March 10, 1942. F. S. BROADHURST 2,275,502

PRIMING SYSTEM FOR CENTRIFUGAL PUMPS

Filed Dec. 6, 1939 5 Sheets-Sheet 1

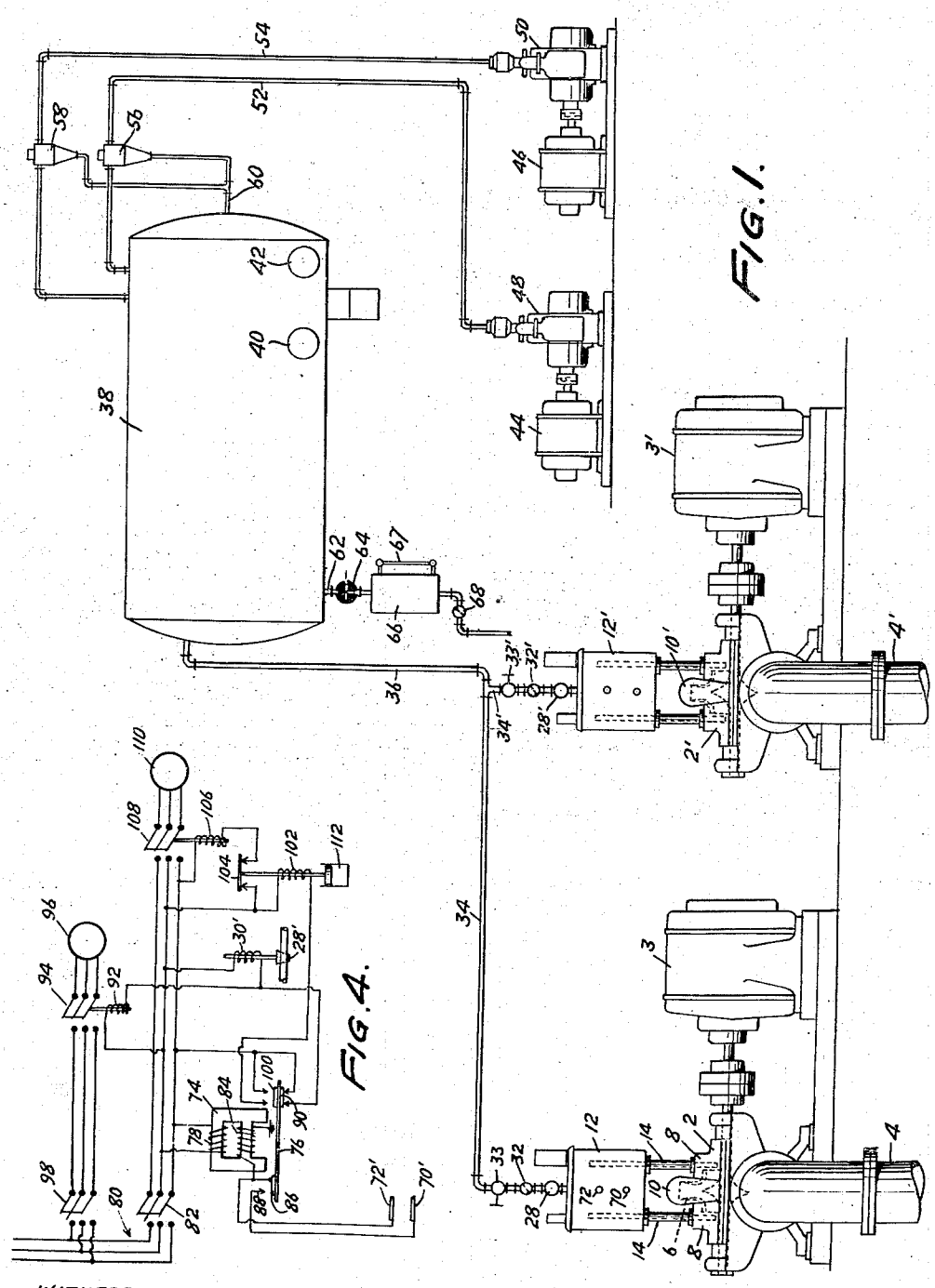


FIG. 1.



FIG. 4.

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PRIMING SYSTEM FOR CENTRIFUGAL PUMPS

Filed Dec. 6, 1939 5 Sheets-Sheet 2

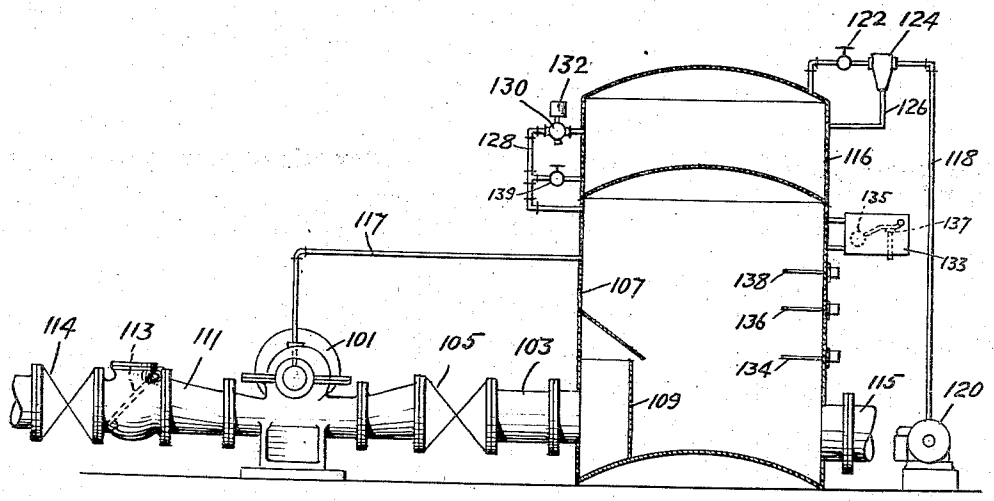



FIG. 5.

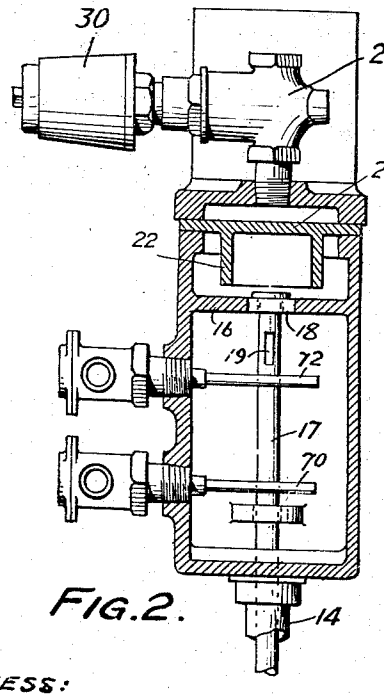



FIG. 2.

