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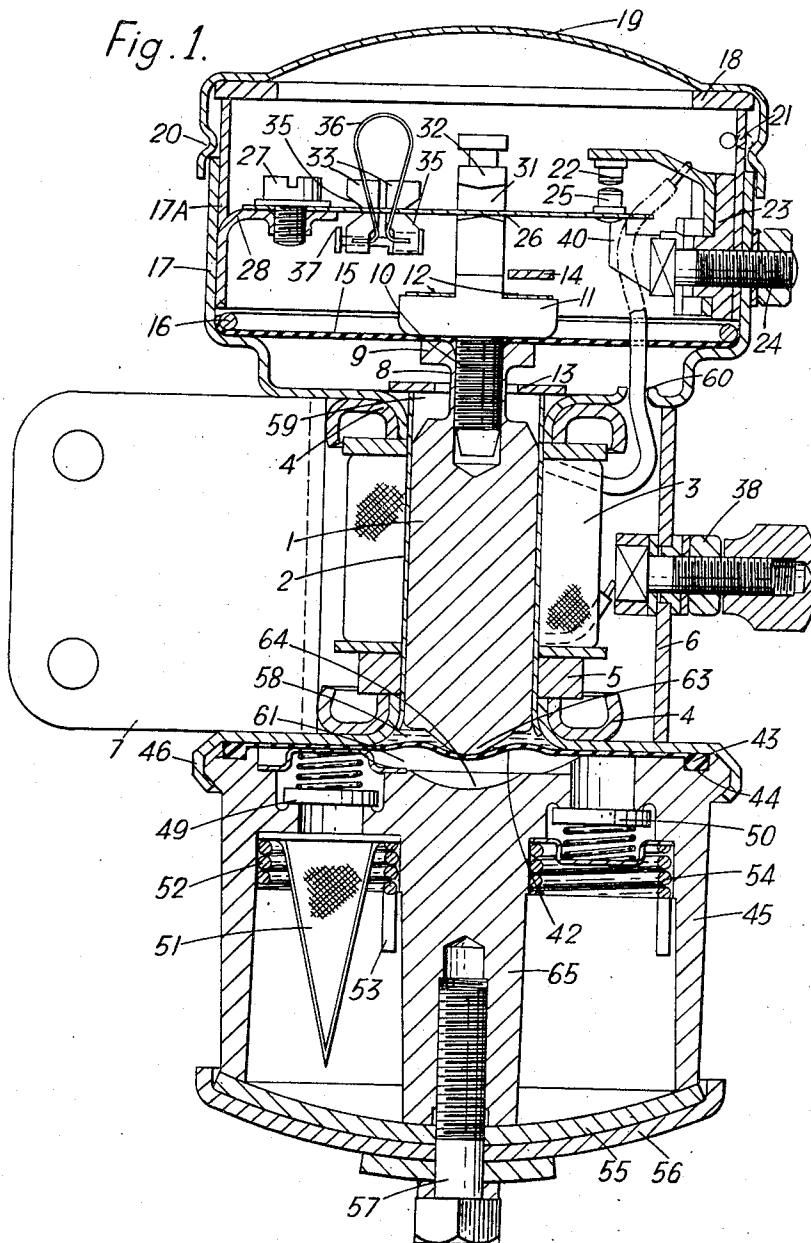
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ELECTRICALLY-OPERATED PUMPS

