1, when the combined unit is used; and there will be one outlet to the burner, one input pipe from the tank, and one return pipe to the tank when the combined regulator and pump unit of Figs. 8 to 10 is employed.

The sizes of the gears 19 and 20 relative to the gears on the high pressure side may be varied considerably, but the low pressure stage should preferably pump an excess of liquid over that necessary for the high pressure stage. Thus the low pressure stage may be adapted to suck up about fifty gallons of liquid per hour, and to supply liquid to the high pressure side at a pressure which may be slightly sub-atmospheric or slightly above atmospheric.

The intake pressure for the high pressure side may even be sub-atmospheric if the tank is located below the pump, so that there would be no tendency for leakage through the packing. In the ordinary installation the output pressure of the low pressure stage would be slightly above atmospheric on account of the return resistance of the overflow pipe 31, but the input pressure at the intake of the low pressure side would be sub-atmospheric so that any leakage past a packing 127 will be sucked back into the low pressure stage through the conduit 137 (Fig. 6), and the packing need not be subjected to any severe conditions of service. About fifteen gallons per hour, for example, of the liquid supplied by the low pressure stage may be taken into the high pressure stage and delivered through the high pressure outlet 33, while the balance of thirty-five gallons may be

returned to the tank through the overflow conduit 31.

The characteristics of a pump of this type should be noted in the case of the pump per se and in connection with an oil burner system, as all of the advantages may not be evident from the performance in an oil burner system.

The present pump has improved characteristics, from the point of view of regulation, over the devices of the prior art, and these characteristics are illustrated by the curves shown in Figs. 11 and 12.

In Fig. 11, the ordinates are provided with indicia indicating the gallons per hour, and the base line has indicia indicating the pressure in pounds per square inch. In the test upon which these curves were based, the head of liquid in the tank was kept substantially constant and, as indicated at the top of the figure, the suction was fifteen inches of mercury.

The output pressure of the pump was regulated by increasing the spring pressure on the regulating valve on the output side and was varied from zero to three hundred pounds per square inch in determining the curve A. The volume of output remained substantially constant at about thirty-four gallons per hour, thus demonstrating that at constant suction the pump was capable of delivering a constant volume through a variation of pressure from zero to three hundred pounds per square inch.

In the same test, the by-pass delivery was measured, the results being indicated by curve B, and it will be noted that the suction being constant, while the output pressure of the high pressure side was varied from zero to three hundred pounds per square inch, the by-pass delivery changed very slowly from twenty-two gallons per hour to twenty-five gallons per hour. The slight upward slope of the by-pass delivery curve B shows a very slight variation in by-pass delivery.

The curve C, which is based upon the same test, indicates the results of measurement of the pressure delivery from the high pressure side of the pump, which varied only slightly, from twelve gallons per hour to nine gallons per hour.

The slight downward slope of the pressure delivery curve shows that the volume output on the high pressure side of the pump varied only slightly during an extremely large variation which was made in the pressure of the output.

The curve A represents the sum of the by-pass delivery B and the pressure delivery C, since the total volume is the sum of the by-pass delivery volume and the pressure delivery volume.

These curves demonstrate conclusively that the volume output does not fall off materially, although the pressure may be raised considerably by the resistance encountered at the output side. The pump will continue to deliver its rated volume, or substantially that volume, irrespective of the resistance encountered at the output side.

Referring to Fig. 12, these curves D, E and F show the results attained in a test at constant output pressure of one hundred pounds per square inch at the high pressure side. The gallons per hour output are plotted against the suction in inches of vacuum. In this case a throttle was applied to the conduit at the suction side of the pump, and the result of increased resistance at the suction side of the pump on delivery in gallons per hour was determined. The curve E shows the gallons per hour delivered at the by-pass as the suction was increased. Of course, the

by-pass delivery volume is important only for the purpose of providing an excess supply of liquid to maintain the characteristics of the high pressure side of the pump by providing a constant supply of liquid at the input of the high pressure stage. As the suction was increased by-pass delivery, starting at twenty-six gallons per hour, dropped off rather slowly until about fifteen inches of suction when the by-pass delivery dropped off quickly and the curve strikes the axis at about 27 inches of vacuum in the pump tested; that is, at the ordinate 27 the resistance at the input side of the pump had so affected the pump that all of the liquid which was sucked up by the pump was being put out at the high pressure side of the pump and there was no excess left to be returned to the tank through the by-pass delivery from the pump.