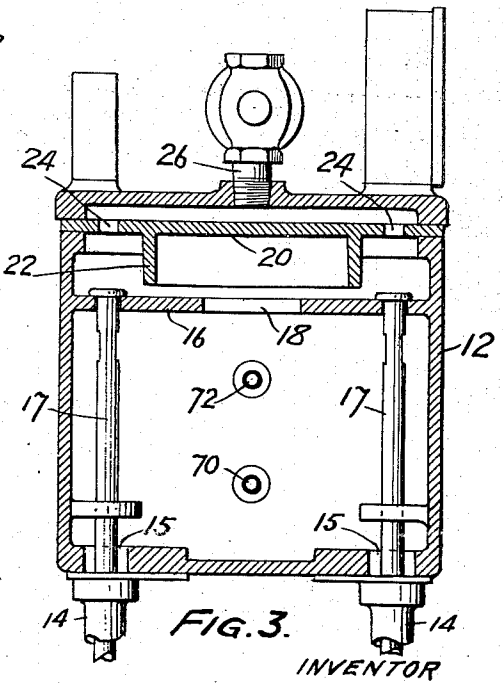



FIG. 3.

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PRIMING SYSTEM FOR CENTRIFUGAL PUMPS

Filed Dec. 6, 1939 5 Sheets-Sheet 3

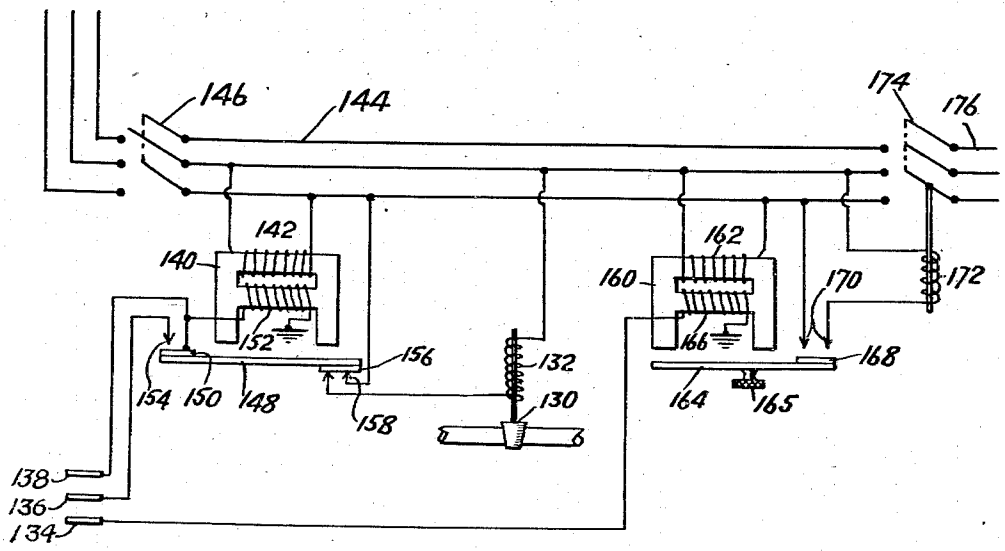



FIG. 6.

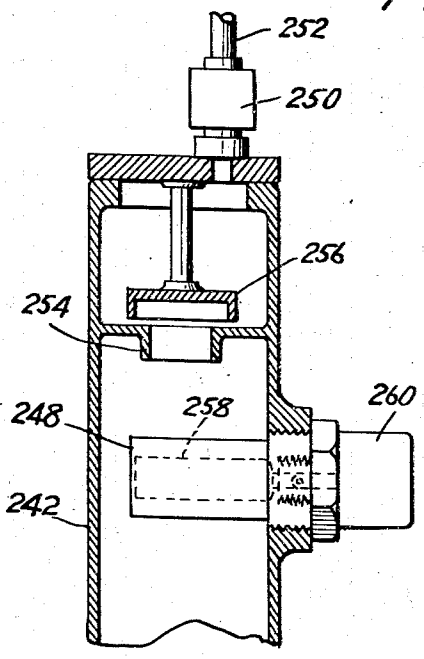



FIG. 10.

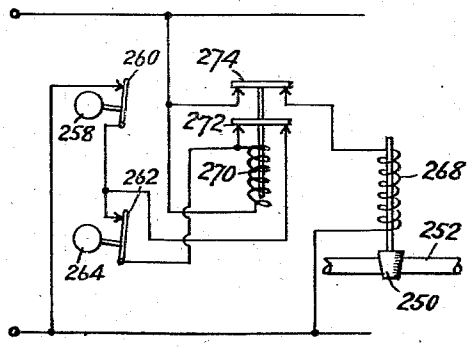



FIG. 11.

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PRIMING SYSTEM FOR CENTRIFUGAL PUMPS

Filed Dec. 6, 1939 5 Sheets-Sheet 4

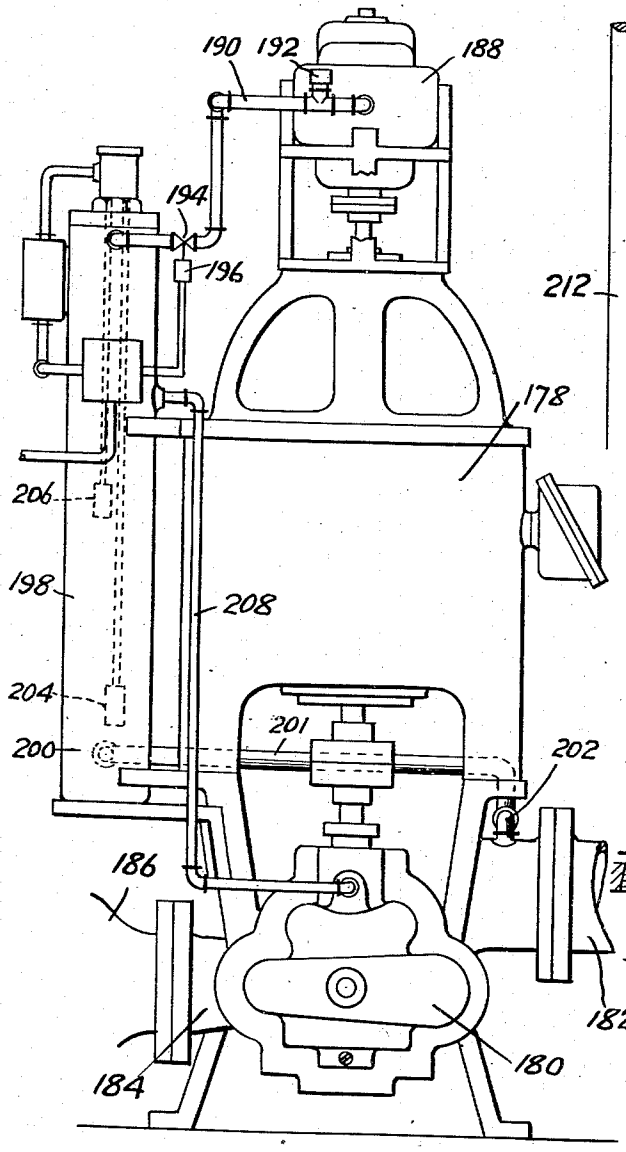



FIG. 7.

