

April 21, 1942.

A. HOLLANDER ET AL

2,280,087

PUMPING APPARATUS

Filed April 24, 1940

4 Sheets-Sheet 1

Fig. 1.

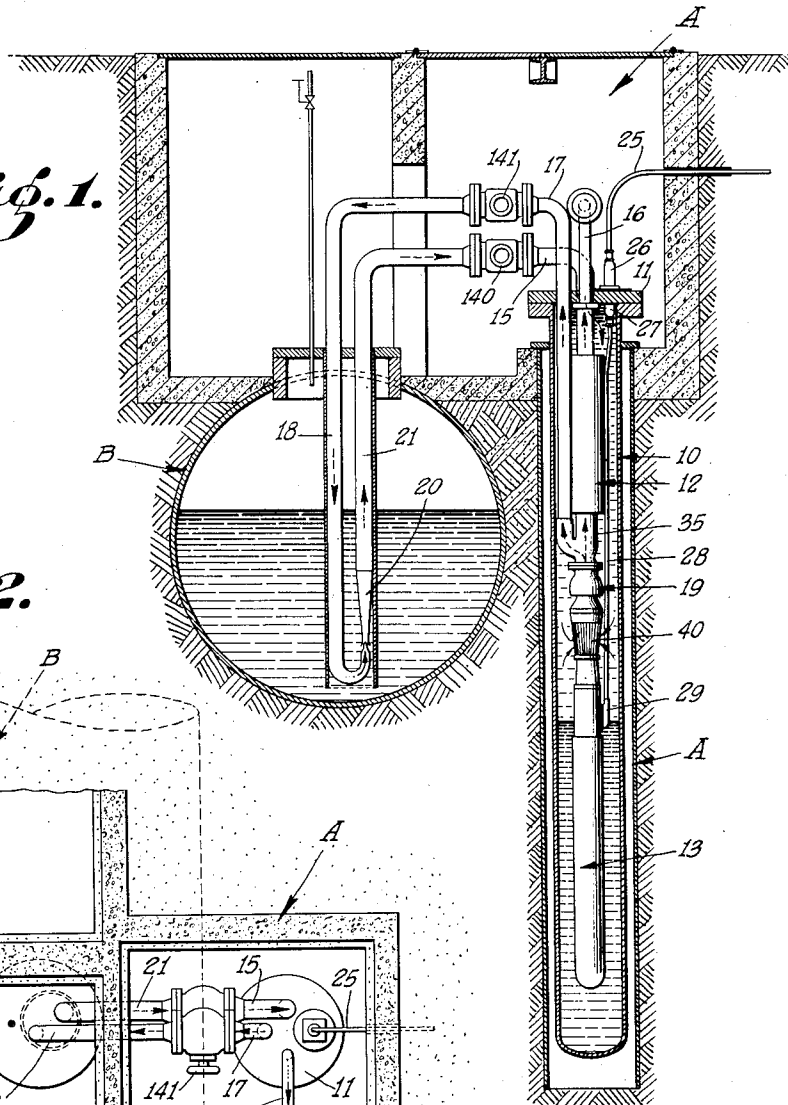
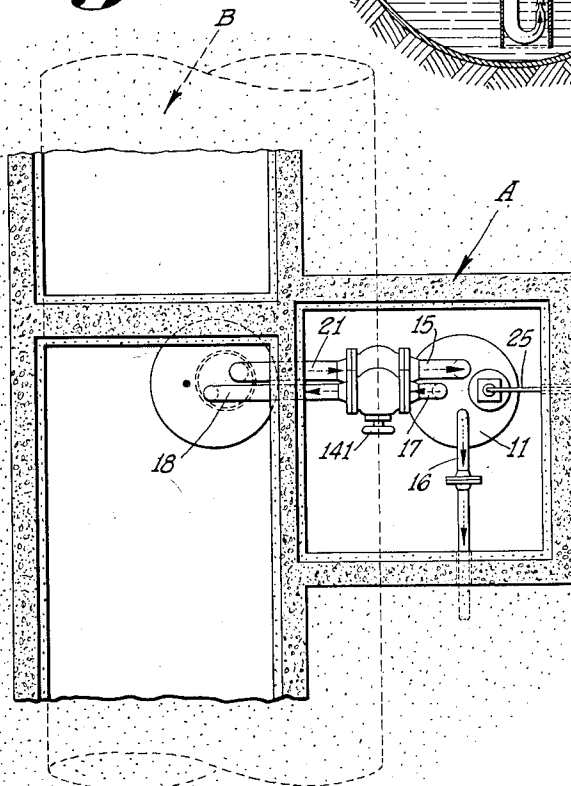


Fig. 2.



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Fig. 3.

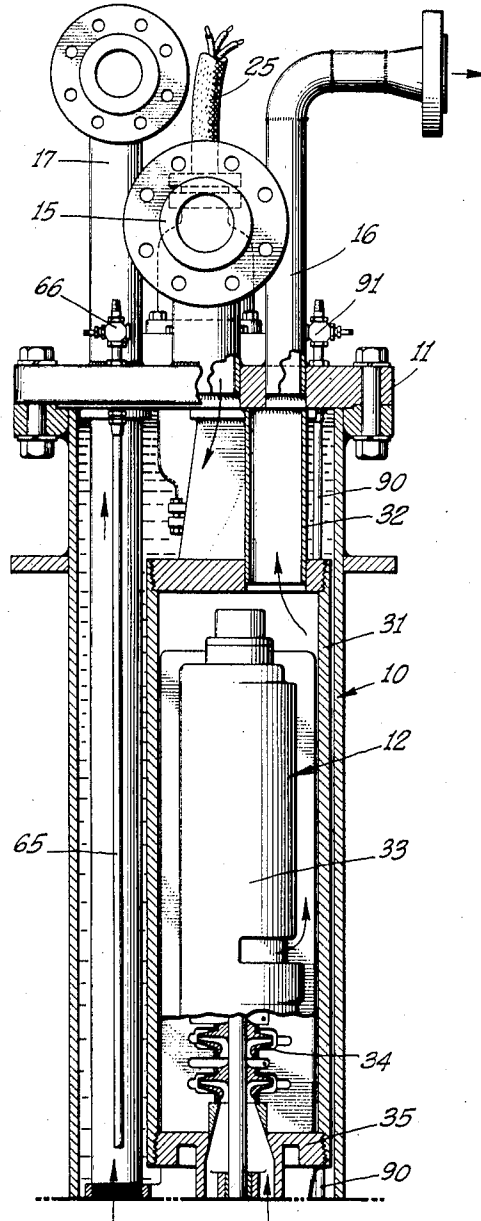
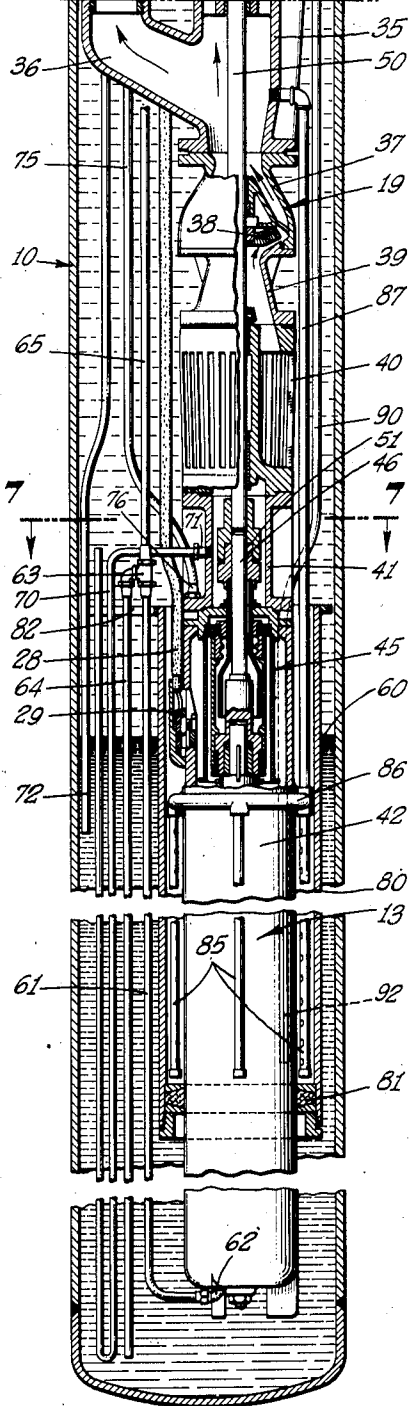


Fig. 3a.