Referring to the curve F, this curve shows the gallons per hour output from the high pressure side of the pump to the burner at a constant pressure of one-hundred pounds per square inch during a variation of from zero to twenty-seven inches of vacuum. It will be noted that the gallons output to the burner or other consuming device was substantially constant so long as sufficient liquid was supplied to the high pressure side by the low pressure side.

The curve represents the sum of the ordinates of curves E and F and is the total output curve under the same conditions. At the point G in the curves D and F, the suction resistance was so great that sufficient liquid was not supplied to the high pressure stage by the low pressure stage to maintain the volume, and consequently the volume dropped off.

The important conclusion to be drawn from the curves of Fig. 12 is that throughout a very wide variation in suction at the input side, with a constant output of pressure of one hundred pounds per square inch, the volume output at the high pressure side to the burner remains substantially constant.

It should be remembered that these tests were carried on without the use of any regulator valve 35 or 141 except as a means to throttle the output passage to increase output resistance and raise the pressure and the curves show the characteristics of the pump per se under the conditions described. For certain types of installations it may be entirely unnecessary to utilize any regulator valve when a pump constructed according to the present invention is employed, but the regulator valve is adapted to insure even a more close regulation of the conditions under which liquid is supplied to the burner.

A regulator valve is generally necessary in any ordinary oil burner installation as a safety device to prevent pressure building up in the lines beyond a predetermined limit and to prevent bursting of the conduits because the output resistance interposed by a nozzle usually varies somewhat, due to the dirt and other foreign matter in the oil, which tends to clog the nozzle at least momentarily, causing fluctuations in the resistance, resulting in fluctuations in output pressure. The present pumping system is, however, adapted to deliver a constant volume of oil with or without a regulating valve.

The operation of the present invention will be apparent from the description of the various parts and the functions of each part. When the pump 10 is driven by the motor 15, liquid is pumped up or sucked up from the supply 28 in tank 27 by the low pressure stage of the pump

and an excess supply is constantly provided at a predetermined pressure for the high pressure stage of the pump. The excess is such that although the head of the liquid in the tank 27 may vary considerably from a full tank to an empty or almost empty tank, the high pressure stage is still supplied with the full amount of liquid at its inlet necessary to assure its operation under substantially the same conditions. The pump is thus capable of supplying liquid fuel under pressure at a substantially constant pressure, irrespective of the head of liquid in the tank, and the present pump has highly improved characteristics with respect to regulation over the pumps of the prior art.

In the case of an oil burner system, it should be noted that the pump and regulator valve (if one is employed) will be adjusted when the conditions are ideal, at the installation of the system. At that time, if the system is properly installed, the oil strainers should be clean and interpose but little resistance in the suction line. There should be no leaks in the suction line, and the only variation to be expected under ideal conditions is the variation in the head of the liquid in the tank. However, as the use of the oil burner system goes on, the strainers become clogged and leaks often develop in the suction line, the leaks sometimes being under ground where they cannot be found or corrected. The characteristics of the burner nozzle may also change due to clogging or burning. The present pump and pumping system is adapted to make the oil burner system operate satisfactorily, even under the most adverse conditions, and the pump has often been installed and the burner found to operate satisfactorily under conditions where there were under-ground leaks or other troubles which would prevent the pumps of the prior art from operating satisfactorily.