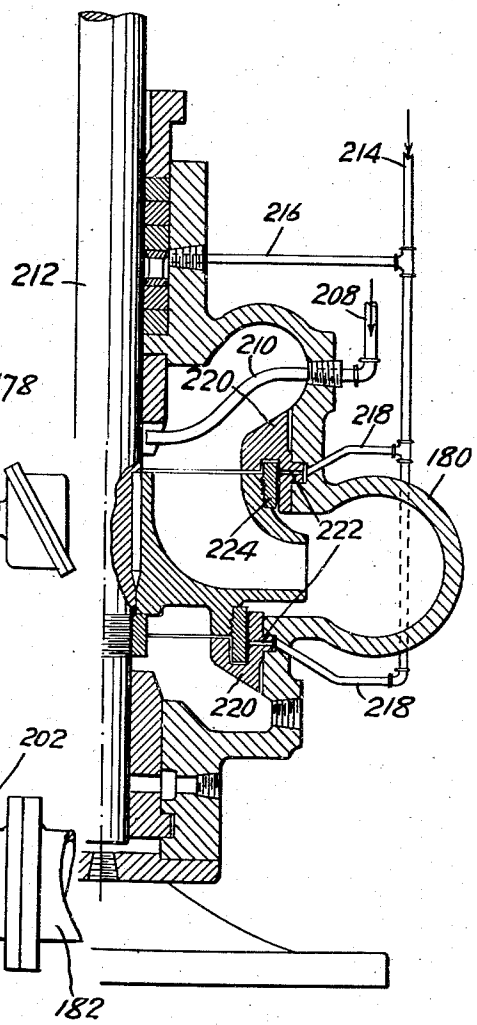



FIG. 8.

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PRIMING SYSTEM FOR CENTRIFUGAL PUMPS

Filed Dec. 6, 1939 5 Sheets-Sheet 5

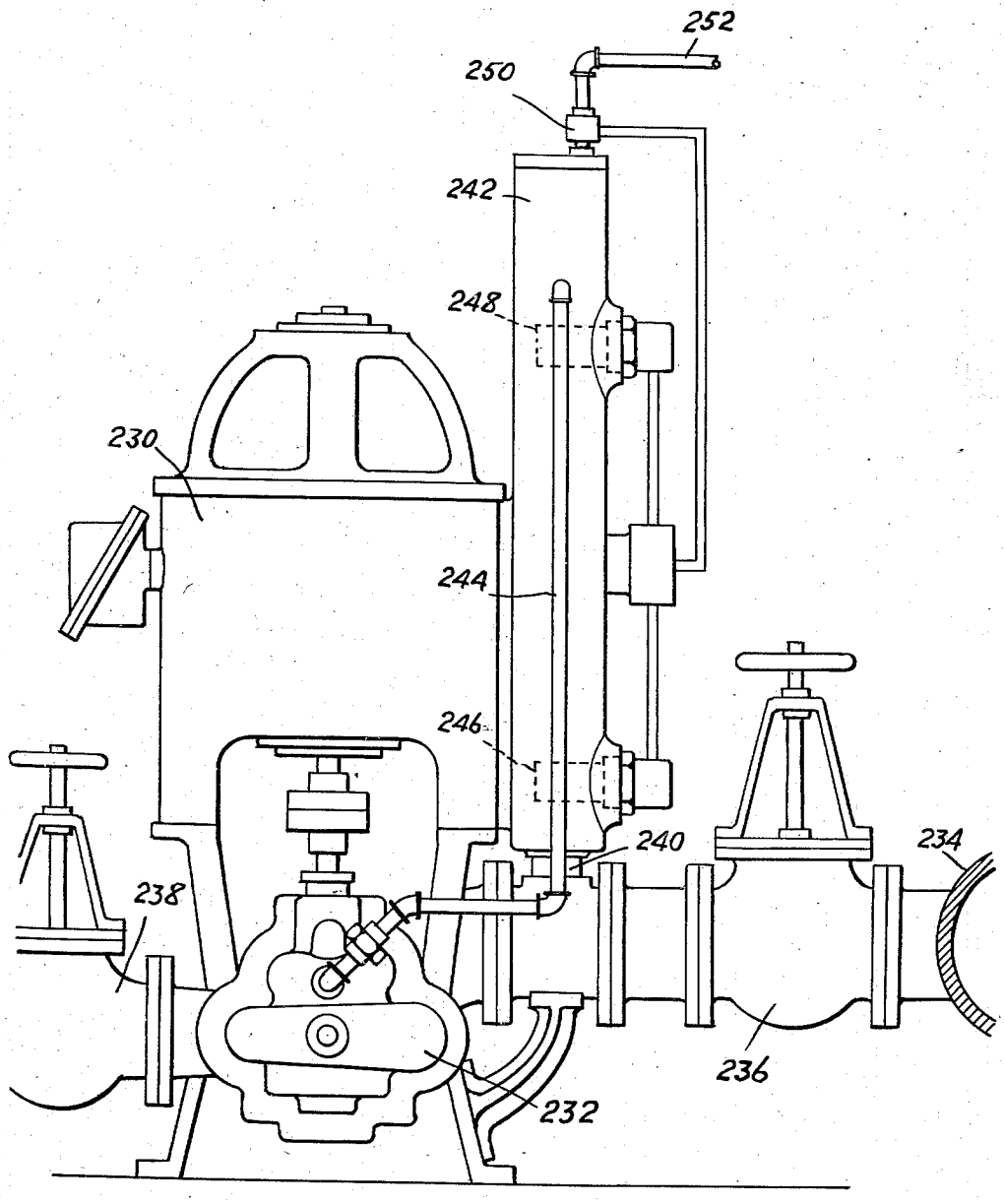



FIG. 9.

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WITNESS:

R. B. Mitchell

Patented Mar. 10, 1942

2,275,502

# UNITED STATES PATENT OFFICE

2,275,502

## PRIMING SYSTEM FOR CENTRIFUGAL PUMPS

Frank S. Broadhurst, Watertown, Mass., assignor to De Laval Steam Turbine Company, Trenton, N. J., a corporation of New Jersey

Application December 6, 1939, Serial No. 307,743

9 Claims. (Cl. 103—113)

This invention relates to priming systems for centrifugal pumps.

In cases where there is no supply of liquid available to prime a centrifugal pump by gravity flow, or where it is undesirable or impossible to prime the pump by the use of an auxiliary water pump, it has been customary to provide the centrifugal pump with an air pump in the same casing to evacuate the main pump and so render it self-priming. A system of this character is usually unsatisfactory for several reasons, among which may be mentioned the fact that most centrifugal pumps may not be driven for an appreciable time without priming without resulting damage to their labyrinth packing, the fact that there is absorption of considerable power by the air pump which is running throughout operation of the main pump, and the fact that scoring and plugging of the air pump may occur due to grit, dirt, seaweed, etc., in the water being pumped, some of which is passed through the air pump for sealing purposes.