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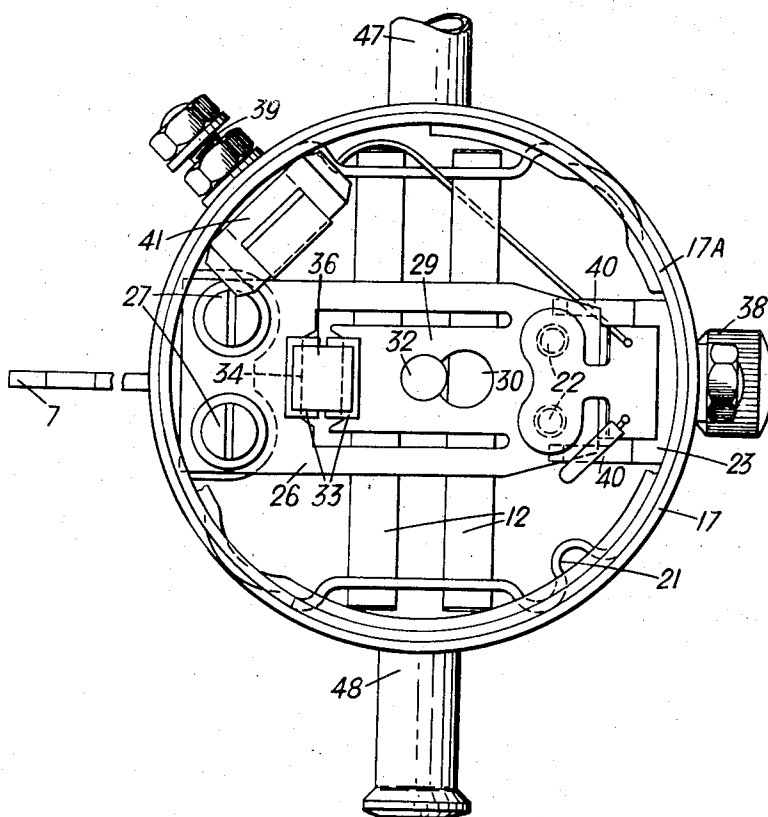
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3 Sheets-Sheet 2

Fig. 2.



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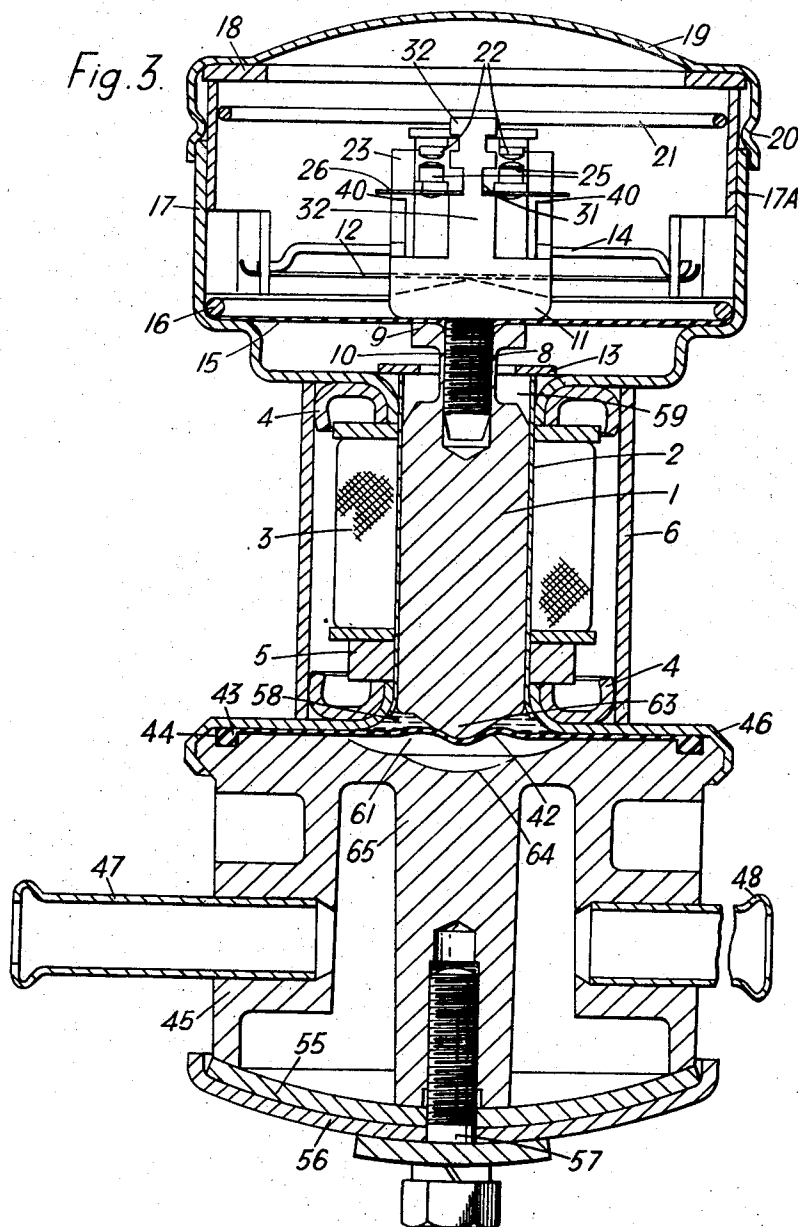
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ELECTRICALLY-OPERATED PUMPS