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4 Sheets-Sheet 3

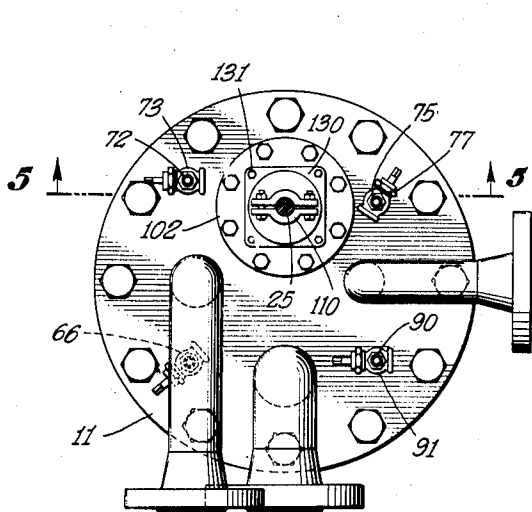


Fig. 4.

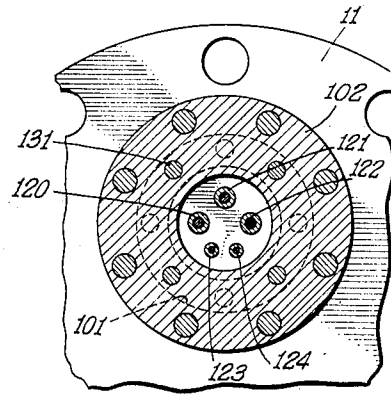


Fig. 6.

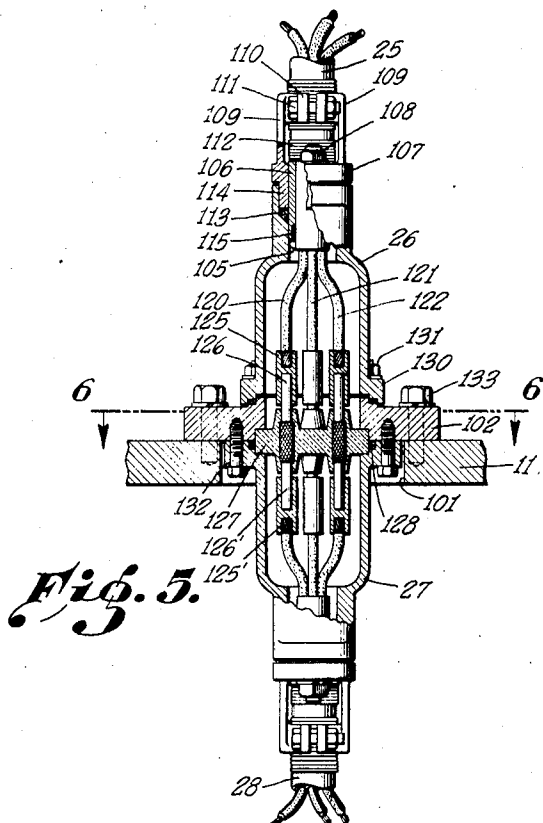


Fig. 5.

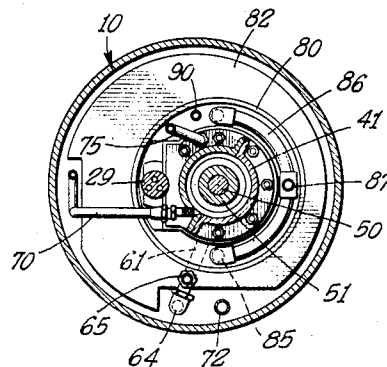


Fig. 7.

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4 Sheets-Sheet 4

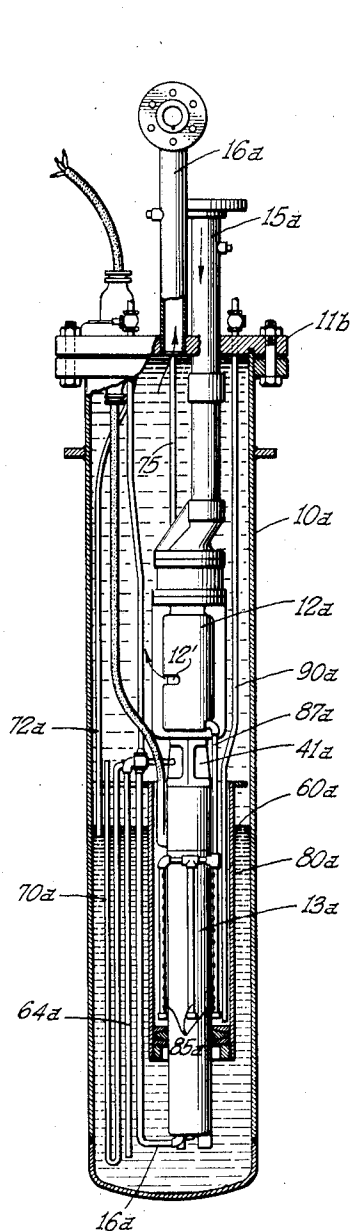


Fig. 8.

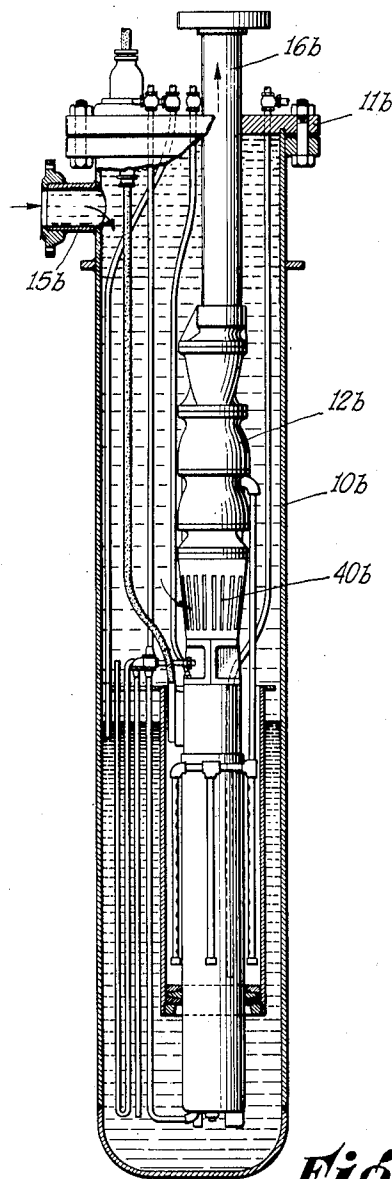


Fig. 9.

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2,280,087

PUMPING APPARATUS

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Application April 24, 1940, Serial No. 331,344

11 Claims. (Cl. 103—5)

This invention relates generally to pumping apparatus, and particularly to apparatus for pumping liquids which must be handled without leakage because of their volatile, poisonous, corrosive, obnoxious, or other characteristic which renders it imperative that leakage of the liquid from the pumping apparatus be reduced to a minimum, and preferably that it be eliminated entirely.

High pressure pumps for handling ordinary, harmless liquids customarily embody a pump shaft projecting from the pump casing, preferably at the suction end thereof, in order to subject the stuffingbox around the shaft to the lowest pressure and thereby minimize leakage of pump liquid from the casing. So far as we are aware, however, no stuffingbox has yet been developed which will maintain an absolute seal during a sustained period of use, particularly against a pressure of substantial magnitude. Many instances may be cited in which the liquid to be pumped is of such a nature that even very slight leakage creates a hazardous condition, as a consequence of which the conventional pumping equipment heretofore available is not suitable for handling such liquids. For example, liquefied petroleum gases such as butane and propane have a vapor pressure considerably higher than atmospheric pressure at normal temperature, and therefore they must be subjected to super-atmospheric pressure in order to maintain them in the liquid phase. Consequently, when pumping such liquids they must be introduced into the suction side of the pump at super-atmospheric pressure. Pumps of the aforementioned type, embodying a stuffingbox about the pump shaft projecting from the suction side of the pump, are not well adapted to such service because of the inevitable leakage of some of the volatile liquid through the stuffingbox. Even slight leakage of such liquids is highly objectionable because of their volatile and explosive nature.