It has also been customary to prime centrifugal pumps on the delivery side, sometimes with the provision of float valves or the like designed to prevent the passage of liquid to a vacuum pump after the centrifugal pump is primed and operating. The valves under such conditions are exposed to high pressures and are liable to damage by impact and plugging by solid or semi-solid material jammed against them, for example, in the handling of sewage.

In general pumping, and particularly in the pumping of driven wells, air is carried into the centrifugal pump with the liquid. This air is separated by the centrifugal action of the pump and accumulates adjacent the shaft. When the accumulation reaches such extent as to substantially cut off the intake passages, the pump will lose its prime, and, with previous priming systems, it was necessary to shut down the pump, reprime, and then restart the pumping operations. In my Patent No. 2,144,613, there are disclosed priming arrangements for centrifugal pumps which overcome the aforementioned objections to prior priming arrangements.

The present invention relates to priming systems of this general type in which priming is effected by evacuation of the suction side of a centrifugal pump, and relates more particularly to improvements on the priming systems disclosed in my application Serial No. 260,469, filed March 8, 1939. The present invention involves, for example, various improvements whereby the operation of the vacuum pumps may be reduced to a minimum, normal operation, even though it involves a considerable accumulation of gas, being accompanied with no operation of the vacuum pump or pumps unless abnormally high quantities of gas enter the system. Under normal conditions, the evacuation only takes place in the initial priming of the system on starting. Thereafter, accumulated gas is removed automatically by the action of the centrifugal pump itself.

Subsidiary to the broad objects of the invention just indicated are various secondary objects having as their ends the proper rapid, reliable operation of the priming systems to take care of modern centrifugal pumping operations which are designed to operate automatically over long periods with little or no attention. Specifically, the subsidiary objects of the invention relate to the provision of arrangements for taking care of abnormal gas accumulation, for handling water carrying sediment or floating material, for maintaining proper operation despite surges attending unusual conditions in the supply or discharge lines, for securing rapid and positive operation of valves, and for the priming of centrifugal pumps used in marine installations in which the splashing of water in priming chambers in heavy seas would be likely to disturb the operation of the priming system. Additionally, provision is made for the operation of pumps in parallel or the operation of pumps receiving their liquid from different supplies.

The primary and specific objects of the invention will be clear from the following description, read in conjunction with the accompanying drawings in which:

Figure 1 illustrates diagrammatically an embodiment of the invention applied to the priming of a plurality of centrifugal pumps and specifically pumps used in a marine installation;

Figure 2 is a vertical section illustrating the elements associated with one of the priming chambers of Figure 1;

Figure 3 is a similar vertical section taken at right angles to the section of Figure 2;

Figure 4 is a wiring diagram adapted to installations of the general type illustrated in Figure 1, but showing electrical rather than vacuum control of an evacuating pump;

Figure 5 is a diagrammatic view illustrating a modification of the invention particularly applicable to the pumping of liquid containing relatively large quantities of gas or dirt;

Figure 6 is a wiring diagram of the installation of Figure 5;

Figure 7 is an elevation illustrating a vertical

pumping arrangement applicable particularly to marine use;

Figure 8 is a partial vertical section through the pump of the unit of Figure 7;

Figure 9 is a view somewhat similar to Figure 7, but showing a modified arrangement suitable for marine use;

Figure 10 is a fragmentary vertical section through the upper portion of the priming chamber of Figure 9; and

Figure 11 is a wiring diagram of the installation of Figure 9.

Referring first to the modification of Figures 1, 2 and 3, there is illustrated therein a priming system designed for marine service, though it will be readily understood that it is applicable to land service as well. Briefly stated, it involves a central priming system for a plurality of pumps, which, in marine service, might, for example, be bilge pumps, ballast pumps and emergency fire pumps. While any number of pumps may be connected to the common priming devices, there are illustrated in Figure 1 only two of these, indicated at 2 and 2'. These pumps driven, respectively, by motors 3 and 3', are provided with connections 4 to their sources of supply and are adapted to discharge through the usual discharge check valves, not illustrated. Each of these pumps comprises a rotor 6 provided with the impeller passages and receiving liquid from suction bells 8 and discharging the liquid through the discharge volute 10. If the pumps are of double suction type, as illustrated, a pair of suction bells are located at each end of the rotor. It will be obvious, however, that the invention is applicable to a single suction pump and to multiple stage centrifugal pumps as well as the type illustrated.

Located above the pumps are priming chambers 12 and 12', respectively, the arrangements of which are shown more particularly in Figures 2 and 3. Chamber 12 is supported on the pump by means of pipes 14 communicating with the chambers through openings 15 and with the upper portions of the suction bells 8. Extending through the pipes 14 are smaller pipes 17, which open within the suction bells closely adjacent the shaft. These tubes are conveniently mounted by being upset at their upper ends so as to be hung from a baffle plate 16 having a central opening 18 and, except for such opening, substantially closing the chamber 12. Above the baffle plate 16 is a second baffle plate 20 provided with a skirt portion 22 approaching the plate 16 and having openings 24 outside the skirt to furnish communication with the uppermost portion of the chamber 12 beneath its cover into which is tapped a nipple 26 communicating with a valve 28 controlled by a solenoid 30. Beneath the baffle plate 16 the pipes 17 are slotted as indicated at 19. As will be pointed out, the high water level is at the level of these slots, and by reason of the presence of the baffles, water is prevented from splashing out through the outlet 26 despite rolling and pitching of the ship.

In the line running from the chamber 12 above the valve 28 are, in order, a check valve 32 and a stop valve 33. Similar valves, indicated with these numerals primed, are indicated as associated with the priming chamber 12'. From the valves 33 and 33', respectively, extend the pipes 34 and 34', connected to a common pipe 36, running to the vacuum tank 38. Communicating with this vacuum tank are vacuum switches 40 and 42, two of them being provided for safety purposes. One of them, for example, may be effective to start the motors 44 and 46 at a vacuum of 18 inches of mercury and to stop these motors at 26 inches of mercury, while the other may start the motors at a vacuum of 16 inches and stop them at 26 inches. Thus the former will normally be the controlling switch, while the latter serves to effect its control only under emergency conditions. Both of these should be of a snap type to avoid any instability of operation. The motors 44 and 46 driving the vacuum pumps 48 and 50, respectively, are provided in duplicate for safety purposes. The vacuum pumps 48 and 50 are connected with the tank 38 through the lines 52 and 54 with the interposition of diaphragm controlled check valves 56 and 58 connected through a common balancing connection 60 to the tank 38. Such valves are of conventional type, insuring that the slightest increase of pressure in the lines 52 and 54 will result in a differential action on the diaphragm positively closing communication to the tank 38. Thus the vacuum in the tank is maintained from the instant the motors 44 and 46 cease operating.

