March 21, 1961 G. W. WRIGHT 2,975,713

LIQUID FUEL SUPPLY APPARATUS

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Fig. 1.

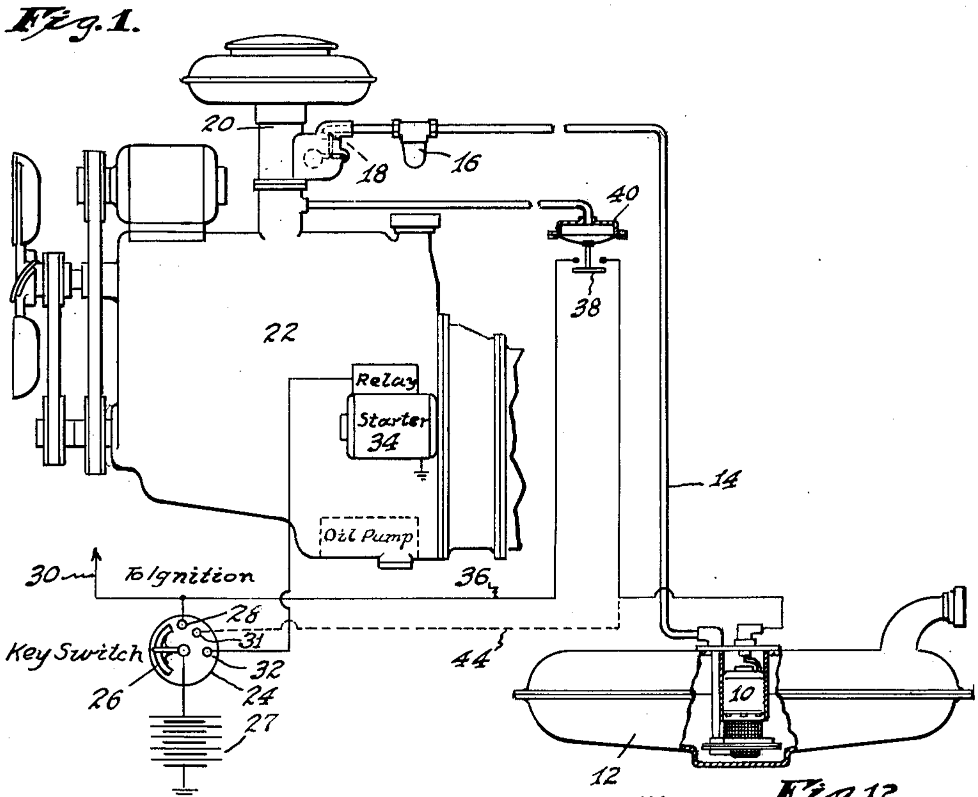


Fig. 11.

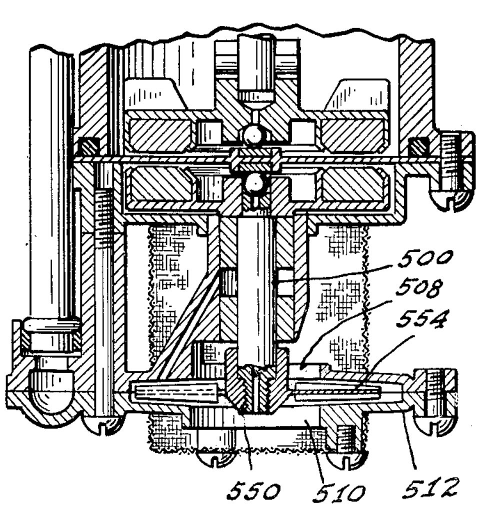


Fig. 12.

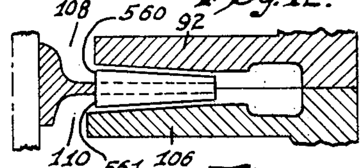


Fig. 13.

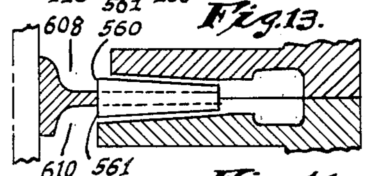
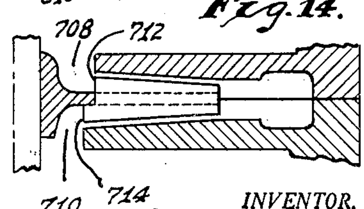


Fig. 14.



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LIQUID FUEL SUPPLY APPARATUS

Filed June 9, 1955 4 Sheets-Sheet 2

Fig. 2.

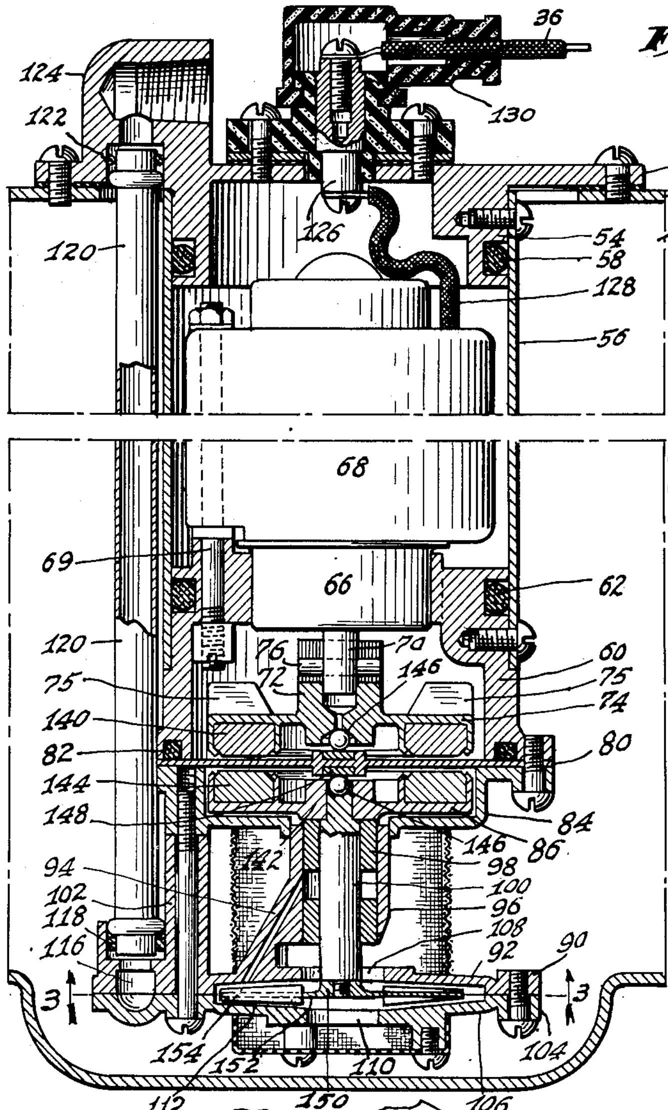


Fig. 4.

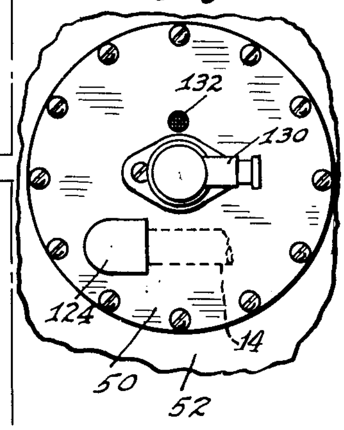
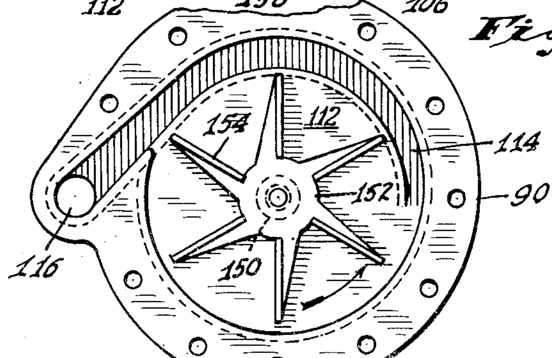


Fig. 3.