Another service which is incapable of being properly handled by a pump having a stuffingbox about the pump shaft at the suction end of the pump casing, is that of boosting the pressure of a harmful liquid from an initial high pressure to a still higher pressure. Two common examples of this service are that rendered by booster pumps for handling hydrocarbons, acids, etc., in oil refineries, and by booster stations in long pipe lines for transporting crude oil from producing oil fields to refineries or for transporting gasoline or other refinery products from refineries to distribution centers. In this case,

as in that previously discussed with reference to propane and butane, the liquid enters the pump at relatively high suction pressure, and, so long as stuffingboxes are relied on to seal the shaft openings in the pump casing, some leakage will inevitably occur.

Many industrial processes involve pumping liquids of a corrosive, poisonous, or obnoxious nature under conditions which are such that stuffingboxes cannot be relied on to prevent leakage, even though high pressures are not encountered. For example, many industrial solutions are what are known as "fugitive liquids"—i. e., they cannot be confined by stuffingboxes even at low pressure because of their unusually low surface tension or other uncommon physical property.

Various prior attempts have been made to overcome the difficulties enumerated above. Stuffingboxes have been improved somewhat, but only to the extent of reducing but not eliminating the inevitable leakage. Oil seals and other complicated auxiliary devices for use with stuffing boxes have been tried but have not proven satisfactory. In an endeavor to avoid the necessity of a stuffing box, it has previously been proposed to encase both the pump and an electric motor in a single housing which is completely filled with pump liquid. Inasmuch as the motor must operate immersed in the pump liquid, successful operation of such a unit is limited, however, to those cases in which the liquid being pumped is not only a good lubricant but also has good dielectric properties and is otherwise harmless to the motor. The scope of application of such a unit is thus so limited as to render it of only negligible commercial value.

In a further attempt to widen the scope of usefulness of a unit such as that discussed in the preceding paragraph, it has also been proposed to fill the motor housing of such a unit with an inert gas or, alternatively, with a dielectric liquid. Gas-filled motors, however, present additional problems of heat transfer and of bearing lubrication and consequently are less desirable than oil-filled motors. Prior attempts to avoid the use of a stuffingbox by enclosing an oil-filled motor and a pump in a single casing filled with pump liquid, have been limited to those cases where the pumped liquid is not readily miscible with the oil or other dielectric liquid contained in the motor housing. If the two liquids are miscible, a progressive molecular interchange inevitably occurs in the zone of contact of the two liquids, resulting in contamina-

tion of the pump liquid with dielectric liquid and dilution of the latter with pump liquid. For the foregoing reasons, this solution of the problem is inapplicable to the pumping of hydrocarbons such as gasoline, butane, propane, etc., which are readily miscible with the dielectric in common use. Inasmuch as hydrocarbons constitute a substantial percentage of the liquids which present a difficult problem of sealing with a stuffing box, the foregoing expedient falls far short of providing an adequate and universally applicable solution of the problem.

This invention has as its principal object the provision of a system and apparatus for pumping liquids, characterized by the elimination of all stuffing boxes and the consequent prevention of any leakage whatsoever of pump liquid from the apparatus.

A further object is to provide a pumping apparatus which is capable of handling, without leakage, a wide variety of liquids which cannot be handled by conventional pumps equipped with stuffing boxes, and which is particularly adapted to handling highly volatile liquids such as gasoline, butane and propane.

The invention in its broader aspects contemplates the complete enclosure of the pump and of an oil-filled, pressure-balanced, submersible electric motor within a fluid-tight casing which is adapted to be substantially filled with the liquid being pumped, either at suction or discharge pressure. The apparatus is rendered universally applicable to the pumping of a wide variety of liquids, irrespective of their miscibility with oil or other dielectric liquids, by completely isolating the pumped liquid from the dielectric liquid contained in the motor housing.

A still further object of this invention is to provide pumping apparatus of the type wherein a pump and a direct-connected electric motor are encased in a fluid-tight vessel through which the pump liquid flows, and wherein the motor is completely isolated from the pump liquid by being enclosed within a housing which is filled with a dielectric liquid, the pump-liquid and the dielectric liquid being in turn isolated from each other by a liquid seal surrounding the motor shaft at its juncture with the motor housing.

A still further object of the invention is to provide pumping apparatus of the type set forth in the preceding paragraph, wherein the dielectric within the motor housing is subjected to the pressure of the pump liquid within the outer vessel, thus eliminating the necessity of a stuffing box about the juncture of the motor shaft and the motor casing.

Provision must also be made in oil-filled, pressure-balanced submersible motors for enabling the motor to "breathe"—that is, to provide for the expansion of the dielectric liquid due to rise of temperature during the operation of the motor, and the corresponding contraction of the dielectric liquid as it cools down when the motor is stopped. During expansion of the dielectric liquid, a portion thereof is necessarily displaced from the motor housing, and is returned to the housing upon subsequent contraction. In order to maintain the aforementioned isolation of the pump liquid from the dielectric liquid while at the same time permitting the motor to "breathe," the invention contemplates the interposition of a body of a third liquid between the pump liquid and the dielectric liquid, the third liquid being immiscible with both of the other liquids. In

this manner, while open communication is established between the interior of the motor housing and the interior of the outer vessel, the dielectric liquid and the pump liquid are prevented from directly contacting each other by the interposed third liquid.

A still further object of the invention is to provide pumping apparatus of the type wherein a pump and a motor are encased in a fluid-tight pressure vessel through which the pump liquid flows, and the housing of the motor contains a dielectric liquid, and wherein the dielectric liquid within the motor housing is in pressure transfer relation to the pump liquid at each end of the motor housing but is isolated from the pump liquid by separate bodies of intermediate liquids, one of which surrounds the motor shaft at its juncture with the motor housing and the other body of intermediate liquid being interposed between quiescent bodies of pump liquid and dielectric liquid.

In a preferred embodiment of the invention the outer vessel is an elongated cylinder adapted to be mounted in an upright position, with the major portion of the vessel disposed within an underground shaft or pit, and having suction and discharge nozzles for pump liquid adjacent its upper end. The pump and direct-connected motor are mounted within the outer vessel with the pump suspended from a removable cover plate enclosing the upper end of the vessel, and the motor is suspended beneath the pump. Under these circumstances the motor is not mounted directly in the path of flow of the pump liquid through the outer vessel, and hence is deprived of the cooling effect of the moving stream of pump liquid. A further object of the invention is to provide means for cooling the motor, preferably by by-passing a small proportion of the pump liquid in heat-exchange relationship with the motor housing.

A still further object of the invention is to provide a unit of the aforementioned type wherein the pump and motor and its accessories are assembled as a unit independently of the outer vessel. In a preferred embodiment, this object is attained by suspending the pump and its motor from the under side of the cover plate of the outer vessel, the power leads for the motor and the auxiliary piping being also attached to the cover plate. In this manner the outer vessel performs the sole function of a liquid container, and all of the operative parts of the unit may be assembled prior to insertion into the vessel, and may be removed as a unit for inspection and repair simply by detaching the cover plate from the outer vessel.

As previously mentioned, one of the principal objects of this invention is the provision of apparatus particularly adapted for pumping butane and propane and other liquids having a vapor pressure greater than atmospheric pressure. For obvious reasons, the handling of such liquids involves various problems not encountered when handling liquids which remain in the liquid phase at atmospheric pressure. For example, a vessel such as the outer vessel in the instant case, when filled with gasoline, may be vented to the atmosphere and will remain full, whereas if it were filled with butane or propane and vented to the atmosphere it would blow itself empty. If evaporation occurs within the vessel, the cooling effect would be such as to lower the temperature within the vessel to such a low degree as to have a detrimental effect on the equipment with-

in the container. If an intermediate liquid is employed as mentioned above, there is the possibility that the temperature may be lowered below the freezing point of the intermediate liquid. A still further object of this invention is to provide pumping apparatus of the type discussed above, which is especially adapted to handle liquids having super-atmospheric vapor pressure, and in which provision is made for venting the outer vessel without materially lowering the temperature therein.