In the event that the pumps 48 and 50 are of the type not designed to handle liquid except, for example, for sealing purposes, it is necessary that any flow of liquid to them should be prevented. Accordingly, not only is the flow of liquid to the tank 38 carefully prevented, but provision is made to remove from the tank 38 from time to time such liquid as may condense therein from the air. A drain pipe 62 is accordingly connected to a three-way valve 64 which, in turn, communicates with a chamber 66 provided with a sight glass 67 and adapted to drain through a check valve 68. By turning the three-way valve 64, liquid may be permitted to flow into the chamber 66 while the vacuum is held in 38, the check 68 then being closed. Moving the valve to another position opens the chamber 66 to the atmosphere so that the liquid may flow therefrom through the check valve 68. The sight glass 67 permits note to be made of the amount of water which has collected in the chamber 38 and thus serves to advise an operator of any abnormal accumulations of liquid.

Extending into the priming chamber 12 are lower and upper electrodes 70 and 72, respectively, which electrodes function as will be best understood from a modified arrangement illustrated in Figure 4 which would be applicable if the vacuum pumps were controlled not by the vacuum in a tank such as 38, but by the liquid level in a priming chamber.

Passing for the moment the electrical considerations, it may be stated that the arrangement of Figures 1, 2 and 3 operates as follows:

When the pumps 2 and 2' are stationary, they may be empty, and through disuse a substantial pressure may exist in the vacuum tank 38. Upon closing the main power switches of the system, the vacuum pumps 48 and 50 will immediately start operation drawing a vacuum in the tank 38. The solenoid controlled valves 28 and 28' will be open (these valves being energized to open) and the valves 33 and 33' will also be open, these valves being closed only when it is desired to isolate any one of the pumps from the priming system. Accordingly, as the vacuum is drawn in tank 38, the liquid to be pumped will rise into the pumps 2 and 2' and through the pipes 14 and 17

into the chambers 12 and 12', first submerging the lower electrodes 70 without any actions taking place, and finally reaching the electrodes 72. As soon as an electrode 72 is submerged, its corresponding solenoid 30 will be deenergized, and its valve will close, preventing any further withdrawal of air from its priming chamber. Thereafter, air will be pumped out of chamber 38 until the vacuum pumps are shut down by the action of one or the other of the switches 40 or 42. Normally, this vacuum will be maintained over very long periods, since, except for leakage, the pumps will maintain their prime during operation.

When the valves 28 and 28' close, the pumps and chambers 12 are isolated from each other and from the tank 38. As soon as the electrode 72 is submerged, the corresponding pump driving motor is either automatically started, or its circuit is put into condition to be manually closed. As the pump operates, a high velocity of flow, due to the rotation of the shaft, occurs at the lower ends of the pipes 17, producing an ejector action creating in the pipes 17 a lower pressure than that existing in the pipes 14 opening in the upper portions of the suction bells where the liquid is relatively quiet and ejector action is not occurring. Accordingly, the liquid in the chamber 12 is caused to rise until it can flow through slots 19 into the pipe 17, and thereafter a recirculation continues to occur upwardly through pipes 14 and down through 17. The pressure differential producing this circulation is sufficient to draw downwardly through the pipe 17 any air which might flow from the upper portions of the suction bells into the chamber 12, and accordingly small accumulations of air are continuously removed. If air centrifugally separates about the shaft, as sometimes occurs when large quantities enter the centrifugal pumps, the ejector action ceases, and this air will pass upwardly through the pipes 17 into the upper portion of the chamber 12. By this action, however, liquid is again caused to submerge the lower end of the pipes 17, whereby the ejector action is renewed to gradually withdraw through the pipes 17 the air which has accumulated in chamber 12. The air thus withdrawn by ejector action is in the form of fine bubbles and readily passes through the pump. Thus the prime of the pump is maintained despite relatively large accumulations of air. Only if accumulations are such as to cause the liquid level to drop below the lower electrode 70 will the solenoid controlled valve open and permit such air to flow to the vacuum tank 38. The valve 28 is immediately closed as soon as the liquid level is restored to the level of the electrode 72.

The action of the electrodes in effecting this control will be clear from consideration of Figure 4 in which, in view of the somewhat more elaborate controls involved, the electrodes 70' and 72' corresponding to 70 and 72, respectively, are shown associated with means for controlling a vacuum pump operation. In this arrangement a solenoid controlled valve 28' is illustrated and corresponds to the valve 28, the corresponding solenoid being indicated at 30', and operative upon energization to open the valve 28'. At 74 there is illustrated a relay of the well known Bender-Warrick induction type. This relay is provided with an A-shaped core having a coil 84 on its crossbar portion grounded at one end and connected at its other end to the electrode 72' and also to the contact element 86 of the armature 76. The upper connecting element of the core is provided with a coil 78 permanently connected to the alternating current power line 80 through a switch 82. The legs of the core are adapted to attract the armature 76, which is conventionally illustrated as adapted to close a single contact at 88 by engagement with its contact portion 86 thereby connecting the electrodes 70' and 72', together. When the armature 76 is not attracted, it closes at 90 a circuit including the coil 92, which is adapted to close a switch 94 in series with a manually operated switch 98 to control a vacuum pump motor 96 operating a vacuum pump adapted to produce, either with or without the interposition of a vacuum tank, a vacuum in the priming chamber such as 12. Also involved in the circuit closed at 90 is the solenoid 30' controlling the valve 28'.

When the armature 76 is attracted, there is closed at 100 a circuit including a coil 102 adapted to close a switch at 104, which switch will open when the coil 102 is deenergized only after a delay by reason of the provision of a dash pot 112 controlling the movements of the switch. The switch 104 controls the circuit of a starting relay 106, conventionally illustrated as adapted to close a switch 108 controlling the motor 110 operating the centrifugal pump which the arrangement is adapted to prime.

Assuming the electrodes 70' and 72' to be located within a chamber such as 12, the operation of the arrangement of Figure 4 may be readily understood. When the switches 98 and 82 are closed, the starting switch 94 for the vacuum pump motor 96 is immediately closed, and the valve 28' is open. Accordingly, a vacuum is produced to cause rise of liquid into a chamber such as 12. At this time, when neither of the electrodes 70' nor 72' is immersed in liquid, the path of the magnetic flux is through the crossbar of the core 74 and the armature 76 is not attracted. Accordingly, the coil 102 will not be energized and the starter 108 will remain open.

When the liquid rises to a point to submerge electrode 70', nothing occurs, but as soon as 72' is submerged, a current is introduced in the secondary coil 84 producing a flux bucking the flux tending to flow through the crossbar, so that the path of the flux must now be through the armature which is attracted opening the circuit at 90 and closing the circuit at 100 and connecting the electrode 70' to the electrode 72' by making contact at 88. As soon as the contact at 90 is broken, the valve 28' closes, and the vacuum pump motor 96 is stopped. The coil 102 is now energized and serves either to operate the starter conventionally illustrated at 108, or close a switch making it possible to start the motor 110 manually.