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3 Claims. (Cl. 103-44)

This invention relates to electrically-operated pumps intended primarily for supplying liquid fuel, such as petrol, to the carburetter or the fuel-injection pump of an internal combustion engine.

One type of electrical fuel pump, which has been used very extensively on motor vehicles for many years, incorporates a flexible diaphragm constituting one boundary of a pump chamber which is fitted with suction and delivery valves, the diaphragm being attached to, and actuated by, a centrally arranged disc-shaped armature of a pot-type electromagnet the energizing circuit of which is controlled by a snap-action contact breaker operated by a push-rod attached to the armature. When the latter has almost reached the end of its movement towards the magnet (and the diaphragm has consequently performed the suction phase) the push-rod opens the contact breaker, and the armature is then moved back by a return spring to effect the delivery stroke of the diaphragm. Just before the armature reaches the end of its return movement the push-rod causes the contact breaker to close again, and the cycle of operations is repeated.

Although the type of fuel pump referred to above has achieved very great commercial success, it suffers economically from the drawback represented by the prevailing high cost of the copper wire needed for the winding of the electromagnet. In order that this important aspect may be fully appreciated, it is opportune to consider the functioning of the diaphragm assembly. The disc-shaped armature may conveniently be regarded as a diaphragm plate, inasmuch as it supports the central zone of the actual diaphragm. If the latter is of an extremely flexible and distensible character, considerable movement can be imparted to the diaphragm plate without any useful result. This is explained by the circumstance that the unsupported zone of the diaphragm merely alters its configuration without effecting any change in the volume of the pump chamber to which it forms one boundary. If, on the other hand, the diaphragm is relatively stiff and nondistensible, then the amplitude over which it is possible to move the diaphragm plate without exerting inconveniently high loading is somewhat unpredictable. Thus a compromise has to be struck as regards the flexibility and distensibility of the diaphragm material, with the result that the volumetric variation of the pump chamber caused by the intrusion and recession of the diaphragm is by no means commensurate with the amplitude of the movement imparted to the diaphragm plate. In consequence the diaphragm plate has to be given a movement of considerable amplitude, so that a correspondingly large air gap for the flux to traverse exists when the diaphragm plate (i. e. the armature) is at the extremity of its recession from the magnet. In order to cater for that unavoidably large air gap the electromagnet has to be constructed so as to provide a considerably greater magnetising force than would otherwise be necessary. This not only involves a greater current consumption, but an increased amount of expensive copper has to be used for the magnet winding.

Another existing type of electrical fuel pump dispenses with a diaphragm and has instead a hollow magnetic plunger which serves as a pump plunger. This is impelled

2

in one direction by a feed spring, and in the opposite direction by the pull exerted by a surrounding solenoid which is energized by the automatic closing of a contact breaker when the plunger reaches the end of its feed stroke. The plunger is then pulled back by the solenoid against the action of the feed spring; a one-way suction valve situated either at the upstream or downstream side of the plunger closes, preventing backward flow of the fuel already drawn forward by the feed stroke of the plunger, and a one-way delivery valve located within the plunger opens so that the plunger is enabled to move back without obstruction. At the end of this stroke the contact breaker is again opened, and a further feed stroke ensues.