Another advantage of the present invention lies in the fact that the manufacturer of the pump and regulator equipment may effect a material saving in the cost of equipment by working closer to the volume requirements of any particular burner or other consuming apparatus. For instance, if the consumption requirement is ten gallons per hour, an ample factor of safety would be provided in the present system by a pump adapted to supply the specific volume requirement or a little more than the volume requirement on account of the constant delivery characteristics of the pump, while other pumps would require the supply of a pump capable of delivering two or three times the volume requirement in gallons per hour.

The present pumping system is self-priming by virtue of the improved arrangement of the parts of the pump in two stages. There is practically no resistance at the output side of the low pressure stage by reason of the use of the by-pass delivery pipe returning to the tank. The only resistance would be that occasioned by the resistance of the pipe itself, which is negligible. A rotary pump may be made self-priming when the resistance is made very low, both on the input and output sides of the pump, and the suction resistance on the low pressure side is also very low because the pump is preferably disposed at such a point that liquid is forced to the pump by the external pressure of air on the liquid in the tank when a partial vacuum is produced in the input side of the low pressure stage; that is, the output pressure of the low pressure stage may be sub-atmospheric. The

low pressure stage is self-priming and adapted to provide a supply of liquid for the high pressure stage so that the high pressure stage is also made self-priming.

5 There is always a film of oil remaining upon the walls of the gear chambers in the pump and upon the gears, even though the pump be practically empty, and this film of oil is sufficient to insure the operation of the pump to produce
10 a suction at the intake. Pumps of this type have been wiped entirely dry with a cloth and then located high above the tank, and upon starting of the pump it was found to be self-priming, even under those conditions.

15 The pump is preferably arranged with its conduits extending upward above the pumping chambers so that at least the low pressure will always be full or partially full of liquid and adapted to supply liquid to the high pressure
20 stage as soon as the pump is started, whether the pipes have been emptied or not. Thus the pump is self-priming, and this is a very important advantage in connection with oil burners because a great deal of trouble is caused when
25 it is necessary to remove the pipes from a pump to prime the pump after the pipes and pump have become emptied, as experienced with the pumps of the prior art.

30 The present pumping system includes an improved pressure regulator which is more sensitive than the devices of the prior art, and the preferred form of pumping system includes overflows both from the multi-stage pump and from the regulator so that the pressure at the nozzle
35 may be maintained more nearly constant than any of the devices of the prior art.

The only packing which is needed on the pump is used upon the low pressure side of the pump, and this packing need not be subjected to excessive packing pressures because the fluid pressures under operating conditions at this point are not such as to require a very tight packing. Thus one of the greatest difficulties encountered in rotary
40 pumps of the prior art is eliminated by the arrangement of the parts and packing of pumps constructed according to the present invention, and the packing may be expected to perform its functions for a long period of time without necessity for renewal or other attention.

50 The present pump is less noisy than ordinary gear pumps of the prior art, and the pump is adapted to perform its functions very efficiently with a minimum amount of power. Although the pump lifts an excess of liquid from the tank to the pump, it is found that the power which
55 is necessary for this operation is probably not so great, and certainly not any greater, than the power required to drive a pump where excessive packing pressure is used.

60 The pumping system shown diagrammatically in Fig. 1 is also adapted to effect a very close regulation of pressure by means of the tandem arrangement of its regulating devices. For instance, both the pump 10 and the regulator 35
65 have overflow or return conduits so that an excess of liquid is supplied to both of these devices, thereby maintaining constant pressure conditions at the input side of both the high pressure stage and the regulator so far as it is possible.

70 Suppose, for example, the pump is capable of effecting a regulation of the pressure at its output over a given range which does not exceed a permissible variation. The variation which will occur in the supply to the pressure regulator will
75 therefore, be much less than that which would

occur if any other pumping device were used. The regulator will thus be able to provide a more nearly constant pressure output and the variation in pressure at the output of the regulator will be a fraction of the variation which might be expected if only one of these devices were used.

The tandem arrangement of the self-regulating pump and the pressure regulator thus greatly increases the accuracy of maintenance of a constant pressure at the output of the regulator.