A still further object is to provide pumping apparatus of the aforementioned type having a novel and improved means for electrically connecting the motor within the outer vessel to an external source of electrical energy. A more specific object aims to provide a construction whereby the electrical conductor cable is divided into two sections—an inner section within the pressure vessel and subjected to the pressure of the pump liquid, and an outer section under atmospheric pressure—the two sections being separable from each other while the vessel is maintained under pressure. Such an arrangement renders possible the disconnection and replacement of the outer section of conductor cable without venting the pressure vessel or otherwise disturbing the equipment within the vessel. A still further object is to provide a connection between the above-mentioned cable sections and the removable cover plate of the outer vessel, which permits the assembly of the cable sections as a unit before attaching them to the cover plate.

A still further object of this invention is to provide novel means for transferring pump liquid from a storage tank or other container to the pressure vessel of the pumping apparatus. Loading and distributing stations for liquefied petroleum gases such as butane and propane are usually equipped with underground storage tanks. This creates a problem of transferring the butane or propane from the storage tank to the pumping apparatus while maintaining it under sufficient pressure to prevent vaporization. Our novel pumping apparatus embodies simple and effective auxiliary pumping means which constitutes an improvement over prior devices for this purpose.

Other objects and advantages will be apparent from the following detailed description of one embodiment of the invention, reference being had to the accompanying drawings wherein:

Fig. 1 is a vertical sectional view illustrating the application of our novel pumping apparatus to a loading or distributing station;

Fig. 2 is a top plan view of the installation illustrated in Fig. 1;

Fig. 3 is an enlarged view, partly in elevation and partly in vertical section, of the lower portion of the pumping apparatus shown schematically in Fig. 1;

Fig. 3^a is a view similar to Fig. 3, showing the upper portion of the pumping apparatus;

Fig. 4 is an enlarged top plan view of the pumping apparatus;

Fig. 5 is a vertical sectional view taken on line 5—5 of Fig. 4;

Fig. 6 is a transverse sectional view taken on line 6—6 of Fig. 5;

Fig. 7 is a transverse sectional view taken on line 7—7 of Fig. 3;

Fig. 8 is a longitudinal sectional view corresponding to Figs. 3 and 3^a but showing a modified construction; and

Fig. 9 is a view similar to Fig. 8 and showing a still further modification.

Referring to Figs. 1 and 2, we have shown our novel pumping apparatus, generally designated A, as installed in a loading or distributing station particularly adapted for handling butane and propane. It will be understood, of course, that this is solely for illustrative purposes and that the pumping apparatus is adaptable to a wide field of uses. In the illustrative embodiment, the pumping apparatus is connected by suitable piping to an underground storage tank B, and is adapted to dispense liquid from the tank to containers such as the fuel tanks of motor vehicles, drums or other containers for liquefied petroleum gas for domestic use, etc.

The pumping apparatus comprises generally an outer pressure vessel or barrel 10 having a closed lower end and a removable cover plate 11 at its upper end, a pump assembly 12 suspended from the under side of the cover plate, and an electric motor 13 suspended from the lower end of the pump assembly and having its rotor operatively connected with the pump impellers. When the cover plate 11 is attached to the barrel, the latter forms a fluid-tight chamber which is completely sealed except for a suction nozzle 15 and a discharge nozzle 16. In the illustrated embodiment an auxiliary discharge nozzle 17 is also provided, to connect an auxiliary pump 19 with a discharge line 18 leading to an ejector 20 mounted in the lower portion of the storage tank B. The ejector forces the liquid from the tank through the suction line 21 and into the barrel 10, the latter being thus maintained full of pump liquid at a pressure greater than the vapor pressure of the pump liquid, and serving as a reservoir in which the suction of the pump is submerged.

A conductor cable 25 leads from a suitable starting box and control panel (not shown) to an outer pothead section 26 mounted on the barrel cover plate 11, the pothead having suitable terminals connected to a second pothead section 27 secured to the under side of the cover plate. A second section of cable 28 extends from the pothead 27 to a terminal box 29 connected to the housing of the motor 13. The detailed construction of the potheads 26 and 27 will be described more fully hereinafter.

Referring now to Figs. 3 and 3^a, it will be observed that the main pump 12 is a double-case multistage centrifugal pump of well-known construction, and a detailed description thereof is not believed to be necessary. It will suffice to state that the pump comprises generally an outer casing 31 suspended from the cover plate 11 by a short section of discharge pipe 32 secured to the cover plate in alignment with the discharge nozzle 16, and an axially split inner impeller case 33 mounted in the outer casing in spaced relation to the inner wall of the latter, thus forming an annular discharge space between the casings into which the pump liquid is discharged from the inner case. A plurality of impellers 34 are rotatably mounted in impeller cavities in the inner case 33. For a detailed description of the construction of the inner case, reference may be had to U. S. Letters Patent No. 1,997,824, to Aladar Hollander, dated April 16, 1935.

A branch fitting 35 is secured to the lower end of the outer casing 31 of the main pump 12, and provides a main discharge passage extending from the auxiliary pump 19 to the suction inlet of the pump 12, and a branch discharge passage 36 communicating with the nozzle of the ejector 20 through nozzle 17 and pipe 18. It will be observed that the pump 19 is a single stage deep-

well centrifugal pump comprising a bowl 37, an impeller 38, and a suction piece 39. Suspended from the lower extremity of the suction piece is a strainer 40 which establishes communication between the suction inlet of the pump 19 and the interior of the outer barrel 10. An adapter 41 is secured to the lower end of the strainer 40 and has supporting connection at its lower end with the housing 42 of the motor 13.

The motor 13 is preferably an oil-filled, pressure-balanced submersible motor having a liquid seal, generally designated 45, sealing the juncture of the rotor shaft 46 and the motor housing 42. The detailed construction of the motor and of the liquid seal may be similar to that disclosed in our Patent No. 2,171,749, dated September 5, 1939, for Submersible motor assembly, although it will be appreciated that considerable variation in the construction of the motor is permissible so long as the essential features of this type of motor are retained.

As shown most clearly in Fig. 3, the upper end of the rotor shaft is connected in driving relation with the pump shaft 50 by a shaft coupling 51 within the adapter 41. The pump shaft extends upwardly through the strainer 40, auxiliary pump 19, and impeller case 33 of the double-case pump 12, and has keyed thereto both the impeller 38 of the auxiliary pump and the impellers 34 of the pump 12. The motor 13 thus drives both pumps, and by reason of the branch fitting 35 the single stage pump 19 performs the dual function of supplying pump liquid to the ejector 20 in the storage tank B, and of delivering pump liquid to the first stage of the multistage pump 12 at a positive pressure which is determined by the back pressure at the ejector nozzle.

The provision of the ejector 20 is occasioned by the fact that safety regulations require that piping connections between an underground storage tank and an underground dispensing receiver be connected to the top rather than to the base of the tank and receiver, thus requiring the pump liquid to be elevated a substantial distance while being transferred from the tank to a receiver on the same level as the tank. If the pump liquid is one having a vapor pressure greater than atmospheric pressure, the tank is maintained closed and the pressure within the tank is normally the vapor pressure of the liquid. Consequently, any reduction in pressure resulting from friction loss in the transfer pipe or due to the higher elevation of the transfer pipe is likely to cause vaporization of the pump liquid in the transfer pipe. By providing an ejector in the tank, however, the normal pressure of the liquid is increased by an amount at least sufficient to offset the above losses, and vaporization is avoided.