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LIQUID FUEL SUPPLY APPARATUS

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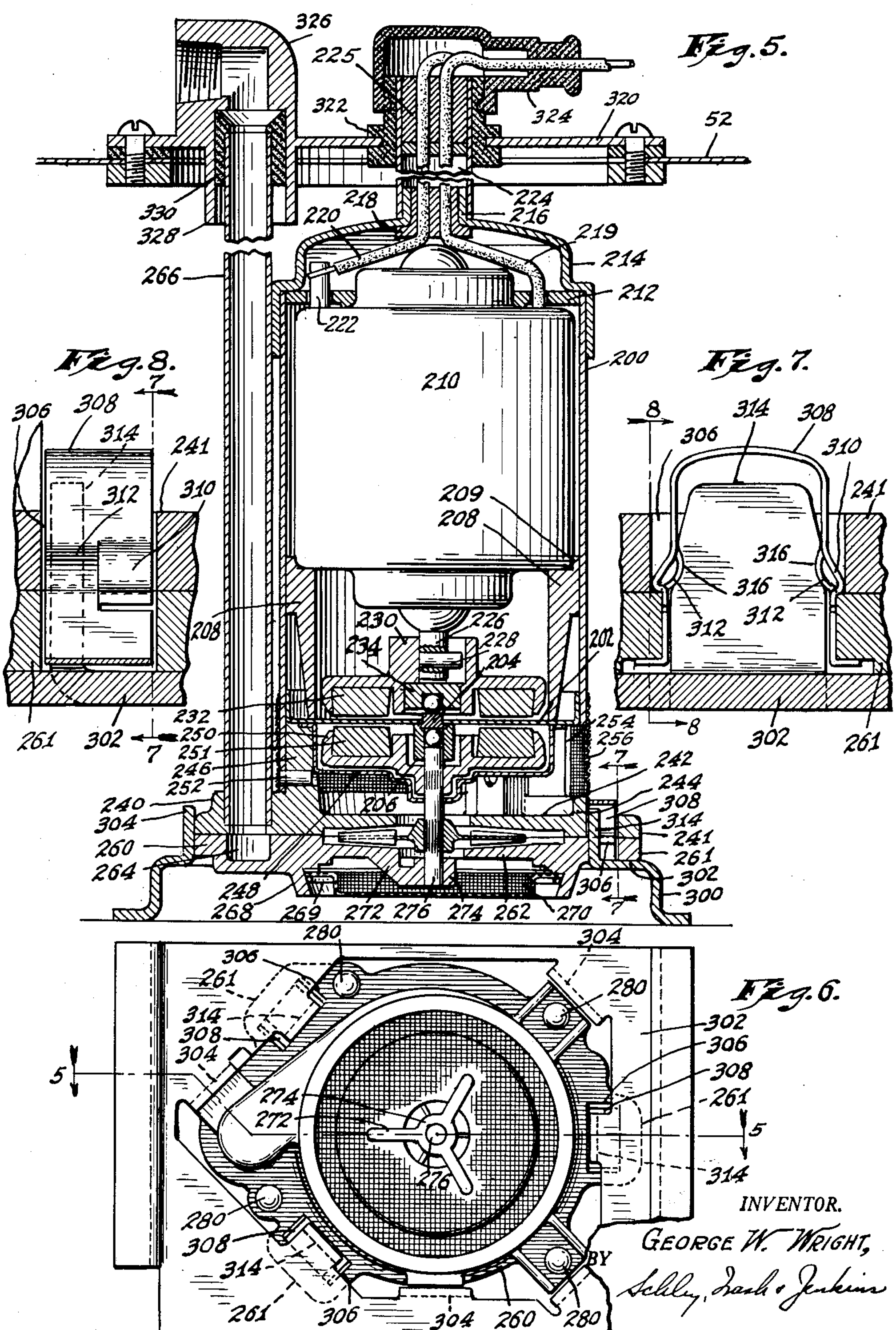

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LIQUID FUEL SUPPLY APPARATUS

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Fig. 9.

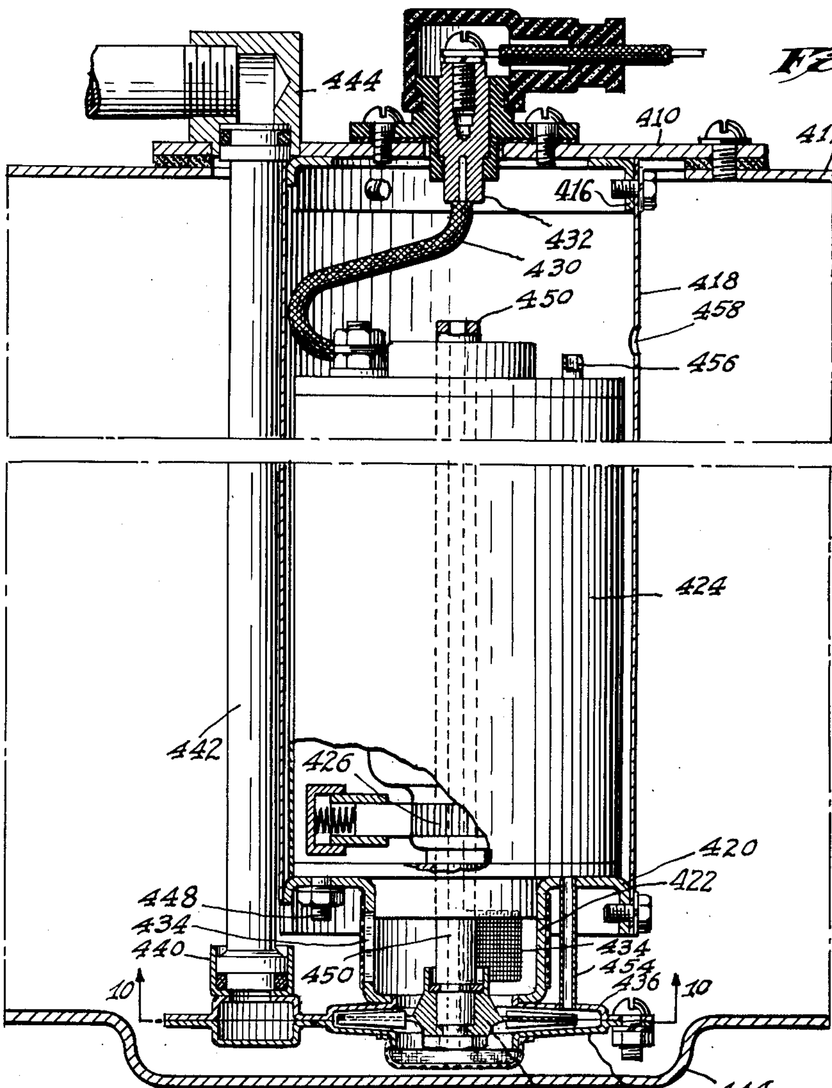
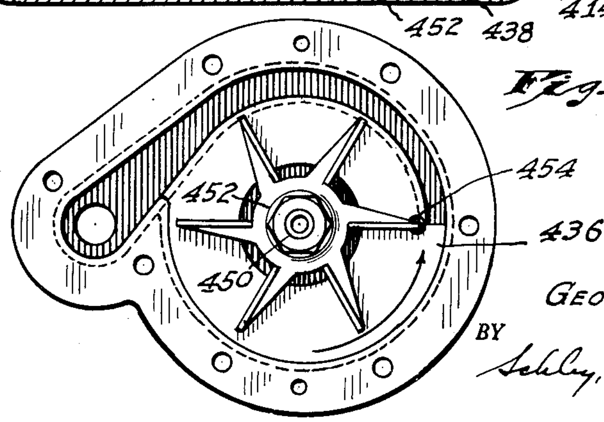


Fig. 10.



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United States Patent Office

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Patented Mar. 21, 1961

2,975,713

LIQUID FUEL SUPPLY APPARATUS

George W. Wright, Fort Wayne, Ind., assignor to Tokheim Corporation, Fort Wayne, Ind., a corporation of Indiana

Filed June 9, 1955, Ser. No. 514,221

10 Claims. (Cl. 103—87)

This invention relates to apparatus for supplying liquid fuel to a combustion engine, especially for automotive use, and particularly to a submerged centrifugal fuel pump and the combination thereof with a fuel tank and other related fuel-supply apparatus.