The plunger-type pump just described, although attractive by virtue of its simplicity, has two major drawbacks. The first of these arises in this way. Since the fuel is fed during the spring-actuated strokes of the plunger, continuously through the system from the fuel tank to the final delivery point, it follows that the effective feed head at this final delivery point will be equal to the head provided by the action of the plunger and its feed spring, together with the gravitational head from the tank to the final delivery point. For example, if the spring load in conjunction with the effective area of the plunger is such as to provide a feed head of 8 ft. of petrol, then, if the tank is situated 5 ft. below the final supply point (as might happen in the case of a motor vehicle ascending a steep gradient), a pressure head of 3 ft. will be provided at the carburetter. If, however, the vehicle is descending the same steep gradient, then the petrol head which will be imposed at the carburetter will be the 8 ft. head applied by the plunger, with an additional 5 ft. of gravitational head. This will result in a total pressure head applied to the carburetter of 13 ft. which will call for abnormal provision in the carburetter float chamber mechanism to avoid flooding.

A more serious objection to the type of pump under consideration, however, is the very serious filtration problem imposed. The plunger operates with very small clearance within a cylindrical barrel of non-magnetic material. It will be realised that since fresh fuel is constantly passing the plunger, there is liable to arise an accumulation of small solid particles which have passed the filter (normally situated at the upstream side of the pump), and these particles are liable eventually to cause sticking or seizure of the plunger. This liability is greatly aggravated in the case of particles of ferrous material, because any small filament of iron or steel, which is at all times liable to be introduced from the fuel tank, and which it is extremely difficult to intercept with any normal form of fuel filter, will adhere magnetically to the plunger. Eventually the accumulation of such particles becomes sufficient to arrest the free movement of the plunger.

The main object of the present invention is to provide an improved version of an electrical pump of the reciprocating type which, whilst preserving their advantageous attributes, obviates the disadvantages associated with the two existing types of pumps already described. To this end the essence of the present invention is that a plunger, arranged to be reciprocated, within a space vented to atmosphere, by the conjoint effects of spring-loading and an intermittently energised solenoid, has its action communicated by an intervening entrapped body of low-viscosity fluid to a pumping membrane of very high compliance (i. e. of extremely supple character) constituting one boundary of a pumping space through which the liquid is caused to flow under the control of one-way suction and delivery valves actuated in response to the repeated volumetric variations of the pumping space which result from deformation of the pumping membrane due to displacement of the entrapped

body of fluid by the reciprocation of the plunger, and in which the working end of the plunger is formed with a rounded protuberance co-operating with a depression provided in an abutment at the opposite side of the pumping membrane, the arrangement being such that when the plunger is at the extremity of its spring-im-
 5 pelled stroke it indents the pumping membrane to an extent such that the volumetric equivalent of the indentation is at least equal to the volumetric displacement of the plunger per stroke. Preferably, the entrapped body
 10 of low-viscosity fluid is constituted by a liquid having its freezing and boiling points widely separated.

It will at once be apparent that, by means of the invention, the functioning of the plunger cannot possibly be affected by any solid particles which, even after filtration,
 15 may remain entrained in the liquid to be pumped, because this liquid does not have access to the space within which the plunger operates.

An example of a pump in accordance with the invention, intended for use with petrol or other liquid fuel, will now be described with reference to the accompanying
 20 drawings, of which:

Figure 1 is a sectional elevation of the pump;

Figure 2 is a plan view, with the top cover removed; and

Figure 3 is a further sectional elevation, the plane of section being at right angles to that of Figure 1.