It will no doubt occur to those familiar with this art that it would be possible to by-pass a portion of the discharge from the main pump 12 back to the ejector 20 to accomplish the same purpose. Such an arrangement, while feasible, would result in a considerable loss of efficiency of the unit, for the following reasons: the efficiency of a liquid-actuated ejector is relatively low, even under the most favorable conditions, and reaches a maximum efficiency of approximately 33% when the pressures of the actuating liquid and the discharged liquid are in the ratio of approximately 2.5 to 1. Under these conditions the ratio of the volumes of the two liquids is approximately 1.4 to 1. If the pressure ratio is increased to 10 to 1, the efficiency of the ejector drops to about 10%. It will thus be

seen that a considerable loss of efficiency is entailed by bleeding off a portion of the discharge of a high-pressure pump to operate an ejector when only a relatively low pressure need be developed by the ejector.

In the instant case, the auxiliary pump 19 serves a dual purpose—that of a preliminary stage of the multistage main pump 12, and of supplying actuating liquid to the ejector 20, and hence it must be of greater volume capacity than the main pump. In an actual installation corresponding to that shown in Figs. 1 to 7 of the accompanying drawings, the loss of head in the ejector discharge pipe 21 is approximately 18 feet, and hence it was necessary to provide an ejector which would develop that pressure while transferring a volume of pump liquid equal to that delivered by the main pump 12. In order to obtain the maximum efficiency from the ejector, the pressure of the actuating liquid should be approximately two and one-half times the pressure to be developed by the ejector, or about 45 feet. Under these conditions, with an efficiency of approximately 33%, the volume of actuating liquid delivered by the auxiliary pump 19 to the ejector is approximately 1.4 times the volume of liquid transferred by the ejector from the tank to the receiver. In the aforementioned installation the main pump 12 delivered 25 gallons per minute against a head of 400 feet, and the auxiliary pump 19 delivered a total volume of 60 gallons per minute—25 gallons per minute to the suction inlet of the main pump and 35 gallons per minute (25×1.4) to the ejector—against a head of 45 feet.

On the other hand, if liquid were by-passed from the discharge of the main pump, at a pressure of 400 feet, to develop a head of 18 feet in the ejector, the efficiency of the ejector would be of the order of 10%, and approximately half the discharge from the main pump would have to be by-passed to the ejector. This would require the use of a pump of double the capacity of that in the instant case, and would greatly increase the consumption of power since the overall efficiency of the unit would be cut in half. It will be apparent that by the provision of a separate pump delivering actuating liquid to the ejector at relatively low pressure, material economies may be effected, both in operating expense and in the size and cost of the equipment. In the instant case, we have provided a simple and effective arrangement whereby the low pressure pump is driven by the same shaft that drives the main pump, and also serves as an initial stage of the main pump.

It will be understood that the foregoing figures are cited solely by way of example and to illustrate the manner in which the required capacity and head of the auxiliary pump is ascertained from a predetermined loss of head in the transfer pipe 21 and a predetermined capacity and head of the main pump.

As stated in the introductory remarks, an important feature of the invention which renders it especially well adapted to handling butane and propane is the complete isolation of the pump liquid from the dielectric liquid within the motor housing 42. The mercury seal 45 which surrounds the rotor shaft at its juncture with the upper end of the housing effectively separates the two liquids at that point. However, a liquid seal will function in a satisfactory manner only if the pressures on opposite sides of the seal are balanced, thus necessitating a pressure-equalizing

connection between the two liquids. If the two liquids are immiscible, it has been found that this can be accomplished satisfactorily by the provision of a breather opening in the lower end of the motor housing establishing communication between the external and internal liquids in a quiescent zone of both liquids. If the pump liquid is miscible with the dielectric, however, it is essential that direct contact between the two liquids be entirely avoided, even in a quiescent zone, in order to prevent intermixing by molecular interchange at the interface or surface of contact between the two liquids.

In the present instance, the lower end of the motor housing 42 is in open communication with the outer barrel 10, but direct contact between the dielectric liquid in the motor housing and the pump liquid in the barrel is avoided by interposing a body of a third liquid between them. The third liquid may be any liquid which is immiscible with the pump liquid and the dielectric liquid and which is preferably heavier than both liquids. If the pump liquid is a hydrocarbon, such as butane, propane, or gasoline, and the dielectric is a pure crystal oil, as is generally the case, water may be used as the third liquid. If temperatures below the freezing point of water are likely to be encountered, an "anti-freeze" solution such as diphenyl glycol may be used instead of water.

Referring to Fig. 3 of the drawings, the lower portion of the outer barrel 10 contains water or other suitable intermediate liquid up to the level indicated at 60. This level is preferably adjacent the upper end of the motor housing, but is a sufficient distance below the strainer 40 to be unaffected by the stream of pump liquid flowing downwardly within the barrel from the suction nozzle 15 at the upper end thereof and into the strainer. A breather or balance tube 61 is connected at 62 to the lower end of the motor housing and extends upwardly to a point slightly above the upper end of the housing, at which point it is connected to a T 63. The leg of the T extends downwardly at 64 and terminates adjacent the lower end of the barrel 10 in an open end immersed in the body of intermediate liquid. A third branch line 65 extends from the T 63 upwardly within the barrel and through the cover plate 11 to a valve 66, to which additional piping may be connected for filling the upper branch line 65 when the unit is first installed.

The two tubes 61 and 64 thus form an inverted U-tube which is open to the intermediate liquid at one end and to the dielectric liquid in the motor housing at the other end. Inasmuch as the surface of the intermediate liquid at 60 is in direct contact with the pump liquid, the pressure of the latter is communicated directly to the intermediate liquid and through the U-tube to the dielectric liquid. When the motor is idle, the dielectric liquid fills the tube 61 and the upper portion of the tube 64, the remaining portion of the latter being filled with intermediate liquid. When the motor is energized its temperature rises causing the dielectric liquid in the motor housing to expand and force intermediate liquid downwardly within the tube 64. The expansion of the dielectric liquid occurs at such a slow rate, however, that the pressure balance is not disturbed.

As a further precautionary measure to assure that abrupt changes in the pressure of the pump liquid within the barrel 10, such as may occur when starting or stopping the unit, will not temporarily unbalance the mercury seal, a balance

tube 70 is connected at 71 to the adapter 41 between the motor housing and the strainer 40, and extends downwardly to the level of the lower end of the tube 64 and then upwardly to approximately the level of the T 63. The interior of the adapter, which communicates directly with the outer side of the mercury seal 45 is thus open to the pump liquid in the barrel 10 through a U-tube consisting of piping of the same size and length as the U-tube 61, 64. The frictional resistance to flow of fluid from the barrel through the U-tube 70 and into the adapter 41 is thus equal to the frictional resistance offered by the tubes 61, 64. Consequently, any abrupt change in pressure in the barrel will be communicated through the two U-tubes to the opposite sides of the mercury seal at equal rates. If the U-tube 70 were omitted and the interior of the adapter were in direct communication with the pump liquid in the barrel, any sudden change in the pressure of the pump liquid would be transmitted to the external side of the mercury seal immediately, while the transmittal of the pressure change to the dielectric liquid in the motor housing and thence to the internal side of the seal would be delayed by the friction drop in the U-tube 61, 64. As a result, the seal would be temporarily unbalanced, possibly resulting in displacing the mercury sufficiently to break the seal. The provision of the tube 70, however, avoids the possibility of unbalancing the seal by sudden pressure changes.

In order to establish and maintain the level of the intermediate liquid at approximately the height indicated at 60, a control line 72 is provided. This line is open at its lower end and extends from a point slightly below the normal level of the intermediate liquid upwardly through the cover plate 11 to a shut-off valve 73 (Fig. 4). A make-up line may extend from the valve to a source of intermediate liquid (not shown). During operation of the unit, there should be no appreciable change in the level of the intermediate liquid, provided it is immiscible with the pump liquid. However, the level may be checked periodically by opening the valve 73 and allowing the pressure of the pump liquid to force intermediate liquid upwardly through the pipe 72. When the level of the intermediate liquid has been lowered to that of the lower end of the pipe, pump liquid will enter the pipe and may be detected at the point of venting. After having established the level of the intermediate liquid at the lower extremity of the pipe 72, a small quantity of intermediate liquid may be added to raise the level slightly above the end of the pipe, such as to the level indicated at 60 in Fig. 3.