It is an object of the invention to provide a centrifugal fuel pump unit for submerged operation in a body of liquid fuel such as the gasoline in a fuel tank, especially an automotive fuel tank, which will be gravity-fed from the body of liquid and will deliver fuel substantially free of air and vapor and in liquid state under pressure from such tank to the fuel feeding device of an engine, and will avoid vapor lock problems which occur with pumps which draw fluid from the tank by suction; which will pump adequate quantities of fuel to the engine at proper pressure under the widely varying and difficult conditions of automotive use, and will continue to pump when the fuel level in the tank is low and will substantially empty the tank of its gasoline; which will expel gas (such as air or vapor) from admixture with liquid passing through the pump and will not become gas-bound as by vapor in the pump or by air admitted by exposure of the pump inlets to air, as from the sloshing of gasoline in the tank; and which will prevent the accumulation of water in the pump, as from condensation in the tank, and will allow water to drain from the pump and adjacent lines when the pump is at rest and will thus reduce the danger of fuel supply failure from ice formation.

It is an object of the invention to provide a small centrifugal pump which is effective at the pumping rates used in automotive fuel systems, which rates, being usually of the order of less than 25 or 30 gallons per hour, are quite small in terms of usual centrifugal design; and to do so in the face of the known fact that the design of such small capacity centrifugal pumps is both perplexing and unpredictable. It is a further object of the invention to provide a fuel pump unit which avoids use of the short-lived pumping diaphragms common in presently used pumps; which will operate with minimum power consumption from the electrical system of the automotive vehicle, and will operate reliably and effectively under the varying conditions which occur in such systems; which will supply adequate fuel at sufficient but not excessive pressures under all conditions, and will quickly purge the fuel system of any vapor accumulation, such as that which strongly tends to occur in the fuel line immediately after a hot engine is stopped. It is a further object of the invention to provide such a fuel pump unit which is compact and adapted to fit a variety of fuel tanks, including the shallow tanks commonly used in passenger cars and the tall narrow tanks commonly used in trucks; which will be highly reliable in operation and have a long life and require a minimum of service; and which will have such reliability under the adverse mounting and operating conditions of a vehicle which is normally in motion and which may be in relatively rough motion and is subject to various adverse road and weather conditions.

It is a further object of the invention to provide a fuel-pump unit and system adapted for mass production at relatively low cost.

It is a further and specific object of the invention in a preferred form, as for automotive use, to provide a pump which causes a minimum of disturbance of the fuel in which the pump is submerged. The pump may be made to cause agitation and beating and recirculation of the fuel in the tank, to separate vapor and light-ends from the fuel prior to its passage through the pump, as in the manner of the Curtis Reissue Patent No. 22,739; but for many uses such disturbance is desirably avoided and the "light-ends" or highly volatile constituents of the fuel are preserved and delivered in liquid state for utilization by the engine.

It is an object of the invention to combine the fuel pump with a motor in an interrelated unit, and to combine the pump with a tank and other related parts of a fuel system, in a manner to provide a more effective and advantageous fuel system, especially for automotive use.

Further and more specific objects of the invention will appear from the following specification.

In accordance with the invention, the fuel pump is a double-inlet centrifugal pump, desirably combined in a unitary assembly with an electrical driving motor with the unit arranged to operate in a generally upright or vertical position with the pump at the bottom, and in normal use the pump is mounted in submerged position close to the bottom of the tank or of a sump formed in the bottom wall of the tank.

The pump comprises a casing which has both top and bottom inlet throats and which forms a thin, annular, and desirably outwardly tapering, pumping chamber extending outward from between the throats. The chamber communicates with an outer volute connected to a pump discharge conduit. A centrifugal impeller on a central shaft carries impeller blades which revolve in the pump casing. Preferably, the blades are supported on the hub by structure which lies between the throats in a medial plane of the pump chamber, and the blades are desirably of the open unshrouded type operating with running clearance between the opposite walls of the pumping chamber. Preferably, the pump has no rotary seals between the impeller and the casing. The blades may have some forward or rearward sweep, but substantially straight blades are found to produce a relatively constant discharge pressure over the range of delivery rates which occur in automotive systems, and straight blades are preferred.

The impeller is formed to provide openings through which gas can freely pass through the impeller from the bottom throat to the top throat, and which permit the pump to be filled by liquid from either throat. Such openings may be wholly or partially within the projected area of one or both throats, and may comprise a central bore on the axis of the impeller. The openings may also be wholly or partially outward of the peripheries of one or both throats, and for reasons which will appear the openings are preferably outward of the peripheries of both throats.

The blades of the impeller may extend inward to within the throats to act on the liquid before it enters the pumping chamber, and in such case the blades exposed through the throat may cause a beating and agitating effect in the entering liquid and a recirculating movement in the surrounding body of liquid. The beating and agitating effect of exposed blades tends to separate from the entering liquid the more highly volatile constituents and to convert these constituents to gas bubbles, and the recirculating movement carries such gas bubbles in a diverging conical stream outward from the periphery of the throat in which the action occurs, as in the manner disclosed in the Curtis Reissue Patent No. 22,739. Such beating and agitating and recirculation can occur at either or both the top and bottom throats, depending on the relation between the throat periphery and the adjacent inner end portions of the blades, and can be made to occur in one throat and be avoided in the other, for example, to occur in the top throat and not in the bottom throat.

For many uses of the pump, particularly in automotive and other systems which are not subject to the low pressures of high-altitude flying, such beating and agitating and recirculating and bubble formation is desirably avoided, in order to preserve all constituents of the fuel in liquid state and to deliver them for utilization by the engine. To this end, in the preferred form of pump for such uses, the blades of the impeller do not extend into the throats, and their inner ends lie at or outwardly beyond the peripheries of those throats. To this same end, the central portion of the impeller, within the throats, is desirably formed with non-agitating surfaces, for example, with smooth and uninterrupted surfaces of revolution, to produce a minimum of agitation and swirling of the entering liquid, and the openings through the impeller (except possibly a circular axial bore) are arranged wholly outward of the peripheries of the throats.

In the pump preferred for automotive use, the impeller comprises a relatively small hub sufficient for mounting on the pump shaft, with a smooth-surfaced and uninterrupted circular web extending outward from that hub to the periphery of the largest of the throats, and the impeller blades are formed as circumferentially spaced blades projecting outward in the pumping chamber from the edge of that web and lying wholly outward from the throats with no blade portions extending into or exposed through the throats. The circumferential spacing of the blades leaves open spaces between them in the pumping chamber, especially at the inner portions of the chamber, to permit both the desired gas escape flow from the bottom to the top throat and the desired cross flow of liquid from one throat to the opposite side of the pump. In the pumping chamber, the impeller is open both in the sense that it carries no shroud and in the sense that its blades are circumferentially spaced to permit free fluid flow and pressure transmission axially across the blades.

Preferably, the impeller blades are tapered outwardly and the opposite walls of the pumping chamber are correspondingly dished. The clearance between the blades and the walls need not be an extremely close clearance, and may be relatively large in proportion to blade width, for example, of the order of 0.015 to 0.025" with blades having a tip width of the order of $\frac{1}{16}$".

It will be evident from the foregoing that certain relationships between the throats and the inner ends of the blades are preferred but that variations are contemplated depending on the effects desired. Thus, the periphery of either throat may lie even with the inner ends of the blades, or may lie either inward or outward therefrom; the relationship at the two throats may be different; and the difference may result from different positioning either of the inner ends of the blades or of the peripheries of the throats.

The blade-supporting web of the impeller desirably lies in a medial plane of the pumping chamber, with the blade edges standing axially both upward and downward therefrom toward the top and bottom chamber walls. The medial plane is desirably the central medial plane. The top and bottom halves of the blades may differ, but desirably the opposite blade halves are of equal height and length and the impeller is symmetrical with respect to a central radial plane, which tends to eliminate end thrust and positions the blade-supporting structure centrally between and spaced from the casing walls. This arrangement and the absence of shrouds on the blades avoids any need for running seals between the pump rotor and the pump casing, and reduces the power consumption over what the pump would require if shrouds and seals were used. With unshrouded blades any reverse leakage flow along the walls of the pumping chamber is in contact with the fluid being pumped, but this is believed to be advantageous to the dispelling of gas from the pump.