The pump illustrated has a plunger 1, made of magnetic material, which is slidably mounted within a thin-walled cylindrical barrel 2 of brass or other non-magnetic material. This barrel, which serves as a guide for the plunger 1, is open at both ends and is surrounded by a
 30 coaxial solenoid 3 provided with a pair of end rings 4 of iron or steel for concentrating the magnetic flux axially through the barrel. An iron washer 5 happens to be shown between the lower end of the solenoid and the bottom ring 4, but this washer was employed solely for convenience in assembling the pump for experimental
 35 purposes. The solenoid assembly is enclosed by a casing 6 which is made as a wrapped around sheet metal part, and which is extended at one side to form an integral mounting plate 7.

The plunger 1 is formed with a neck 8 and a head 9, both of which have an internal screw-thread for receiving a screw 10 which is integral with a button 11 (made, for example, of nylon). Two blade springs 12, acting on the button 11, urge the plunger 1 downwardly. The downward travel of the plunger is limited by engagement of its head 9 with a stop 13, constituted by a slotted
 40 plate fixed to the top of the barrel 2, and the upward travel of the plunger is limited by a stop 14.

Ingress of dust into the barrel 2 is prevented by a flexible membrane 15, of rubber or rubberized fabric, the central zone of which is clamped between the button 11 and the head 9 of the plunger. The membrane 15 is clamped at its periphery by a circlip 16 fitted in a flanged portion of a two-part casing 17, 17A which accommodates the contact breaker. At the top of this casing there is a sealing ring 18 which cooperates with a detachable cover 19. The latter is formed with a rib 20 which
 45 snaps over protruding portions of a wire 21 (see Fig. 2) passed to-and-fro through holes provided in the casing part 17A.

The contact breaker comprises a pair of fixed contacts 22, mounted on a moulding 23 of insulating material which is secured to the casing parts 17, 17A by a bolt 24, and a co-operating pair of movable contacts 25. The latter are mounted at the free end of a cantilever blade spring 26, the other end of which is fixed by screws 27 to a support 28. As can be seen from Figure 2, the blade spring 26 is slotted to form a central tongue 29. This has a keyhole slot 30 the narrower part of which receives a notched portion 31 (Figs. 1 and 3) of a stem 32 which is integral with the button 11. Consequently, as the stem
 50 32 moves up and down with the plunger 1 the resilient

tongue 29 is actuated by the shoulders at the top and bottom of the notched portion 31.

Two nylon blocks 33 (Figs. 1 and 2) are arranged, as shown, in the gap between the tip of the resilient tongue 29 and the neighbouring edge 34 of the slot in the blade spring 26. The blocks 33, which are each formed with a V-shaped notch 35 to engage the respective spring blades, are urged apart by a bow-spring 36. An adjustment screw 37 (Fig. 1) is provided at the lower end of the blocks 33.

Under the influence of their associated spring 36, the blocks 33 exert a toggle-like effect which affords the requisite dwell and snap action in the operation of the contact breaker. When the plunger 1 is at the end of its feed stroke, having been urged downwardly by the springs 12, the toggle device 33, 36 lies tilted to the right as viewed in Figure 1 (i. e. the top of the bow-spring 36 lies nearer the stem 32). In consequence the tip of the spring tongue 29 is deflected downwardly, and the movable contacts 25 engage the fixed contacts 22. When current is supplied by way of the terminals 38 and 39, the solenoid 3 is energised and draws the plunger 1 upwards. The lower shoulder of the notched portion 31 of the stem 32 then deflects the spring tongue 29 upwardly, with the result that the toggle device 33, 36 becomes tilted to the left, as viewed in Figure 1, and deflects the blade spring 26 so that the electrical contacts are separated and the cycle of operations recommences. The moulding 23 has a pair of arms 40 constituting stops for limiting the downward movement of the blade spring 26. The component 41, seen in Figure 2, is the usual condenser associated with the contact breaker.