10 While I have illustrated a preferred embodiment of my invention, many modifications may be made without departing from the spirit of the invention, and I do not wish to be limited to the precise details of construction set forth, but
15 desire to avail myself of all changes within the scope of the appended claims.

Having thus described my invention, what I claim is new and desire to secure by Letters Patent of the United States, is:

20 1. In a combined pressure generating and regulating unit for oil burners, the combination of a casing formed with a low pressure supply stage chamber and a high pressure pumping chamber, said low pressure chamber having a capacity
25 several times as great as that of the high pressure chamber, pumping gears in said low pressure and high pressure chambers of suitable size whereby the low pressure pump is adapted to pump an excess of liquid over that required for the high
30 pressure stage, a conduit extending from the low pressure output to the high pressure intake, said unit having an intake conduit leading to the low pressure chamber, a burner outlet conduit connected with the high pressure outlet, and a by-pass
35 outlet, said by-pass outlet communicating with the output side of the low pressure stage and with a fuel supply tank, said unit having a pressure chamber in communication with the burner outlet conduit and a pressure responsive member in said chamber, a valve member operated
40 by said pressure responsive member adapted to control the burner outlet port and to open the burner outlet port first, said valve member also controlling a conduit from said pressure chamber leading to the by-pass outlet whereby the excess of liquid from said pressure chamber and from said low pressure stage are conveyed back from said by-pass outlet to the supply tank.

50 2. In a combined pressure generating and regulating unit for oil burners, the combination of a casing formed with a low pressure supply stage chamber and a high pressure pumping chamber, said low pressure chamber having a capacity
55 several times as great as that of the high pressure chamber, pumping gears in said low pressure and high pressure chambers of suitable size whereby the low pressure pump is adapted to pump an excess of liquid over that required for the high pressure stage, a conduit extending
60 from the low pressure output to the high pressure intake, said unit having an intake conduit leading to the low pressure chamber, a burner outlet conduit connected with the high pressure outlet, and a by-pass outlet, said by-pass outlet communicating with the output side of the low pressure stage and with a fuel tank, said unit having a pressure chamber in communication with the burner outlet conduit and a pressure responsive member in said chamber, a valve member operated
65 by said pressure responsive member adapted to control the burner outlet port and to open the burner outlet port first, said valve member also controlling a conduit from said pressure chamber leading to the by-pass outlet whereby
70

the excess of liquid from said pressure chamber and from said low pressure stage are conveyed back from said by-pass outlet to the supply tank, said valve member comprising a piston valve for
5 controlling the by-pass outlet and a needle valve for controlling the burner outlet, said needle valve being opened first in point of time over said piston valve.

3. In a combined pressure generating and regulating unit for oil burners, the combination of a
10 casing formed with a low pressure supply stage chamber and a high pressure pumping chamber, said low pressure chamber having a capacity several times as great as that of the high pressure
15 chamber, pumping gears in said low pressure and high pressure chambers of suitable size whereby the low pressure pump is adapted to pump an excess of liquid over that required for the high pressure stage, a conduit extending from the low pressure
20 output to the high pressure intake, said unit having an intake conduit leading to the low pressure chamber, a burner outlet conduit con-

nected with the high pressure outlet, and a by-pass outlet, said by-pass outlet communicating with the output side of the low pressure stage and with a fuel tank, said unit having a pressure
5 chamber in communication with the burner outlet conduit and a pressure responsive member in said chamber, a valve member operated by said pressure responsive member adapted to control the
burner outlet port and to open the burner outlet
10 port first, said valve member also controlling a conduit from said pressure chamber leading to the by-pass outlet whereby the excess of liquid from said pressure chamber and from said low
15 pressure stage are conveyed back from said by-pass outlet to the supply tank, said unit including a pump casing and a valve casing, said pump and valve casing being provided with registering conduits forming a unitary whole for generating and supplying liquid fuel at constant volume
20 irrespective of the output pressure and intake resistance.

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