The top and bottom inlet throats of the pump are in substantially open communication with the body of liquid in which the pump is submerged, and in a pump-motor unit the pump and motor are spaced to provide such communication at the top throat. The inlets are desirably screened with screen which admits fuel but excludes solid particles larger than the pump clearances. The top screen should be of a character to permit the escape of gas through it. The screens may be of a character to exclude water from the pump.

In accordance with present automotive practice, the pump motor is a direct-current motor. It desirably operates at a speed of the order of 4000 r.p.m. to 5000 r.p.m. It may be a wet motor, i.e., one which is filled by the fuel or through which the fuel is circulated for cooling and lubrication. Preferably, however, the motor is an enclosed dry motor, and motion is transmitted from it to the pump by a magnetic coupling operating through an imperforate wall in accordance with the teachings of the co-pending application of William L. Hudson, Serial No. 538,753, filed October 5, 1955, now U.S. Patent No. 2,885,126.

The pump-motor unit is mounted in the fuel tank to position the pump at as low a level as possible which still permits free access of liquid to the bottom throat. When a sump is used, the sump is desirably of sufficient size and depth to position the top throat substantially at or below the level of the surrounding tank bottom wall. The sump may be surrounded by relatively upright walls to baffle lateral fluid flow from the sump.

When the pump inlet screens are of a type which pass water, the pump is desirably positioned with its bottom throat immediately above the lowest point in the tank, i.e., that point where water of condensation tends to collect.

Pumps embodying the invention continue to pump effectively even when the liquid level in the tank falls to or even below the top throat opening. While the top throat is then exposed to air, the pump is sufficiently filled with liquid from the bottom throat to maintain effective pumping and to prevent and oppose passage of air into the pumping chamber. Accordingly, with the pump mounted close to the bottom of the tank, it will continue to pump until the tank is substantially empty.

When both throats are exposed to air, by reason, for example, of the sloshing of fuel in the tank, pumping is of course interrupted so long as such exposure continues. But when the fuel flows back to the pump, the pumping action immediately resumes. Any air or gas which is caught in the pump or bottom throat upon the resubmergence of the pump passes through the impeller openings and is released through the top throat. Gas which may occur in the pump or bottom throat for any other reason, as from vaporization or cavitation under extreme temperature and pressure conditions, is released from the pump in like manner, and the pump does not become gas-bound.

The pressure conditions in the pump are believed to cooperate with its structural features to produce this release of gas and to avoid gas binding. In the direction of progression through the pump from the throats to the volute, the pressure rises increasingly toward the tips of the blades, to produce a relatively high-pressure zone swept by the outer ends of the blades. The discharge head or back-pressure against which the pump normally operates tends to hold liquid in this high-pressure zone; and if the pump is only partially filled, the liquid present collects in this outer or high pressure zone, where it blocks escape of air to the volute, and any air which is present separates inward toward the throats. The openings between the blades in the pumping chamber permit the liquid from either throat to freely fill the chamber across its whole height, and permit the air or gas to rise through the impeller to the top of the pump. Liquid entering the bottom throat will progressively fill the pump, and the air or gas is displaced inward and upward to and through the top throat.

With the pump close to the bottom of the tank and with a screen which admits water, water of condensation which occurs in the tank is discharged therefrom by the pump as it occurs; for as small quantities of water drain to a point below the pump, they are picked up and entrained with the entering fuel and are discharged by the pump with the fuel. Water will then be discharged as a relatively small proportion of the total liquid delivered by the pump, and can pass through the engine without interfering with its normal operation; and water will not accumulate to enter the pump in large proportions. Because the pump has both top and bottom openings, not only does it permit any gas to escape upward, as has been noted, but it also permits any water in the pump or in the adjacent lines to drain from the pump back to the tank when the pump is stopped. Because of such draining and because the accumulation of water is prevented, the fuel system substantially avoids any danger that it will be rendered inoperative by the freezing of water in the pump or in the lines.

The accompanying drawings illustrate the invention. In such drawings:

Fig. 1 is a somewhat schematic diagram of an automobile fuel system embodying the invention;

Fig. 2 is a vertical section of a fuel pump and motor unit in accordance with the invention, in the form of a built-up assembly adapted for automotive use;

Fig. 3 is a bottom section taken on the line 3—3 of Fig. 2, i.e., a bottom plan view of the pump of Fig. 2 with the bottom half of the pump casing removed;

Fig. 4 is a top plan view of the assembly shown in Fig. 2;

Fig. 5 is a vertical section on the line 5—5 of Fig. 6 of a preferred modification of pump-motor unit adapted for quantity production for automotive vehicle use, associated with a preferred mounting;

Fig. 6 is a bottom plan view of the pump-motor unit and mounting shown in Fig. 5;

Fig. 7 is a vertical section taken generally on the line 7—7 of Fig. 5 and more specifically on the line 7—7 of Fig. 8, and showing a mounting clip on an enlarged scale;

Fig. 8 is a section taken on the line 8—8 of Fig. 7;

Fig. 9 is a vertical section of another modification of a pump-motor unit in accordance with the invention, in which the pump motor is a wet motor;

Fig. 10 is a section taken on the line 10—10 of Fig. 9;

Fig. 11 is a fragmentary vertical section similar to Fig. 2, showing an impeller and casing arrangement adapted to produce beating and agitating and recirculation of liquid in the body of liquid in which the pump operates;

Fig. 12 is an enlarged half-section of a pump casing and impeller, showing the preferred blade and throat relationship for automotive use; and

Figs. 13 and 14 are similar half-sections illustrating modified blade and throat relationships.

The system shown in Fig. 1 includes a pump and motor assembly **10** mounted as a depending unit in a fuel tank **12** and connected by a fuel line **14** through a filter **16** to the float-controlled inlet valve **18** of the carburetor **20** for an automotive engine **22**. The pump operates against back-pressure resulting from the static discharge head and the friction head in the line **14** and filter **16**, and especially from the restriction normally provided by the valve **18**.

The ignition system of the engine **22** is controlled by a key-actuated switch **24** having a movable contact **26** connected to a battery **27**, and having a fixed contact **28** connected to the ignition circuit **30**. The switch may also have a second fixed contact **32** connected to the actuating relay for the engine starter **34**. In normal running, the movable contact **26** closes an ignition circuit to the first fixed contact **28**. For starting, the movable contact **26** is moved beyond this normal running position to engage both the first contact **28** and the second fixed contact **32**, and then closes both the ignition circuit and the starter relay circuit. The motor of the fuel pump **10** is energized by a line **36** in parallel with the ignition circuit **30**, and preferably includes a switch which is responsive to engine operation, for example, responsive to intake vacuum, to oil pressure, to generator output, to rotation of some engine part, or to some other engine or accessory function. As shown, this switch is a normally open switch **38** actuated to closed position by a sensitive vacuum-responsive motor **40**, responsive to intake vacuum of the engine **22**. With a suitably sensitive vacuum motor, such vacuum is sufficient both under starting conditions and under all running conditions to effect the closing of the pump energizing switch. If desired, however, the pump can also be energized in response to switch actuation. For this, the switch **24** may be provided with an additional fixed contact **31**, positioned to be energized concurrently with or ahead of the starter contact **32**, and such contact may be connected by a line **44** (shown in dotted lines) to energize the pump **10** independently of the switch **38** during actuation of the starter relay.

The pump and motor assembly shown in Figs. 2 through 4 comprises a mounting plate **50** secured about the edges of an opening in the top wall **52** of the fuel tank **12**. A central depending collar **54** on the plate **50** carries a cylindrical motor housing shell **56**, sealed to the collar **54** by an O-ring gasket **58**. A motor support casting **60** is received and secured in the lower end of the tube **56**, and sealed thereto by an O-ring gasket **62**. The upper end of the casting **60** is formed to receive the bearing boss **66** at the lower end of the motor **68**, and the motor is supported by the casting **60** and is secured in place by bolts **69**.