The pumping of the liquid fuel is effected by a membrane 42 (Figs. 1 and 3) of thin rubber, and of very flexible and distensible character. That is to say, it is of high compliance. This membrane has a peripheral bead 43 which is trapped in a groove 44 formed in the rim of a pumping chamber 45. The peripheral zone of the pumping membrane 42 is clamped between the rim of that chamber and a metal pressing 46 which serves to secure it to the casing 6. The pumping chamber 45, which is fitted with fuel inlet and outlet pipes 47 and 48 respectively, accommodates a suction disc valve 49 (Fig. 1) and a delivery disc valve 50 both of which are spring-loaded. Before the fuel reaches the suction valve it passes through a conical gauze filter 51, which is retained in place by a coiled spring 52. This makes an interference fit in its bore, and is formed with a tail 53 to facilitate insertion and removal of the spring by a "screwing" and "unscrewing" movement respectively. A similar spring 54 is associated with the delivery valve assembly. The pumping chamber is fitted with a sealing washer 55 and a detachable cover 56 secured by a central screw 57.

The space 58 between the upper surface of the central zone of the pumping membrane 42 and the neighbouring end of the plunger 1 is completely filled with a low-viscosity liquid of appropriate nature. That is to say, the liquid in question should have its freezing and boiling points widely separated; should be non-corrosive to the components with which it comes into contact, and should preferably act to some extent as a lubricant. The space 59 between the upper end of the plunger 1 and the associated membrane 15 is vented to atmosphere by way of an aperture 60 (Fig. 1) in the casing part 17, this aperture also serving to enable one end of the solenoid winding to be taken, through a hole in the membrane 15, to the fixed contacts 22. The interior of the casing 6 is open to atmosphere because, as described earlier, this casing is made as a wrapped around part. Accordingly there is a longitudinal gap in it, adjoining the mounting plate 7.

As the plunger 1 rises, there is a corresponding volumetric increment within the space 58. This volumetric increment is exactly reproduced, through the very flexible

5

pumping membrane 42, in the underlying pumping space 61, which therefore increases in volume by a corresponding amount. During this phase fuel is drawn in via the suction valve 49. During the spring-impelled downward stroke of the plunger 1, the space 58 suffers a corresponding volumetric decrement and this, in turn, is reproduced, by way of the pumping membrane 42, as an exactly equal contraction in the pumping space 61, which thereby expels, through the delivery valve 50, the fuel drawn in during the preceding stroke of the plunger.

It will be recalled that the first of the two existing types of pump described earlier suffers from the disadvantage that its diaphragm plate has to be given a considerable amplitude of movement. However, matters are very different in the case of the pump of the present invention. Owing to the fact that the pumping membrane 42 is actuated by the surging motion imparted to a virtually incompressible liquid on one side of it, only a very short stroke of the plunger 1 is needed in order to bring about effective changes in the volume of the adjoining pumping space 61. In consequence, the pump operates with a considerably smaller maximum flux gap than obtains with the type of pump first described. It follows that the improved pump can operate with a much smaller magnetising force, which enables considerable economy to be achieved by reason of the reduction in the ampere-turns of the solenoid winding and in the current consumption.