If the liquid level now drops below the level 70', the secondary circuit of the relay is opened and contact at 90 made to effect opening of the valve 28' and renewed operation of the motor 96. The motor 110, however, is not immediately stopped by reason of the time delay action afforded by the dash pot 112. Preferably a delay of, say, 30 seconds or the like is provided, during which most centrifugal pumps may safely operate without damage due to overheating, even if they do not contain water. In this limited time, if merely a surge has occurred rather than something serious, such as failure of the water supply, the vacuum pump will be able to restore the level of the liquid in the chamber 12, and operation can resume without stopping of the centrifu-

gal pump motor. On the other hand, if, in the limited time, the liquid level is not restored to submerge the electrode 72', the main pump motor will stop and will only restart when the water level is properly restored or when manual starting occurs.

In Figures 5 and 6 there is illustrated an alternative form of the invention, particularly designed for use in connection with driven wells, in which sand or other sediment may be carried by the inflowing water together with large quantities of air. In such case, it is desirable to have a separating tank precede the centrifugal pump, and it becomes impractical to provide a time delay arrangement, as in the previous modification, by reason of the very considerable volume of air which must be pumped to restore an abnormally low liquid level to its normal height.

The inlet 115 communicating with the well or the like from which pumping is taking place, communicates with a chamber 107 of large capacity, provided with a baffling arrangement, indicated at 109, for preventing as much sediment as possible from entering the intake piping 103 of the centrifugal pump 101, in which piping there is interposed a stop valve 105. The pump delivers water through the passage 111 and the check valve 113 and stop valve 114.

Provided preferably as an upper unit of the separating tank, though it may be separate, is a vacuum tank 116, communicating through connections 118 with a motor driven vacuum pump, indicated at 120. A vacuum controlled diaphragm type check valve 124 is interposed in the line 118 having a controlling connection 126 with the vacuum tank. A stop valve 122 is preferably provided in the same line. In an arrangement such as this, particularly where operation of the centrifugal pump must be maintained despite possible failures of the electrical supply, the centrifugal pump or pumps, since a plurality may be connected to the same separating chamber, may be arranged to be alternatively driven by a motor or motors and a gasoline or similar engine. Likewise, in such cases, provision is made for driving one or more vacuum pumps alternatively either by an electric motor or motors or by a gasoline or similar engine. If a plurality of vacuum pumps are provided, then they should be provided with independent connections such as 118 to the vacuum tank 116. In such case, the valve 122 serves to isolate either of the pumps for repair purposes or, in the event, for example, that only one of them is operated by a gasoline engine in an emergency, the other may be cut out of the system.

A connection 128 is provided between the upper end of the separating tank 107 and the vacuum tank 116, there being interposed in this connection a valve 130 controlled by a solenoid 132 and adapted to be opened when the solenoid is energized. To permit proper operation in the event of failure of the electrical supply, an auxiliary connection is provided between the separating tank and the vacuum tank and is controlled by a stop valve 139. Also provided for emergency operation is a tank 133, connected at its upper and lower portions to the separating chamber 107 and housing a float 135 adapted to open an air vent 137.

Extending into the separating chamber are three electrodes indicated at 134, 136 and 138. These are electrically connected into the system, as illustrated more particularly in Figure 6.

A Bender-Warrick relay, indicated at 140, is provided with energizing coil 142 permanently connected to the power line 144, which may be connected to the main power supply through a switch 146. The armature 148 of this relay has one contact permanently connected to the electrode 138 and the coil 152 on the cross member of the relay, the other end of which is grounded. When the armature 148 is attracted by the core, a contact is made at 154 serving to connect the electrodes 136 and 138 together, as in the case of the modification of Figure 4.

The armature 148 has another contact making portion 156 designed to connect the contacts at 158 to energize the coil 132 of the valve 130 to open that valve.

For the purpose of control of the motor driving the centrifugal pump, there is provided a second relay of the same Bender-Warrick type provided with a core 160 and an energizing coil 162, connected to the line 144. The secondary coil 166 is connected at one end of the electrode 134 and at its other end to ground. The armature 164 of this relay is of the type requiring manual resetting, i. e., when once dropped it can be reset only by manual manipulation of the button 165. When this armature is attracted by the core it is adapted to close the switch controlling the circuit through the starter coil 172 controlling the switch 174 in the line 176 to the centrifugal pump motor. Automatic starting may be thus effected, or the arrangement may be such as merely to place the motor circuit in condition for manual starting.

In the operation of this arrangement, assuming the electrical supply is operating, the valve 139 will be closed, and the vacuum pump 120 operating. This vacuum pump may be controlled by the pressure in the tank 116 as in the case of a modification of Figure 1, or, alternatively, by the rise of liquid level as described in the modification of Figure 4. At any rate, it will tend to cause rise of liquid past electrode 134 without effecting any result, since the relay 160 is of the manual resetting type, and then past 136 without effecting any result until the electrode 138 is submerged. Thereupon, the armature 148 is attracted by the core closing the contact at 154, thereby connecting the electrodes 136 and 138 together. At the same time, the contact at 158 is broken so that the solenoid 132 releases the valve 130 to closed position. At the same time, the vacuum pump motor may be stopped, or it may be stopped only after a predetermined vacuum is produced in the chamber 116. Whenever desired the main pump motor or motors may be started by moving the armature 164 into the field of attraction of the core 160 which is now in attracting position by reason of submersion of the electrode 134. As the centrifugal pump operates a circulating effect is produced as in the case of the modification of Figure 1, by reason of the approach of the connection 117 to the shaft of the pump within its eye. Accordingly, a partial vacuum is produced in the line 117 tending to raise the liquid in the tank 107 to the level of the connection 117, whereupon flow of liquid from the tank through the connection 117 takes place with withdrawal of air whenever any accumulation occurs in the tank 107 to cause the liquid level to tend to drop beneath the connection 117. Preferably this connection opens into the tank a substantial distance above the uppermost electrode 138. Thus the pump maintains itself primed and the level of the liquid in the tank.

Under these conditions, no liquid enters the float chamber 133.

In the event that an abnormal accumulation of air occurs, or, for some other reason, a surge occurs tending to drop the liquid level, the valve 130 will not reopen until the liquid level drops below the middle electrode 136. When such drop occurs, however, immediately opening will take place so that air may flow into the vacuum tank and the level will be restored. As soon as 138 is again submerged, the valve 130 will close. If the surge or accumulation of air is abnormal and the liquid clears the electrode 134, the core 140 will drop its armature and the centrifugal pump motor will be stopped and can be restarted only by manual intervention.

If for some reason the valve 130 should stick in open position, liquid might enter the chamber 116 and cause damage to the vacuum pump. To avoid any possibility of the occurrence of this, the float valve 135 is provided which, if the liquid level rises abnormally, will open the vent 137 to the atmosphere, so that air will flow through this vent into the upper portion of tank 107 and then into the vacuum tank, preventing any liquid from rising therein and at worst merely producing an abnormal continued operation of the pump 120.