The motor shaft **70** is carried by radial and thrust bearings in the motor, and projects downward. Its lower end slidably receives the hub **72** of the driver member **74** of a magnetic coupling and is drivingly connected thereto by a cross pin **76** engaged in a slot in the hub **72**. The shaft thus centers and drives the driver member **74**, but neither member transmits or receives thrust from the other. The lower end of the motor support casting **60** is closed by an imperforate wall or diaphragm **80**, sealed thereto by an O-ring gasket **82** and clamped in place by a housing **84** for the driven member **86** of the magnetic coupling.

A pump body **90** is secured to this assembly below the housing **84**, and is spaced therefrom by a series of spacing posts **102**. The body **90** forms the upper wall **92** of the pump casing, and such wall carries one or more struts **94** extending diagonally upward and inward to support a central bearing sleeve **96** which fits into a central opening in the housing **84** and houses a pair of spaced sleeve bearings **98** for the pump shaft **100**. A passage in one of the struts **94** carries fuel from the pressure side of the pump to the space between the bearings **98** for lubrication. A pump cover **104** forms the bottom wall **106** of the pump casing.

The two pump casing walls **92** and **106** have central openings to form axially opposite top and bottom inlet throats **108** and **110**, and define a thin annular pumping chamber **112** which extends outward from between the throats. Such chamber openly communicates with a volute **114** formed in the body and cover, and this leads tangentially through a pump delivery passage **116** to a socket **118** for the lower end of a pump discharge pipe **120**. The pipe is received between that socket **118** and an opposed socket **122** in the mounting plate **50**, and is sealed to each socket by an O-ring gasket. The top socket 122 connects with a discharge fitting 124 adapted to be joined to the fuel line 14.

One side of the motor 68 is grounded, and the other side is connected by a lead 128 to a terminal post 126 extending through an insulating fitting on the mounting plate. The pump-motor line 36 may be connected to the post 126, and the connection is protected by an enclosing shield 130.

The imperforate wall or diaphragm 80 is made of non-magnetic material, such as stainless steel, brass, or a non-conductive material. As shown, the wall 80 is a stiff disk of synthetic resin material reinforced with fiber. It is completely imperforate, and the entire assembly above it is completely closed and sealed from the fuel in the tank. Both the driving member 74 of the magnetic coupling and especially the motor 68 are thus isolated from the tank and operate dry, with suitable lubrication, in an atmosphere free of fuel. The motor chamber may be vented in the atmosphere through a screened opening 132 in the mounting plate 50. Alternatively, the closed assembly may be sealed, and filled with gas to provide a controlled atmosphere.

The driving member 74 of the magnetic coupling is of circular shape, and carries two spaced depending annular walls, which form a seat for an annular permanent magnet 140. This has chamfered lower-corners and is fixed in its seat by deforming the walls over those chamfered corners. The magnet is magnetized, preferably after assembly, to provide spaced magnetic poles at its bottom face. Preferably, four such poles are used, of alternate polarity. The member 74 may carry fan blades 75 on its top surface, to circulate air through the motor. The driven member 86 of the magnet coupling is of similar construction, with a central hub 142 and two upstanding spaced annular walls which form a magnet receptacle. A companion annular permanent magnet 144 is secured therein, and is magnetized like the magnet 140 but with its poles at its top face.

Each coupling member 74 and 86 has a central thrust bearing seat 146, and thrust balls are interposed between such seats 146 and a pair of thrust plates 148 inserted in a thickened portion at the center of the wall 80. The thrust arising from the traction between the permanent magnets 140 and 144 is taken directly by this central thrust bearing structure and is not imposed on the housings or on either the motor bearings or the pump shaft bearings. The driven coupling member 86 is fixed on the pump shaft 100 and is centered thereby, and the magnetic traction holds the coupling and shaft upward in the position determined by the bottom thrust insert 148 of the wall 80.

The pump impeller shown in Figs. 2 and 3 (and similarly in Fig. 12) comprises a small central hub 150 threaded onto the pump shaft 100, with a circular web 152 extending radially therefrom in the central plane of the pumping chamber, and with a series of circumferentially spaced impeller blades 154 carried at the edge of the web. The blades shown are T-shaped in cross section. Their reinforcing central ribs are integral with the web 152 and extend in its plane along the leading faces of the blades. From the central rib of each blade, the blade edges stand upward and downward into running clearance with the pumping chamber walls 92 and 106. The top and bottom blade halves are of the same height and of the same radial length. The impeller is thus symmetrical with respect to the central plane of the pump. The blades are tapered outwardly, and the pumping chamber walls 92 and 106 have a corresponding shallow conical shape. The circumferential spacing of the blades about the circular web 152 leaves relatively large open spaces between them, and such spaces extend inward to the inner ends of the blades. With such spacing, liquid from either throat can freely cross the central plane of the pump to fill the impeller, pressure will be equalized across the whole axial width of each blade, and any air or gas in the pumping chamber can freely rise to the top of that chamber for escape through the top throat 108.

As has been noted, an automobile fuel pump desirably avoids beating and agitating the fuel, and desirably produces a minimum of recirculation or swirling or other movement in the surrounding liquid in the tank. To this end, the inner ends of the blades 154 lie at or outwardly from the peripheries of the throats, with no portions of the blades directly exposed through either throat to the surrounding liquid. To this same end, the central hub 150 and the web 152 of the impeller in Figs. 2 and 3 are formed with smooth uninterrupted surfaces of revolution over the whole surface area which is exposed through the throats, and the flat smooth web 152 extends outward to the periphery of the largest of the throats 108 and 110. The two throats may be of the same size, but in the preferred relation shown, the top throat is of the size as the circle of the inner ends of the blades, and the bottom throat is somewhat smaller.

The blades may have some forward or rearward sweep, but preferably are substantially straight. As shown, the leading edge of the central rib of each blade has a slight rearward sweep, while the blade edges lie radially of the impeller axis. The pump pressure should remain fairly constant over the whole range of delivery rates called for by the engine, and especially should remain within the range of pressures which can be controlled reliably by the inlet valve of the fuel mixing device. A desirable discharge pressure range is below about 5 pounds per square inch as a maximum and above about 3 pounds per square inch as a minimum, with normal voltage in the motor supply circuit. Moreover, effective output pressure should be maintained over a wide range of delivery rates despite voltage drops which are likely to occur in the automotive electrical system from which the pump motor is energized. The preferred straight blades are found to give these desired characteristics.

The pump of Figs. 2 to 4, with an impeller of 1.5" diameter and 1/16" blade-tip width, operating at 4000 r.p.m. to 5000 r.p.m., is found to have an output capacity ranging up to about 25 gallons of gasoline per hour in a pressure range of from 3 to 5 p.s.i. With the pump operating at normal delivery conditions, the smooth-centered impeller has no beating or agitating effect on the entering liquid and hence does not produce vaporization or volatile constituents of gasoline even when the gasoline is under boiling conditions. While some swirling of liquid occurs adjacent the inlet throats, the movement is relatively mild. Even under substantially boiling conditions, the swirling does not normally produce a hollow vortex with gas occurring along its axis and does not produce a recirculating stream or current of bubbles in the liquid. All constituents of the gasoline entering the pump are thus preserved and delivered in liquid state under pressure to the fuel mixing device of the engine.

When the tank in which the pump is operating contains a relatively low level of fuel, movement of the tank will slosh the liquid away from the pump and temporarily expose the inlets to air.

While such exposure of the throats to air interrupts pumping, the delivery line is maintained full of fuel and pumping resumes immediately upon resubmergence of the throats, and the pump does not become gas-bound.

The assembly shown in Figs. 5 and 6 is adapted for quantity production as a substantially permanently assembled unit. The main body of the assembly comprises a tubular shell 200, conveniently made of commercial tubing. A diaphragm 202 is inserted in its lower end, and is fixed and sealed in place as by soldering. The center of the diaphragm 202 carries a thrust bearing insert 204 and a depending sleeve bearing 206, which are secured and sealed to the diaphragm as by welding or soldering. Above the diaphragm 202, the shell 200 receives a motor-supporting spacer 208 which may be molded from a synthetic resin material such as nylon and is generally cylindrical in shape. It rests on the diaphragm, and its upper portion fits closely within the shell 200. At three spaced points around its upper edge, it is provided with upward extensions 209 to center the motor 210 within the shell 200.