On oil filler line 75 is also provided for supplying oil or other dielectric liquid to the interior of the motor housing. This line is preferably connected to the upper end of the motor housing, as at 76, and extends upwardly through the cover plate 11 to a shut-off valve 77 (Fig. 4), and thence to a suitable source of dielectric liquid (not shown).

It will be apparent from an inspection of Figs. 3 and 3a that the motor 13 is located in a quiescent body of liquid outside the path of flow of pump liquid through the barrel 10, and hence the main stream of pump liquid cannot be utilized to dissipate the heat generated by the motor windings. Special means must therefore be provided for cooling the motor. In the present instance this is accomplished by by-passing a small amount of pump liquid in heat-exchange relationship with the motor housing. It will be ob-

served that the major portion of the motor housing is disposed below the level 60 of the intermediate liquid. In order to provide an open system of circulation of pump liquid about the motor housing and at the same time avoid intermixing of the two liquids, a jacket 80 is provided about the motor housing. The lower end of the jacket has fluid-tight engagement with the wall of the housing as by means of packing 81, and the upper end of the jacket is open and projects a substantial distance above the level 60 of the intermediate liquid, thereby forming an annular channel about the motor housing in open communication with the pump liquid in the outer barrel but sealed off from the intermediate liquid. An annular baffle plate 82 is secured to the upper extremity of the jacket 80 and bridges the annular space between the motor housing and the inner wall of the outer barrel 10 at a point a slight distance above the level 60 of the intermediate liquid, to form a barrier against eddy currents in the pump liquid and thereby provide a quiescent zone at the level 60.

Cooling of the motor housing is effected by spraying pump liquid onto the motor housing over a substantial area thereof from a plurality of perforated pipes 85 suspended from an arcuate header 86 partially surrounding the motor housing. Pump liquid is supplied to the header through a pipe 87 connected to the pumping unit at any desired point above the single stage pump 19. The branch fitting 35 forms a convenient point from which to by-pass the cooling liquid at one-stage pressure. By this construction a small volume of pump liquid is continually sprayed over the motor housing and is returned to the outer barrel through the jacket 80.

Reference has previously been made to the fact that volatile liquids such as butane and propane, having a vapor pressure greater than atmospheric pressure, must be subjected to superatmospheric pressure at all times in order to maintain them in their liquid phase. In a storage and transfer unit such as that illustrated and described herein, the pump liquid is maintained at superatmospheric pressure throughout the system not only when the unit is in operation but also while it is idle, and consequently no evaporation of the pump liquid can occur. It may become necessary or desirable, however, to remove the pumping unit from the outer barrel for inspection or repair, and in such event the pressure within the barrel must obviously be reduced to atmospheric, causing any pump liquid within the barrel to vaporize when the pressure drops below the vapor pressure of the liquid. If the entire volume of pump liquid in the barrel were permitted to vaporize within the barrel, the resulting drop in temperature would be such as might have a deleterious effect on the equipment, and if water were used as the intermediate liquid it would be frozen.

In the present instance, provision has been made for venting the pump liquid from the barrel from the lowest level of the pump liquid, thereby enabling the unit to blow itself empty of pump liquid and causing the vaporization of all except a small amount of pump liquid to occur outside the barrel. A blow-off line 90 extends from an external shut-off valve 91 through the cover plate 11 and downwardly within the barrel and within the cooling jacket 80 and terminates adjacent the bottom of the cooling reservoir formed by the jacket, as indicated at 92 in Fig. 3. It will be apparent that upon opening the valve 91, the pump liquid will be forced from the barrel

by its own pressure, and that only a relatively small amount of pump liquid will vaporize within the barrel to maintain the pressure at the vapor pressure of the liquid until it has been blown down to the level of the lower end of the blow-off line. The pump liquid within the annular space between the baffle 82 and the surface 60 of the intermediate liquid may be blown off in its liquid phase by opening the valve 74 and first blowing off intermediate liquid until the level of the latter is reduced to the lower end of the level control line 72, and thereafter pump liquid will be blown from the line 72. If desired, the barrel may be blown down simultaneously through lines 72 and 90 until vapor issued from one line.

Referring now to the electrical connections to the motor 13, it has previously been observed that these connections comprise an outer cable section 25, and inner cable section 28, a pair of outer and inner pothead sections 26 and 27 interconnecting the two cable sections, and a motor terminal box 29 connecting the inner cable section 28 to the motor housing. As most clearly shown in Figs. 5 and 6, the cover plate 11 is provided with a circular opening 101, which is of sufficient size to permit the insertion of the motor terminal box 29 (Fig. 7) and of the inner pothead section 27 (Fig. 5). The two pothead sections 26 and 27, which are preferably of identical construction, are bolted to opposite sides of a connector plate 102 which in turn is bolted to the outer face of the cover plate 11. In this manner the two cable sections may be secured to their individual pothead sections and the latter may be electrically interconnected and structurally assembled on the connector plate 102 prior to assembly on the cover plate. Thereafter the terminal box 29, inner cable section 28, and inner pothead section 27 may be inserted through the opening 101 in the cover plate and secured in place by bolting the connector plate to the cover plate. The terminal box 29 may then be attached to the motor housing. It will be understood that the entire pumping unit including the pump, motor, and the various auxiliary control lines, is assembled on the cover plate before it is inserted in the outer barrel, and the foregoing arrangement enables the electrical conductors to be made up as a complete sub-assembly prior to being attached to the pumping unit.

Inasmuch as the two pothead sections are identical, a detailed description of one will suffice. As most clearly shown in Fig. 5, the section 26 comprises a hollow cylindrical housing member having a reduced bore 105 at its upper extremity. An adapter sleeve 106 is mounted in the bore 105 with a close sliding fit, and has snug engagement with the cable 25 extending therethrough. By the selection of an adapter sleeve of proper internal diameter, various sizes of cable may be attached to a standard pothead section. The cable is rigidly clamped to the pothead by a clamping member 107 secured to the pothead as by bolts 108 and having formed integral therewith a pair of upstanding arms 109 and a diametrically split clamping sleeve 110 embracing the cable. The two halves of the sleeve are adapted to be drawn together by bolts, as at 111, to thereby grip the cable and secure it firmly to the pothead. A wrapping of soft iron wire 112 is preferably wound about the cable in the region of the clamping sleeve 110, to prevent injury of the outer fabric coating of the cable by the sleeve. Suitable packing 113 is inserted in a packing recess formed by a counterbore in

the upper portion of the pothead, and is compressed by a follower sleeve 114 formed on the clamping member 107, to seal the joint between the pothead and the adapter sleeve 106. Packing may also be provided between the adapter sleeve and the cable as shown at 115.

The motor 13 in the present instance is of the three-phase induction type, and the cable 25, 28 contains three power conductors 120, 121, 122, as well as two motor control wires 123, 124 (Fig. 6). Within the pothead the individual conductors are separated and each terminates in a socket member 125 adapted to engage a terminal plug 126. Attention is particularly directed to the novel manner in which the terminal plugs are mounted in the pothead. It will be observed that they are cast or molded within a one-piece block 127 of insulating material such as Bakelite, which is clamped between one of the pothead sections and the connector plate 102. A sealing ring 128 forms a fluid-tight seal between the insulating block, the pothead section 27, and the connector plate 102. Each of the terminal plugs projects entirely through the insulating block and terminates at its opposite end in a plug 126' adapted to engage a socket member 125' on the end of each of the conductors of the inner cable section 28, thus electrically connecting the corresponding conductors of the two cable sections.

Inasmuch as the inner cable section 28 is immersed in the pump liquid and subjected to the prevailing pressure in the outer barrel 10, it is desirable that it be pressure-balanced internally and externally. This may be accomplished by employing a motor terminal box 29 which establishes communication between the interiors of the motor housing and of the cable, thus permitting the dielectric within the motor housing to be forced upwardly within the cable and exert an internal pressure equal to the pressure of the pump liquid. Such a terminal box is disclosed in detail in applicant's aforementioned U. S. Letters Patent No. 2,171,149.