It might be thought that the improved pump, as so far described, would operate satisfactorily even if the lower end of the plunger 1 were quite remote from the upper surface of the pumping membrane 42 when the plunger was at the end of its downward stroke. This arrangement is not, however, a serviceable one since it is possible for the liquid in the space 58 slowly to percolate or to be forced from that space into the space 59 at the upper end of the plunger 1. Thus, in certain circumstances, the space 58 could become largely emptied of liquid by transference into the space 59, and consequently the pumping membrane 42 would be lying hard up against its upper bounding surface formed by the casing part 46. If it now happened that, simultaneously with this state of affairs, the plunger were at the bottom of its downward stroke and that the solenoid 3 were then to become energised, the plunger would become hydraulically locked and only able to move upwards at a speed which would correspond with a slow return of the liquid from the space 59 to the space 58, under the action of cavitation arising under the lower surface of the plunger, due to the sustained application of the upward magnetic pull on the plunger. Consequently a very slow upward stroke would result during which the pumping action would have ceased. It will be appreciated that this state of affairs could for instance arise in practice if a pressure which was, on the average super-atmospheric were applied to the pumping space 61, and consequently to the space 58, while the pump was switched off. In these circumstances the space 58 would slowly discharge its liquid through the clearance between the plunger and its guide barrel 2 into the space 59, and at the same time the plunger would be maintained, by its feed springs 12, at the lower extremity of its stroke. If, following upon this condition, the pump were switched on, the hydraulic lock as described above would ensue. In order to preclude such an occurrence it is necessary to ensure that, when at the extremity of its spring-impelled stroke, the plunger abuts against and definitely indents the pumping membrane 42, the extent of the indentation of the membrane being such that its volumetric equivalent is at least equal to the volumetric displacement of the plunger per stroke. This is achieved by forming the bottom of the plunger with a rounded protuberance 63, and providing a depression 64 in an abutment part 65 of the pumping chamber 45. As a result, when the pump is again switched on, the pumping membrane 42 under-

6

goes a preliminary re-configuration which enables the plunger to begin at once its initial upward stroke.

When the delivery line of the pump is completely obstructed and when, as a consequence, the pumping space 61 becomes progressively enlarged under the pumping action, the pumping membrane 42 finally assumes a position in which it is capable of supporting the plunger 1. It then brings the plunger permanently to rest (provided, of course, that the suction valve 49 forms a perfect seating) until such time as the delivery line becomes unobstructed. Without this last-mentioned effect, it will be realised that, even when the delivery line were completely closed, the pump would continue to reciprocate slowly due to leakage of the liquid from the space 58 to the space 59 during the spring-impelled strokes of the plunger.

If the liquid referred to above was not provided in the space 58 the pump would still function, although not so effectively, by reason of the alternate compression and rarefaction of the air that would then occupy the space 58. In either case the coupling between the plunger 1 and the pumping membrane 42 is a fluid one, as distinct from a mechanical one. However, a better result is obtained when the fluid is a virtually incompressible liquid than when it is a compressible gas (air).

It should perhaps also be pointed out that other forms of contact breaker may be employed, if desired; for example, a known magnetic device could be substituted for the mechanical toggle device 33, 36.

I claim:

1. An electrically-operated pump for liquids comprising a cylinder mounted in a supporting casing and a free plunger arranged to be reciprocated in said cylinder, one end of the cylinder being vented to atmosphere, spring means carried by said casing and engaging the plunger to move it in one direction and an intermittently energised solenoid supported by said casing and surrounding the plunger to move it in the opposite direction, a supple pumping membrane supported by said casing at the end of the cylinder remote from the vented end thereof and an intervening space between said plunger and pumping membrane filled with an entrapped body of low-viscosity fluid, said pumping membrane constituting one boundary of a pumping chamber provided with an abutment having a central depression at the opposite side of the pumping membrane adapted to be engaged by said membrane at the end of the spring-impelled stroke, and one-way suction and delivery valves communicating with said pumping chamber and actuated in response to the repeated volumetric variations of the pumping space which result from deformation of the pumping membrane due to displacement of the entrapped body of fluid by the reciprocation of the plunger, one end of the plunger directly engaging said pumping membrane in making its working stroke, said end being formed with a rounded protuberance conforming to and cooperating with said central depression formed in said abutment, the arrangement being such that when the plunger is at the extremity of its spring-impelled stroke it indents the pumping membrane to an extent such that the volumetric equivalent of the central depression in said pumping chamber abutment is at least equal to the volumetric displacement of the plunger per stroke.

2. An electrically-operated pump according to claim 1, in which the entrapped body of low-viscosity fluid is constituted by a liquid having its freezing and boiling points widely separated.

3. An electrically-operated pump according to claim 1, in which ingress of dust into the space within which the plunger reciprocates is prevented by means of a flexible membrane mounted in the casing at its periphery and at its center associated with the end of the plunger remote from its working end.

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