The motor assembly 210 is inserted within the shell 200 to rest on the upper face of the spacer 208. It is held down, and its upper end is centered, by a stabilizing plate 212 molded of synthetic resin such as nylon. The stabilizing plate is held in place, and the upper end of the shell 200 is closed, by a cap 214 which has a central tubular upward extension 216. This receives a grommet 218 through which the motor leads are passed. Such leads include a live lead 219 and a ground lead 220, the latter being connected to one of the bolts 222 which hold the motor assembly 210 together. The tubular extension 216 of the cap 214 is connected and sealed to a conduit 224 which carries the motor leads and serves to stabilize the mounting described below. The conduit may be sealed, as with a mass of sealing compound 225.

The motor shaft 226 is carried by radial and thrust bearings in the motor 210 and its lower end projects downwardly and is provided with a drive pin 228. The driver member 230 of a magnetic coupling is slidably and drivingly mounted on the end of the shaft 226, and carries an annular magnet 232. The magnet is conveniently a pressed ferrite magnet, magnetized after assembly to provide for circumferentially spaced poles at its lower face. The member 230 may be an anodized aluminum casting provided at its center with a hardened cup-shaped thrust bearing insert 234 which rides on a thrust ball between itself and the diaphragm insert 204.

The shell 200 projects a short distance below the diaphragm 202, and receives a pump body casting 240. Such casting forms the upper wall 242 of the pump casing, and has a rim 244 which abuts the lower edge of the shell 200. Three circumferentially spaced posts 246 extend upward from the pump body 240 and fit closely within the lower end of the shell 200. Their upper ends abut the lower face of the diaphragm 202, and support a shroud 248 which forms a housing for the driven member 250 of the magnetic coupling. The pump body 240 is conveniently secured in place by one or more pins 252 pressed into aligned holes in the shell 200 and the legs 246.

The lower end of the shell 200, between the posts 246, is punched to provide inlet openings 254, and these are covered by a screen 256 wrapped around the lower end of the shell 200 and overlapping the rim 244 of the body 240.

The lower half of the pump casing is formed by a cover 260, which may be molded of a synthetic resin material such as nylon. It provides the lower wall 262 of the pump housing. A volute 264 is formed by the pump body and cover, around the pump chamber, and leads to a socket in the pump body 240 which receives the lower end of the discharge pipe 266.

The bottom throat of the pump is formed in the bottom pump casing wall 262, and is bridged by a spider 272 which supports a bearing sleeve 274 for the lower end of the pump shaft 276. The bearing sleeve may be integral and homogeneous with the cover 260 when that cover is made of a bearing material such as nylon. The bottom throat is protected by a screen 270 fitted within a tapering collar 268 on the body 260 and held in place by a snap ring 269.

The pump shaft 276 is journaled at its ends in the sleeve bearing 206 on the diaphragm and in the bearing sleeve 274 of the pump cover. Its upper end face forms a thrust bearing riding against a thrust ball received between it and the diaphragm insert 204.

The driven member 250 of the magnetic coupling is similar in construction to the driver member 230, and carries a companion magnet 251 magnetized after assembly to provide magnetic poles at its upper face in positions for alignment with the poles of the driving magnet 232. The driven member 250 is fixed on the upper end of the pump shaft 276, as by a press fit on a knurled section of the shaft, and the magnetic traction holds the shaft upward against the thrust bearing and fixes its axial position. The shroud 248 encloses the driven member 250 to prevent agitation and stirring of the liquid in the tank by the rotation of that member 250.

The pump impeller in Fig. 5 is generally similar to that shown in Figs. 2 and 3, both in construction and in its relationship to the top and bottom throats of the pump casing. It has a central hub which is pressed on a knurled section of the pump shaft 276, and has a circular central web of smooth and uninterrupted surface configuration within the throats of the pump, and such web supports spaced impeller blades which revolve in the pump chamber defined by the walls 242 and 262.

The pump body 240 and cover 260 are provided with peripheral flanges 241 and 261 and are secured together by four rivets 280 passed through such flanges at spaced points around the periphery of the pump. The flanges may be used as a mounting for the pump and motor assembly.

In the mounting shown in Figs. 5 to 8, the pump-motor unit is carried by its flanges 241 and 261 on a bracket 300 secured to the bottom wall of a tank. The bracket has a raised mounting plate 302, with downwardly offset feet at its end edges which support the plate above the bottom of the tank. The pump flanges 241 and 261 are of unsymmetrical peripheral shape, and mounting plate 302 is punched to provide an opening of generally similar unsymmetrical shape. To orient the pump with respect to the bracket 300, the plate 302 carries four upturned guide posts 304, and the flanges of the pump are provided with flat outer faces in complementary relationship with the inner faces of those posts 304. The relationship permits the pump to be inserted in only a single position, and the posts 304 loosely receive and guide the pump housing as it is inserted.

The pump is secured in place on the bracket by snap fasteners, comprising clips carried by either the pump or bracket and engaged with retainers carried by the other. As shown, the assembled flanges 241 and 261 are provided with three circumferentially spaced rectangular openings 306, with that portion of each opening which lies in the flange 241 being slightly wider than the portion which lies in the cover 260. A generally U-shaped spring clip 308 is inserted upwardly in each of the openings 306. At the outer side of the central plane of each clip, its side walls are deformed outward to form clip-retaining fingers or lugs 310 which engage over the upper edges of the pump body flange 261 to retain the clip in its opening 306. At the inner side of the central plane of each clip 308, its side walls are deformed inward to form spring latches 312. For cooperation with the three clips 308, the bracket plate 302 carries three upturned retaining fingers 314 which have notches 316 in their side edges, as shown in Fig. 7, to receive the spring latches 312. The guide posts 304 orient the pump in proper relationship with the bracket, and align the clips 308 with the retaining fingers 314, and when the pump is then pressed downward to its mounting position, the spring latches 312 engage over the retaining fingers 314 and in the notches 316 to secure the pump assembly on the mounting bracket 300.

The top wall 52 of the fuel tank is provided with a suitable opening for insertion of the pump-motor assembly, and such opening is closed by a cover plate 320. Such cover plate has a central opening containing an elastic grommet 322 to closely embrace the upper end of the conduit 224 at the top of the motor and pump assembly. The upper end of the grommet 322 is closed by a terminal shield 324 through which the leads 219 and 220 are passed. The plate 320 also carries a pump discharge fitting 326, in communication with a depending socket 328 which receives the upper end of the pump discharge pipe 266. The upper end of such pipe desirably carries an elastic grommet 330 which frictionally engages the wall of the socket 328.

In mounting the pump, the pump-motor assembly, including a discharge pipe 266 carried in the socket of the pump body, is inserted through the opening in the tank top wall, is properly oriented with respect to the bracket 300 by engagement of the flanges 241 and 261 between the posts 304, and is then pressed firmly downward to engage the retaining posts 314 in the clips 308 carried in the openings 306 of the pump flanges. This substantially locks the pump to the bracket 300, although the engagement can be released when it is desired to remove the pump from the tank. After the pump has been locked on the bracket 300, the cover plate 320 is applied to the top tank wall. The motor leads 219 and 220 are led up through the grommet 322, and that grommet is then engaged over the end of the conduit 224, and the socket 328 is engaged over the end of the grommet 330 carried by the discharge pipe 266. The plate is then pressed downward to its seated position on the tank top wall and is secured in place. The conduit 224 serves a supplementary mounting function, as noted above, for its engagement in the grommet 322 stabilizes the upper end of the assembly, to suppress vibration and prevent rocking movements which might tend to dislodge the pump from its mounting bracket 300. The grommets 322 and 330 prevent transmission of vibration to the top wall of the tank.

The conduit 224 and discharge pipe 266 can be made of any desired length to suit the depth of the tank in which the assembly is mounted. Thus, in a shallow passenger car tank, the conduit 224 will usually be relatively short, and the relationship may be substantially that shown in Fig. 5; while in a tall tank such as is commonly used in trucks, the conduit 224 and pipe 266 may be quite long.