The manner in which the two pothead sections 26 and 27 are secured to opposite sides of the connector plate will be understood by reference to Figs. 4, 5 and 6. As shown most clearly in Fig. 4, the bolting flange 130 on the outer pothead section 26 is square in outline, providing space for four cap screws 131 at the corners thereof engaging tapped holes extending only partially through the connector plate 102. Similarly, the inner pothead section is bolted to the under side of the connector plate by four cap screws 132 engaging tapped holes extending only partially through the connector plate. It will be observed from Fig. 6, however, that the inner pothead is turned through an angle of 45° with respect to the outer section, whereby the two series of bolt holes are arranged in staggered relation on the same radius. The two sections are thus secured to the connector plate independently of each other, while at the same time the overall width of the flanges is kept to a minimum and the size of the opening 101 in the cover plate is accordingly small. The connector plate 102 is secured in fluid-tight relation to the cover plate 11 by cap screws 133.

The pothead assembly described above affords a simple and effective means for electrically interconnecting a section of cable under relatively high internal and external pressure and a section of cable under atmospheric pressure. The insulating block 127 forms a fluid-tight parti-

tion dividing the interior of the pothead into two separate chambers, and thus enables the removal of the outer pothead section 26 and its connected cable 25 from the connector plate 102 without venting the interior of the barrel 10 or otherwise disturbing conditions within the barrel. Furthermore, the cable assembly is secured in fluid-tight relation to the cover plate by only a single joint—that between the connector plate and the cover plate. The possibility of leakage of pump liquid is thus eliminated.

A pumping unit constructed in accordance with the foregoing description may be aptly termed a "stuffingboxless" pumping unit, inasmuch as an outstanding characteristic is the elimination of all stuffingboxes or seals disposed between relatively movable parts and exposed on one side to the atmosphere. The outer barrel 10 is completely closed, not only during operation but also while the unit is idle, and is sealed by metal-to-metal seals between stationary surfaces, and hence leakage of pump liquid from the barrel is eliminated. The elimination of all seals which are dependent on operation of the unit for their effectiveness is of paramount importance when handling highly volatile liquids, since the pumping unit must be maintained under a pressure at least equal to the vapor pressure of the liquid when the unit is idle.

Of primary importance from an assembly and maintenance standpoint is the fact that the entire pumping unit, including the pump, motor, power cable, and all auxiliary piping is assembled on the cover plate 11 and is independent of the barrel 10. The latter functions solely as a receiver for pump liquid, and all problems of alignment between the barrel and the pumping unit are eliminated. To remove the unit from the barrel for inspection or repair, it is merely necessary to remove the bolts from the cover plate 11 and to disconnect the flanges on the nozzles 15, 16, and 17, and the entire unit may then be raised from the barrel in a single operation. If it is desired to disconnect the outer section of cable 25, this may be done without venting the barrel, by removing the cap screws 131 securing the outer pothead section 26 to the connector plate 102.

A unit such as that described may be operated in intermittent pumping service over an indefinite period without attention. To start the unit it is merely necessary to close the switch in the motor circuit and then open a valve in the discharge line. Inasmuch as the main pump 12 is a centrifugal pump having a definite shut-off head, it is not necessary to de-energize the motor before closing the discharge valve. When the motor is shut off, the entire unit remains under pressure, and the barrel 10 remains full of pump liquid in readiness for subsequent operation.

When the unit is first installed, the barrel 10 is obviously filled with air above the level 80 of the water or other intermediate liquid. Assuming that the storage tank B contains a volatile liquid, such as butane or propane, under a pressure greater than the vapor pressure of the liquid, the valves 140 and 141 in the lines 15 and 17 are first opened to permit pump liquid to flow from the tank B into the barrel 10 and equalize the pressure in the two tanks. The discharge valve (not shown) in the discharge line 16 may then be opened slightly to vent the air from the barrel, and the consequent reduction in pressure in the barrel will cause pump liquid to be forced

into the barrel from the tank and fill the barrel. The unit is then ready for operation.

Although we have shown and described a pumping unit which embodies various control means, it is not to be inferred from this that the unit requires frequent attention. On the contrary, the control lines extending through the cover plate, such as the water level control line 72 and the oil filler line 75 are provided solely as a precautionary measure, in the remote event that the dielectric liquid or the intermediate liquid should require replenishment due to loss of one of these liquids through possible faulty construction. If the unit is properly constructed, it is capable of operation for an indefinite period of time without attention.

In the embodiment shown in Figs. 1 to 7, provision has been made for transferring the pump liquid from a storage tank at the same elevation as the pumping unit. In many instances, however, the unit may be connected to an overhead storage vessel, in which case the ejector or other auxiliary transfer means may be dispensed with. In Figs. 8 and 9 we have shown two modifications of the pumping unit previously described, in which the auxiliary transfer pump has been eliminated, and in which the main pump is of a different type from that shown in Fig. 3^a.

Referring to Fig. 8, it will be observed that the pumping unit shown therein is in most respects substantially identical with the embodiment previously described, and hence a detailed description thereof is deemed unnecessary. Whereas in Figures 1 to 7 the outer barrel or receiver 10 is under the pressure of the pump liquid entering the pump, in Figure 8 the barrel 10^a is subjected to the discharge pressure of the pump liquid. The inlet nozzle 15^a is connected directly to the suction inlet of the pump 12^a, and the pump liquid discharges from an outlet 12' in the pump casing directly into the barrel 10^a, from which it is discharged through the discharge nozzle 16^a. The pump 12^a is, in this case, a single case multistage centrifugal pump similar to the inner case 33 of the double case pump 12 of Fig. 3^a, with the outer casing 31 omitted. In this instance the pump and motor are suspended from the cover plate 11^a by the suction pipe 15^a.

The motor 13^a of this embodiment may be identical with the motor 13 of Fig. 3, and is provided with a cooling jacket 80^a extending downwardly into the water or other intermediate liquid with which the lower portion of the barrel 10^a is filled. Suitable perforated cooling pipes 85^a are provided for circulating pump liquid over the outer surface of the motor housing, although in this case the direction of flow of cooling liquid will be in a direction opposite to that in Fig. 3. Inasmuch as the pump liquid in the barrel 10^a is under discharge pressure, the by-passed cooling liquid flows downwardly into the jacket 80^a and over the surface of the motor casing, and thence into the perforated pipes 85^a through the perforations therein, and thence upwardly through the pipe 87^a to an intermediate stage of the pump. It is preferable that the pipe 87^a be connected to a pump stage as close as possible to the lower extremity of the pump, in order that the pump liquid may be drained from the pump through the cooling pipes and into the jacket 80^a when the unit is vented, and thus avoid vaporization of any substantial amount of pump liquid within the pump casing during the venting operation.

The arrangement for establishing a pressure

balance between the pump liquid and the dielectric liquid within the motor housing, and for enabling the dielectric liquid to expand and contract while maintaining it isolated from the pump liquid, is identical with that shown in Fig. 3, and includes breather tubes 61^a and 64^a, and a U-shaped balance tube 70^a connected to the adapter housing 41^a. A liquid level control line 72^a extends downwardly within the barrel to a point slightly below the level 60^a of the intermediate liquid, and a vent line 90^a extends to a point adjacent the base of the cooling jacket 80^a, and function in the same manner as the corresponding elements in Fig. 3. An oil filler line 75^a is connected to the upper portion of the motor housing for replenishing the dielectric liquid if this should become necessary. The electrical connections to the motor are preferably identical with that shown in Figs. 3, 3^a, and 5, and a description thereof is believed to be unnecessary.

The operation of this unit is similar to that of the previously described embodiment except for the omission of the auxiliary transfer pump, the pump liquid in this case being fed to the pump by gravity or by other means independent of the pumping unit. Under some pressure and temperature conditions, it is advantageous to maintain the outer barrel or receiver under discharge pressure instead of suction pressure, and in the embodiment shown in Fig. 8 this is rendered possible by connecting the suction inlet of the pump directly to the suction nozzle of the outer barrel, and by discharging from the pump into the outer barrel and thence to the discharge nozzle.