The float valve 135 has another emergency function coming into play when the electrical supply fails. Under such conditions, the valve 130 would remain closed, since all of the electrical parts of the installation will be ineffective. To permit operation in such case, the valve 139 in the bypass is open and both the centrifugal pump and vacuum pump are operated by the emergency engines. The float valve 135 will now prevent, as before, any rise of liquid above the level tending to unseat its valve member from the vent 137. Any accumulated air is drawn off through the valve 139. Continuous operation of the vacuum pump must, of course, take place.

In Figures 7 and 8 there is shown an alternative arrangement involving a centrifugal pump with its axis vertical particularly adapted for marine installations. In this case, the pump, indicated at 180, is driven by the motor 178, and its suction bell, in this case arranged uppermost, takes liquid through the intake connection 182, the liquid being discharged from the pump through the outlet connection 184 in which is interposed in conventional fashion a combination check and stop valve 186. The vacuum pump in an installation of this character may be continuously operated and is indicated at 188 as driven continuously by the motor 178. It is connected through the passage 190, in which is interposed the valve 194 controlled by the solenoid 196, to the upper end of a standpipe 198. The lower end of this standpipe at 200 communicates with a pipe 201 which, at 202, is connected into the intake passage 182. Electrodes 204 and 206 are located as indicated in the standpipe 198 and correspond to the electrodes 70' and 72' of Figure 4, with the exception, however, that they control only the valve 194 corresponding to 28' of Figure 4, and have no control over the motor 178. Above the electrode 206 the standpipe 198 is connected through pipe 208 to the tube 210 passing into the suction bell of the pump and extending closely adjacent its shaft 212.

The centrifugal pump in this case must be of a type which can run for extended periods in dry condition. Since high efficiency is not particularly necessary in pumps for marine installations, the runner clearances may be larger than in the case of land pumps, and the pumps may run indefinitely while dry without damage. If closer clearances are present, however, it may be desirable to lead from the water line 214 which normally supplies water through 216 to the packing gland of the pump some additional flow through pipes 218 and passages 222 to the wearing rings 224 serving for their temporary cooling, which, when the pump is operating to pump water, is effected by the water being handled.

In the vacuum line 190 there is preferably provided a relief valve 192 which will open this line to the atmosphere when the vacuum drawn exceeds that required for the priming, so that the vacuum pump 188 will handle sufficient air to cool it.

In the operation of this modification, the motor 178 is started and the valve 194 is open, due to energization of its solenoid 196. Accordingly, a vacuum is drawn from the standpipe and the liquid to be pumped rises in the intake connections and the pump and through connection 201 in the standpipe 198 until the upper electrode 206 is submerged, whereupon the valve 194 closes, and shortly thereafter the relief valve 192 opens. By reason of the ejector action at the end of the tube 210 approaching the shaft 212 a difference in pressure is produced as in the other modifications, causing a further rise of liquid in the standpipe 198 and then flow of liquid therefrom through connection 208 to the suction chamber of the pump. Thus continuous removal of air which may accumulate in the standpipe through the intake connections in the passage 201 occurs. If any abnormal amount of air accumulates in the suction bell of the pump so that the tube 210 which is in its upper portion is uncovered, the ejector action will cease and this air will flow into the upper portion of the standpipe 198. As soon as the tube 210 is again submerged, however, the ejector action will reoccur, gradually removing from the standpipe the air which has flowed therein. If the liquid level falls below the level of the electrode 204, the valve 194 will be opened and the vacuum pump will again act to draw a vacuum in the standpipe to reprime the system.

The systems so far described are adapted for operation only with alternating current if the Bender-Warrick type of relay is to be used, since a current introduced in the secondary thereof is responsible for its operation. It may be noted that it is not generally permissible to provide electrodes for operating purposes which are connected directly to a power supply, since accidental grounding might very well occur. The Bender-Warrick type of relay, on the other hand, provides a thoroughly safe arrangement, since the secondary is of such high resistance that even complete short circuiting of it will not result in any abnormally high current flow. Furthermore, the voltages induced in this secondary are sufficiently high to overcome the relatively great resistances of waters containing little mineral matter.

While alternating current is available on many ships, there are others on which only direct current is available, and for proper operation of the priming system in such cases, there must be provided a switching arrangement which is illustrated in the modification of Figures 9, 10 and 11 in conjunction with other features of the arrangement.

In these figures there is indicated at **230** a motor arranged to drive the centrifugal pump **232**. This motor may be automatically controlled, as in the previous modification, or manually controlled. A suction manifold, indicated at **234**, may be selectively connected, for example, to various bilges and the line running therefrom to the centrifugal pump **232** contains the combination stop and check valve **236** of conventional type. Discharge takes place through a similar valve indicated at **238**.

Communicating with the intake connection at **240** is a standpipe **242**, extending from which is the vacuum line **252** controlled by the solenoid controlled check valve **250**. The vacuum producing device used in this instance may be either automatically controlled or manually controlled when the pump is operated. In either case, as will be evident hereafter, the valve **250** controls automatically the priming operation.

A connection indicated at **244**, similar to the connection **208** of the modification of Figure 7, furnishes communication between the upper portion of the standpipe **242** and the suction bell of the centrifugal pump, extending therein closely adjacent the shaft.

In the present case, instead of using electrodes, there extend into the pipe shells **246** and **248** in which are located, respectively, lower and upper floats **264** and **258**. These floats control, through interposition of an expandible bellows arrangement, switches **262** and **260**, which should be of snap type to secure rapid making and breaking of contact. Such switches are well known per se, and need not be specifically described. Above the uppermost float **258** is an arrangement of baffles **254** and **256**, designed to prevent the splashing of water into the vacuum connection when the arrangement is used in marine service.

The switches **258** and **264** are connected in circuit as indicated in Figure 11. A relay coil **270** is adapted to close contacts through armatures **272** and **274**. When the latter is closed it serves to energize the solenoid **268** controlling the valve **250** to hold this valve open. The float switches **258** and **264** are arranged to open when liquid rises to their level.

The operation of this arrangement is quite similar to that of the arrangement of Figure 7. When the liquid level is below the float switch **264**, the circuit is closed at **260** and **262** through the solenoid **270**, and also through the action of the relay armature **272**, which, it will be noted, is in parallel with **262**. Accordingly, the solenoid **268** is energized and the valve **250** held open to permit the withdrawal of air.

When in the priming operation the liquid rises to the level of the float **264**, switch **262** is opened, but without effecting any result, since the circuit is closed in parallel with this switch at **272**. When the level rises to the float **258**, the switch **260** is opened, deenergizing the coil **270** and thus permitting it to drop the conductors **272** and **274**, deenergizing the solenoid **268**, whereupon valve **250** closes under the action of its controlling spring.