In the modification shown in Figs. 5 through 8, the motor 210 and the driving member 230 of the coupling are completely enclosed in the compartment formed above the imperforate wall or diaphragm 202, and such compartment is hermetically sealed from the tank. The compartment may be permitted to breathe to the atmosphere outside the tank, by providing for leakage past the grommet 218 in the conduit 224 and along the wire leads 219 and 220 where they pass through the terminal shield. Preferably, however, the assembly is sealed as by applying a sealing compound 225, such as litharge, around the wire leads in the conduit 224, and in such case, the motor compartment may be filled with a controlled atmosphere favorable to motor operation and life.

Operation of the motor rotates the driver 230 of the magnetic coupling, and the driven member 250, being magnetically coupled thereto, is driven at the same speed. The torque required for normal operation of the small centrifugal pump is readily transmitted by the coupling, and the coupling effect is desirably limited to a value sufficient for normal pump operation but less than the normal torque of the motor and less than sufficient to reestablish itself during operation once it is broken. If the pump should become locked, the coupling effect would then be broken and the motor would run free, without danger of overheating or burning out.

The pump of Figs. 5 and 6 operates in substantially the same way as the pump of Fig. 2. Its surfaces exposed through the throats are non-agitating surfaces and produce no beating and vaporization of the entering liquid and but little swirling or other movement in the surrounding body of liquid. Swirling movement at the lower throat is further reduced by the spider supporting the bearing 274 below the bottom throat. The pump does not become gas-bound even when its throats are exposed to air by the sloshing of fuel in the tank, and resumes pumping immediately on resubmergence of the throats. Air or gas caught in the bottom throat or in the pump is displaced upwardly between the spaced blades and escapes through the top throat. The pump produces effective pumping until the liquid level in the tank (or sump) falls below the top throat of the pump casing, and thus will substantially empty the tank in which it is mounted.

The pump-motor unit shown in Figs. 9 and 10 is made substantially entirely of sheet-metal stampings, and utilizes a wet motor, i.e., a motor through which fuel is circulated for cooling and lubrication. The unit includes a mounting plate 410 by which it is carried by the top wall 412 of a fuel tank. Like the other modifications, the pump may be positioned in a sump 414 formed in the bottom wall of the tank. The mounting plate 410 carries a depending collar 416 on which a hanger tube 418 is supported. The lower end of the tube 418 is closed by a motor supporting plate 420 which has a central depending cup 422 for the reception of the lower bearing boss of the motor unit 424. The motor unit is desirably disposed with its commutator 426 at the bottom, to insure lubrication of the commutator under all conditions, and the motor is secured to the mounting plate 420 by bolts 448. One side of the motor is grounded, and the other side is connected by a lead 430 to a terminal post 432 like that shown in Fig. 2.

The depending cup 422 of the motor support plate 420 has inlet openings 434 in its side wall, and such openings are desirably covered by a cylindrical screen. The pump housing is formed of a pair of sheet-metal stampings 436 and 438 which are secured together at their peripheries and are supported from an inturned flange at the bottom of the cup 422. The casing walls form top and bottom inlet throats, a pumping chamber extending outward from between such throats, and a volute at the periphery of the pumping chamber. The outer end of the volute connects with a socket 440 for the reception of the lower end of a pump discharge pipe 442, whose upper end is received in a socket in an outlet fitting 444 carried by the mounting plate 410.

The motor shaft 450 extends downward from the motor into the pump casing, and the pump impeller 452 is mounted directly on its lower end. In this case the top and bottom throats of the pump casing are relatively larger than those shown in the modifications described above, and the impeller blades extend inward into the throats. With the blades thus exposed through the throats, the impeller produces an agitating effect on the entering liquid and a relatively violent swirling both in the entering liquid and in the surrounding body of liquid. Such agitation and swirling tend to separate the more volatile constituents from the fuel as gas bubbles, and such gas bubbles may be discharged from the throats in outward conical streams. Gas may also tend to collect at the center of the vortex or swirling body of liquid. Any bubbles which occur at the top throat are free to rise therefrom and to escape back to the tank through the openings 434, and to this end the openings extend upward to a point above the bottom of the motor bearing boss. Bubbles which are discharged with the recirculating liquid from the periphery of the bottom throat are free to rise about the pump casing to the top of the tank. Bubbles which collect at the center of the vortex at the bottom throat are desirably led off from the center of the vortex, and for this purpose, the pump shaft 450 is desirably a hollow shaft with a bore which leads from the center of the bottom throat upward to and through the projecting top end of the pump shaft 450.

To lubricate and cool the motor, a small stream of liquid is led off from the periphery of the pumping chamber by a tube **454** fitted into an opening in the top wall of the pump casing **436** and leading upward into the housing of the motor **424**, desirably to a point above the commutator of the motor. The motor housing is substantially closed to retain liquid therein, and is provided at the top with an outlet nipple **456**. Desirably, the mounting tube **418** is also substantially closed below the top of the motor, to retain a supply of liquid in cooling relation with the motor casing. Overflow from within the tube **418** is provided through one or more openings **458** adjacent the top of the motor.

Fig. 11 illustrates a modification of the pump and motor unit shown in Fig. 2, in which the pump casing and the impeller are arranged to produce beating and agitating and recirculation of the liquid. The top and bottom throats **508** and **510** of the modified pump are substantially larger than those in the pump of Fig. 2, and the impeller blades **554** are extended inward from the pumping chamber **512** substantially to the hub **550** of the impeller, so that their inner portions are openly exposed through the enlarged throats. With such exposure through the relatively large throats, the impeller tends to produce a recirculation of the liquid adjacent the pump, with liquid flowing inward adjacent the axis of the pump and with liquid flowing outward from the peripheries of the throats, and to produce a relatively strong swirling of the liquid adjacent and outward from the pump. The agitating or beating effect produced by the exposed blades on the recirculating liquid separates volatile or gaseous constituents from it as bubbles which become entrained in the stream of recirculating liquid discharged from the peripheries of the throats. The bubbles which are so entrained, both at the top and bottom throats escape outwardly and rise through the body of liquid in the tank. Gas may also pass through the impeller between its spaced blades, to escape from the top throat. The swirling of the liquid forms a vortex, and gas also tends to collect at the center of such vortex. To bleed off gas from the center of the bottom throat, the pump shaft **500** contains a central bore which discharges past the thrust ball at the upper end of that shaft and into the housing for the driven member of the magnetic clutch. Gas so discharged displaces liquid from that housing, and provides a gaseous medium rather than a liquid medium about the driven coupling member, to reduce the frictional drag on that member.

Figs. 12 to 14 supplement the other figures of the drawing to illustrate on an enlarged scale modifications in the relationships between the pump throats and blades. The relationships shown in Fig. 12 are like those of Figs. 2 and 5, and are preferred. The top and bottom halves of the impeller are symmetrical, and the inner ends **560** and **561** of the top and bottom blade portions all lie the same radial distance from the pump axis. The bottom throat **110** is smaller than the open area within the circle of the inner ends **561** of the bottom blade portions, and is of a size to give adequate inlet capacity. Its relationship to the blades is especially effective to minimize swirling of the bottom inlet stream. The top throat **108** is larger than the bottom throat **110**, and has the same radius as the inner ends **560** of the top blade portions, and the top wall **92** of the pump neither overhangs nor exposes the inner ends **560** of the blades. The relationship both facilitates the upward expulsion of gas from the pump and avoids beating and agitation of the liquid entering the throat.

In Fig. 13, the bottom throat **610** is of the same radius as the circle of the inner ends **560**—**561** of the blades, while the top throat **608** is larger than that circle. With the blades separated by open spaces which extend inward to the circle of the inner ends of the blades, such spaces are overlapped by the top throat opening, and the arrangement provides upwardly-unobstructed gas-escape openings at the inner periphery of the pumping chamber. The upwardly exposed inner ends **560** of the blades tend to swirl the liquid in the upper throat, and to produce a recirculation to carry gas bubbles upward and outward in a conical path from the periphery of the throat.

The bottom throat **610** in Fig. 13 is the same size as the circle of the inner ends **561** of the blades, and in comparison with Fig. 12 gives a larger inlet area.

In Fig. 14, the top throat **708** and bottom throat **710** are of different radii, and the inner ends **712** and **714** of the top and bottom portions of the blades lie on different circles. This further illustrates that the top and bottom relationships may be modified to vary the pumping and gas-dispelling characteristics.