In Figure 9 we have shown a pumping unit embodying the essential features of the two forms previously described, and differing from that shown in Fig. 8 in that the pump liquid enters the outer barrel 10^b through an inlet nozzle 15^b and enters the inlet of the pump 12^b through a strainer 40^b. A discharge nozzle 16^b is connected directly to the discharge of the pump, and it is thus seen that the outer barrel is subjected to the suction pressure of the pump liquid as in the embodiment shown in Figs. 1 to 7, rather than to discharge pressure as in Fig. 8. The pump shown in Fig. 9 is a multistage centrifugal pump of the deepwell type, comprising a plurality of pump bowls in series. Inasmuch as the motor and its various auxiliary control devices are identical with that previously described in connection with Figs. 1 to 7, except for the omission of the auxiliary pump for operating the ejector, further description thereof is deemed unnecessary.

Although we have shown and described several embodiments of the invention, it is to be understood that the invention is not limited to the specific details thereof, and that various modifications may be made therein within the spirit of the invention and the scope of the appended claims.

We claim:

1. Pumping apparatus particularly adapted for handling volatile liquids comprising, in combination: a fluid-tight receiver having a pair of pump liquid passages through the wall thereof; pump means mounted in said receiver and comprising a pump casing having a fluid passage therethrough, one end of which is in communication with one of said pair of passages and the other end of which is in open communication with the interior of said receiver; a pumping element mounted in said pump casing; and a motor

mounted in said receiver and comprising a rotor, a stator and a housing enclosing the rotor and stator and containing an internal liquid; shafting projecting through a wall of said housing and connecting said rotor in driving relation with said pumping element; a seal for sealing the juncture of said shafting and said housing; a body of intermediate liquid in said receiver of greater specific gravity than the pump liquid and said internal liquid and immiscible with both of said liquids, and means for establishing pressure transfer relation between a quiescent zone of said internal liquid and said intermediate liquid, and between a quiescent zone of said pump liquid and said intermediate liquid.

2. Pumping apparatus as set forth in claim 1, in which said means for establishing pressure transfer relation between said intermediate and internal liquids comprises an inverted U-tube having one leg thereof in open communication with said intermediate liquid in the lower portion of the body of intermediate liquid, and having the other leg thereof in open communication with the interior of said motor housing adjacent the end thereof remote from said projecting shafting.

3. Pumping apparatus as set forth in claim 1, in which said motor housing extends at least partially below the surface of said body of intermediate liquid, and including means for circulating pump liquid in heat exchange relation with said motor housing below the level of said intermediate liquid, comprising walls extending into said intermediate liquid and defining a chamber about said motor housing, said chamber being isolated from the intermediate liquid and having open communication with the pump liquid, and a by-pass conduit connecting said chamber and the interior of said pump casing.

4. A stuffingboxless pumping apparatus comprising: an elongated fluid-tight vessel having fluid inlet and outlet passages through the wall thereof adjacent one end thereof; a submersible motor pump unit mounted in said vessel and including a pump and a motor connected thereto; said pump comprising a casing having a fluid passage therethrough, one end of which is in communication with one of said fluid passages and the other end of which is in open communication with the interior of said vessel whereby pump liquid flows through said pump and through said vessel between the inlet and outlet passages therein, and a pumping element operable in said casing; said motor comprising a motor housing immersed in the pump liquid in said vessel in a portion thereof removed from the path of flow of pump liquid through said vessel; stator and rotor elements in said housing, said rotor element connected in driving relation with said pumping element; and means for cooling said motor comprising means for circulating cooling fluid in heat exchange relation with said motor housing at least in the region of said stator element therein.

5. Pumping apparatus as set forth in claim 4, including a jacket surrounding said motor housing in the region of the stator element therein, said cooling fluid being circulated through said jacket in heat exchange relation with said motor housing.

6. A stuffingboxless pumping apparatus comprising, in combination: an elongated fluid-tight vessel adapted to be mounted in an upright position and having a closed lower end and inlet

and outlet fluid passages formed in the wall thereof adjacent its upper end, a portion of the upper end wall of said vessel being detachable to afford access to the interior thereof; and a submersible motor-pump unit mounted in said vessel and including a pump and a motor connected thereto; said pump comprising a casing having a fluid passage therethrough, one end of which is in communication with one of said fluid passages and the other end of which is in open communication with the interior of said vessel whereby the latter constitutes a receiver for pump liquid; a pumping element operable in said casing; said motor comprising a motor housing immersed in the pump liquid in said vessel and subjected externally to the pressure of the pump liquid, said housing containing an internal liquid different from the pump liquid, motor elements in said housing and including a driving member extending through a wall of said housing into driving relation with said pumping element, a seal for sealing the juncture of said driving member and said housing, and means independent of said seal for establishing pressure-equalizing relation between the pump liquid and the internal liquid and thereby balance the pressures on opposite sides of said seal, said last-named means being operable in a quiescent zone of both liquids.

7. A stuffingboxless pumping apparatus comprising a fluid-tight vessel having a pair of fluid passages extending through the wall thereof; and a submersible motor-pump unit mounted within said vessel and including a pump and a motor connected thereto; said pump comprising a pump casing having a fluid passage therethrough, one end of which communicates with one of said fluid passages and the other end of which is in open communication with the interior of said vessel; a pumping element operable in said pump casing; said motor comprising a motor housing immersed in the pump liquid in said vessel and subjected externally to the pressure of the pump liquid and containing a second liquid, motor elements in said housing and including a driving member extending through a wall of said housing into driving relation with said pumping element, a seal for sealing the juncture of said driving member and said housing, and means for establishing pressure-equalizing relation between the pump liquid and the liquid in said housing in a quiescent zone.

8. A stuffingboxless pumping apparatus comprising, in combination: a vessel having a pair of fluid passages extending through the wall thereof, a portion of the wall of said vessel being detachable to afford access to the interior thereof, said vessel being normally completely closed except for said fluid passages; a motor-pump unit mounted within said vessel and secured to said detachable wall portion and comprising a pump casing having a fluid passage therethrough, one end of which is in communication with one of said fluid passages and the other end of which is in open communication with the interior of said vessel; a pumping element operable in said pump casing; a motor housing connected to said pump casing, and containing a liquid different from the liquid to be pumped; a motor in said housing and having a driving member extending through a wall of said housing into driving relation with said pumping element; a seal for sealing the juncture of said driving member and said housing; means for establishing pressure-balancing relation between the pump liquid in said ves-

sel and the liquid contained in said motor housing in a quiescent zone; electrical conductor means extending from an external source through said detachable wall portion to said motor; said motor-pump unit and said conductor means being removable from said vessel as a unit with said detachable wall portion.

9. A stuffingboxless pumping apparatus as set forth in claim 8, in which said conductor means comprises an outer conductor cable section extending from an external source to the outer side of said detachable wall portion, a separate inner conductor cable section extending from the inner side of said detachable wall portion to said motor, and a cable connector secured in fluid-tight relation to said closure member and operatively interconnecting said cable sections.

10. A stuffingboxless pumping apparatus as set forth in claim 8, in which said conductor means comprises an outer conductor cable section extending from an external source to said detachable wall portion, a separate inner conductor cable section extending from said detachable wall portion to said motor, a cable terminal box connecting said inner cable section to said motor, and a connector member secured in fluid-tight relation to said

detachable wall portion and operatively interconnecting said cable sections, said detachable wall portion having an opening therethrough of a size sufficient to pass said terminal box, whereby said cable sections, terminal box, and connector member may be assembled as a unit prior to securing the unit to said detachable wall portion.

11. A stuffingboxless pumping apparatus as set forth in claim 8, in which said conductor means comprises an outer cable section having an outer pothead section secured to one end thereof, an inner cable section secured at one end to said motor and having an inner pothead section secured to the other end thereof, a connector plate detachably secured in fluid-tight relation to said detachable wall portion, means detachably securing said pothead sections to opposite sides of said connector plate, and an insulating block clamped between said potheads and having one or more terminal elements extending there-through and engageable with corresponding conductors in the respective cable sections.

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