When the liquid level drops, there will first occur closure of switch **260**, but this will have no effect, since the switch **262** remains open and the conductor **272** is already in open position. As soon as the float **264**, however, is uncovered, switch **262** closes, whereupon the relay **270** is energized and the valve **250** is opened. Thus the valve **250** does not close until the liquid level rises to the float **258** and does not reopen until the liquid level drops below float **264**, giving rise to the same general type of operation as heretofore described with reference to the electrode arrangements.

As soon as the pump is primed, a suction is produced in the connection **244**, as in the previous modifications, and by reason of the ejector action which then takes place, the liquid level is raised to the level of the connection between pipe **244** and the standpipe **242**. Air accumulations are removed, as in the case of the previous modification.

It will be evident that the modifications specifically referred to herein as for marine use may be used in land installations, in which case the baffles become unnecessary. It may also be pointed out that the modification in Figures 9, 10 and 11 is applicable to alternating current operation as well as direct current operation.

It will be evident that various changes in details of the invention may be made within the scope of the appended claims.

What I claim and desire to protect by Letters Patent is:

1. In combination, a centrifugal pump; means providing a chamber connected to the intake passage of the centrifugal pump for accumulation of gas contained in the liquid being pumped; means for evacuating said chamber to raise liquid therein to a level above the intake passage to thereby prime the pump; means connected to said chamber and subjected to an ejector action of liquid within the intake passage and being pumped to maintain a partial vacuum in said chamber, said last means comprising a tube opening closely adjacent the shaft of said pump and subjected to the ejector action of liquid adjacent said shaft; an electrode within said chamber below the top thereof; and means operating when liquid reaches said electrode to close communication between the chamber and said evacuating means, whereby the means subjected to said ejector action serves alone to maintain the partial vacuum in said chamber.

2. In combination, a centrifugal pump; means providing a chamber connected to the intake passage of the centrifugal pump for accumulation of gas contained in the liquid being pumped; means for evacuating said chamber to raise liquid therein to a level above the intake passage to thereby prime the pump; means connected to said chamber and subjected to an ejector action of liquid within the intake passage and being pumped to maintain a partial vacuum in said chamber, said last means comprising a tube opening closely adjacent the shaft of said pump and subjected to the ejector action of liquid adjacent said shaft; and means comprising a solenoid controlled valve effective to close communication between the chamber and said evacuating means when liquid in the chamber reaches a predetermined level below the level of connection with the chamber of the means subjected to said ejector action of liquid.

3. In combination, a centrifugal pump; means providing a chamber connected to the intake passage of the centrifugal pump for accumulation of gas contained in the liquid being pumped; means connected to said chamber for evacuating it to raise liquid therein to a level above the intake passage to thereby prime the pump; means connected to said chamber and subjected to an ejector action of liquid within the intake passage and being pumped to maintain a partial vacuum

in said chamber; and means effective to close communication between the chamber and said evacuating means when liquid in the chamber reaches a predetermined level below the level of connection with the chamber of the means subjected to said ejector action of liquid; and baffles within the chamber located above the level of connection with the chamber of the means subjected to said ejector action of liquid and below the connection with the chamber of said evacuating means to prevent splashing of liquid to the last named point of connection.

4. In combination, a centrifugal pump; means providing a chamber connected to the intake passage of the centrifugal pump for accumulation of gas contained in the liquid being pumped; means connected to said chamber for evacuating it to raise liquid therein to a level above the intake passage to thereby prime the pump; means connected to said chamber and subjected to an ejector action of liquid within the intake passage and being pumped to maintain a partial vacuum in said chamber, said last means comprising a tube opening closely adjacent the shaft of said pump and subjected to the ejector action of liquid adjacent said shaft; and means effective to close communication between the chamber and said evacuating means when liquid in the chamber reaches a predetermined level below the level of connection with the chamber of the means subjected to said ejector action of liquid; and baffles within the chamber located above the level of connection with the chamber of the means subjected to said ejector action of liquid and below the connection with the chamber of said evacuating means to prevent splashing of liquid to the last named point of connection.

5. In combination, a centrifugal pump; means providing a chamber connected to the intake passage of the centrifugal pump for accumulation of gas contained in the liquid being pumped; means connected to the upper portion of said chamber for evacuating said chamber to raise liquid therein to a level above the intake passage to thereby prime the pump; means for limiting the average level to which liquid will rise in said chamber during operation of the pump; and baffle means located above said average level and below the level of connection with the chamber of the means for evacuating said chamber to prevent splashing of liquid to the last named level.

6. In combination, a centrifugal pump; means providing a chamber connected to the intake passage of the centrifugal pump for accumulation of gas contained in the liquid being pumped; means for evacuating said chamber to raise liquid therein to a level above the intake passage to thereby prime the pump; means connected to said chamber and subjected to an ejector action of liquid within the intake passage and being pumped to maintain a partial vacuum in said chamber, said last means comprising a tube opening closely adjacent the shaft of said pump and subjected to the ejector action of liquid adjacent said shaft; and electrically controlled means effective to close communication between the chamber and said evacuating means when liquid in the chamber reaches a predetermined level below the level of connection with the chamber of the means subjected to said ejector action of liquid.

7. In combination, a centrifugal pump; means providing a chamber connected to the intake passage of the centrifugal pump for accumulation of gas contained in the liquid being pumped; means for evacuating said chamber to raise liquid therein to a level above the intake passage to thereby prime the pump; means limiting the level to which liquid may rise in said chamber under the action of said evacuating means; and means effective following a predetermined delay after the liquid level drops to a predetermined level lower than the aforementioned level to stop the operation of said centrifugal pump.

8. In combination, a plurality of centrifugal pumps; means providing a plurality of chambers, one for each pump, connected to the intake passages of the centrifugal pumps for accumulation of gas contained in the liquid being pumped; common means for evacuating all of said chambers to raise liquid in each to a level above the intake passage of the corresponding pump to thereby prime the pump; means connected to each chamber and subjected to an ejector action of liquid within its own intake passage and being pumped to maintain a partial vacuum in each chamber; and means individual to the chambers effective to close communication between any chamber and said evacuating means when liquid in said chamber reaches a predetermined level below the level of connection with said chamber of its means subjected to said ejector action of liquid.

9. In combination, a centrifugal pump; means providing a chamber connected to the intake passage of the centrifugal pump for accumulation of gas contained in the liquid being pumped; means connected to said chamber for evacuating it to raise liquid therein to a level above the intake passage thereby to prime the pump; means connected to said chamber and subjected to an ejector action of liquid within the intake passage and being pumped to maintain a partial vacuum in said chamber and a liquid level below the connection with the chamber of the first mentioned evacuating means, said last means comprising a tube opening closely adjacent the shaft of said pump and subjected to the ejector action of liquid adjacent said shaft; and electrically controlled means effective to close communication between the chamber and the first mentioned evacuating means when liquid in the chamber reaches a predetermined level below the level of connection with the chamber of the first mentioned evacuating means.

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