I claim as my invention:

1. A self-purging fuel pump for operation in submerged position in a fuel tank such as the gasoline tank of an automotive vehicle, comprising a pump casing adapted to be mounted in the fuel space in a fuel tank and forming an annular centrifugal pumping chamber having top and bottom walls, said top wall having a central upward-facing inlet opening for admitting liquid to the chamber and for releasing gas therefrom, said bottom wall having a central downward-facing inlet opening for admitting liquid to the chamber, said openings being in open communication with the space surrounding the pump whereby fuel can freely enter said openings from said space and gas can freely escape to said space from said upward-facing opening, a centrifugal impeller in said casing having pumping blades in said pumping chamber to pump liquid outward therein from said inlet openings, said pumping blades and the annular pumping chamber portion swept thereby being of greater radial width than axial thickness, said impeller being axially open therethrough in areas adjacent said upward-facing inlet opening and the top surface thereof inward of such axially open areas being a substantially bladeless surface of revolution, whereby gas entering the bottom inlet can freely pass through the impeller to the top inlet and be released therethrough ahead of substantial pumping action at the top inlet.

2. A fuel pump according to claim 1 in which said impeller has pumping blades with upper unshrouded edges in running clearance relation with the top wall of the pumping chamber whereby reverse leakage flow along said wall toward the top inlet opening is in contact with fluid in the pumping chamber.

3. A self-purging fuel pump for operation in a fuel tank such as the gasoline tank of an automotive vehicle, comprising a pump casing adapted to be mounted in the fuel space in a fuel tank and forming an annular centrifugal pumping chamber having top and bottom walls separating the chamber from the space surrounding the pump, said wall having a central upward-facing inlet opening in open communication with the surrounding space for freely admitting liquid therefrom to the chamber and freely releasing gas thereto from the chamber, said bottom wall having a central downward-facing inlet opening communicating with such space for freely admitting liquid therefrom to the chamber, a centrifugal impeller rotatable in said casing and having a central portion between said inlet openings and having blade means supported thereby in said chamber to pump liquid outward in said chamber from said inlet openings, said pumping blades and the annular pumping chamber portion swept thereby being of greater radial width than axial thickness, said blade means being openly spaced from each other at their inner ends and defining fluid-receiving spaces in the chamber which are in inlet communication with both inlets and which provide openings through the impeller through which gas entering the bottom inlet can freely pass upward through the impeller inward of the main pumping action of the impeller for release through said top opening.

4. A self-purging pump according to claim 3, in which the impeller comprises a central circular portion of substantially the same size as the top inlet opening with the surfaces thereof facing said opening being substantially smooth non-agitating surfaces, and said pumping blades comprise substantially free-standing arms projecting outward in spaced relation from the periphery of said circular portion.

5. A self-purging fuel pump for operation in submerged position in a fuel tank such as the gasoline tank of an automotive vehicle, comprising a pump casing adapted to be mounted in the fuel space in a fuel tank and forming an annular centrifugal pumping chamber having top and bottom walls, said top wall having a central upward-facing inlet opening for admitting liquid to the chamber and for releasing gas therefrom, said bottom wall having a central downward-facing inlet opening for admitting liquid to the chamber, said openings being in open communication with the space surrounding the pump whereby fuel can freely enter said openings from said space and gas can freely escape to said space from said upward-facing opening, a centrifugal impeller in said casing, said impeller having a central portion standing between said inlet openings, the surfaces of said central portion within the axially projected areas of the inlet openings being bladeless surfaces, said impeller having blade arms projecting substantially radially outward from said central portion and forming pumping blades for pumping liquid outward in said pumping chamber, said blade arms and the annular pumping chamber portion swept thereby being of greater radial width than axial thickness, said blade arms being openly spaced from each other over at least the inner radial portion of the pumping chamber and providing open liquid-receiving spaces therebetween in substantially open inlet communication with both casing inlets and in which gas in said pumping chamber can separate from liquid therein and wherein such gas and gas entering the bottom opening can freely pass upward through the impeller and be released through said top inlet.

6. A self-purging fuel pump for operation in submerged position in a fuel tank such as the gasoline tank of an automotive vehicle, comprising a pump casing adapted to be mounted in the fuel space in a fuel tank and forming an annular centrifugal pumping chamber having top and bottom walls, said top wall having a central upward-facing inlet opening for admitting liquid to the chamber and for releasing gas therefrom, said bottom wall having a central downward-facing inlet opening for admitting liquid to the chamber, said openings being in open communication with the space surrounding the pump whereby fuel can freely enter said openings from said space and gas can freely escape to said space from said upward-facing opening, a centrifugal impeller rotatable in said casing, said impeller having a blade supporting web in a medial plane of said pumping chamber and blade portions standing upward and downward from said structure to form pumping passages open to said casing inlet throats on opposite sides of said medial plane, the blade portions of said impeller and the annular pumping chamber portion swept thereby being of greater width radially in said medial plane than the over all axial thickness of said blade and chamber portions, and said pumping spaces on opposite sides of the medial plane being in open communication with each other at the inner ends of said up-standing blade portions, the impeller structure exposed through the inlet openings being defined by non-agitating bladeless surfaces and the blade portions adjacent each inlet opening lying wholly outward of such opening, and the pumping spaces on opposite sides of the medial structure being in open communication with each other adjacent the inner periphery of the pumping chamber.

7. A self-purging fuel pump for operation in submerged position in a fuel tank such as the gasoline tank of an automotive vehicle, comprising a pump casing adapted to be mounted in the fuel space in a fuel tank and forming an annular centrifugal pumping chamber having top and bottom walls, said top wall having a central upward-facing inlet opening for admitting liquid to the chamber and for releasing gas therefrom, said bottom wall having a central downward-facing inlet opening for admitting liquid to the chamber, said openings being in open communication with the space surrounding the pump whereby fuel can freely enter said openings from said space and gas can freely escape to said space from said upward-facing opening, an open impeller rotatable in said casing between said top and bottom inlets and having circumferentially spaced pumping blades in said chamber for pumping liquid outward therein, the spacing of said blades forming liquid-receiving spaces therebetween which are open axially across the whole axial width of the blades and extend inward to the inner ends of the blades and are in open communication with both casing inlets, said pumping blades and the annular pumping chamber portion swept thereby being of greater radial width than axial thickness, whereby said spaces can be filled by fluid from either casing inlet alone and gas in said spaces can freely rise therethrough for escape through said top casing inlet.

8. A self-purging fuel pump according to claim 7, in which said blades have unshrouded top edges in running clearance relation with the top wall of the pumping chamber whereby reverse leakage along said wall toward said top inlet is in contact with said liquid-receiving spaces to drive gas therefrom to said top inlet.

9. A self-purging fuel pump for operation in submerged position in a fuel tank such as the gasoline tank of an automotive vehicle, comprising a pump casing adapted to be mounted in the fuel space in a fuel tank and forming a centrifugal pumping chamber having a central upward-facing inlet opening for admitting liquid to the chamber and for releasing gas therefrom and having a central downward-facing inlet opening for admitting liquid to the chamber, said openings being in open communication with the fuel surrounding the pump whereby fuel can freely enter said openings from said space and gas can freely escape to said space from said upward-facing opening, said pumping chamber being in the form of a relatively thin annular chamber extending radially outward from said inlet openings a greater distance than its axial thickness, a centrifugal impeller rotatable in said casing, said impeller having blades across said annular pumping chamber for pumping liquid outward in said chamber, said blades being openly spaced from each other over a substantial portion of their length inward of their outer ends and having unshrouded top edges in running clearance relation with the top wall of said chamber, said relatively thin and wide annular pumping chamber and impeller forming an outer pressure zone swept by the outer ends of the blades and an inward zone wherein the fluid-containing spaces are open through the impeller and openly communicate with both inlet openings to be filled thereby and to release gas therefrom upward through the top opening.

10. A self-purging fuel pump according to claim 9 in which said impeller blades extend substantially radially across said pumping chamber and the axially open fluid-containing spaces in said inward zone are defined by impeller walls having substantially no sweep.

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