

Sept. 8, 1959

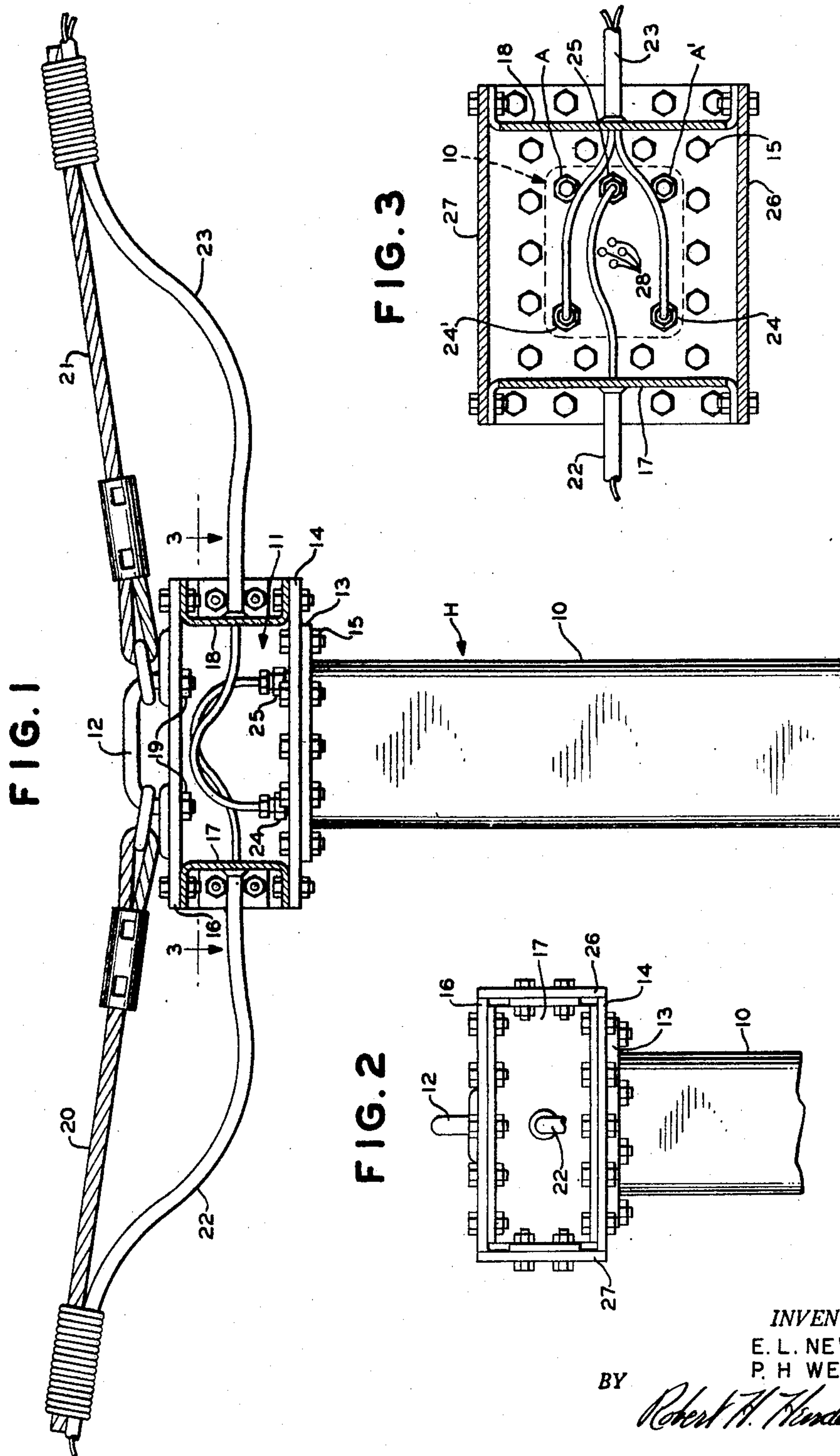
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2,902,803

METHOD FOR CHARGING SUBMERSIBLE CHAMBERS

Original Filed Oct. 28, 1952

4 Sheets-Sheet 1



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FIG. 4

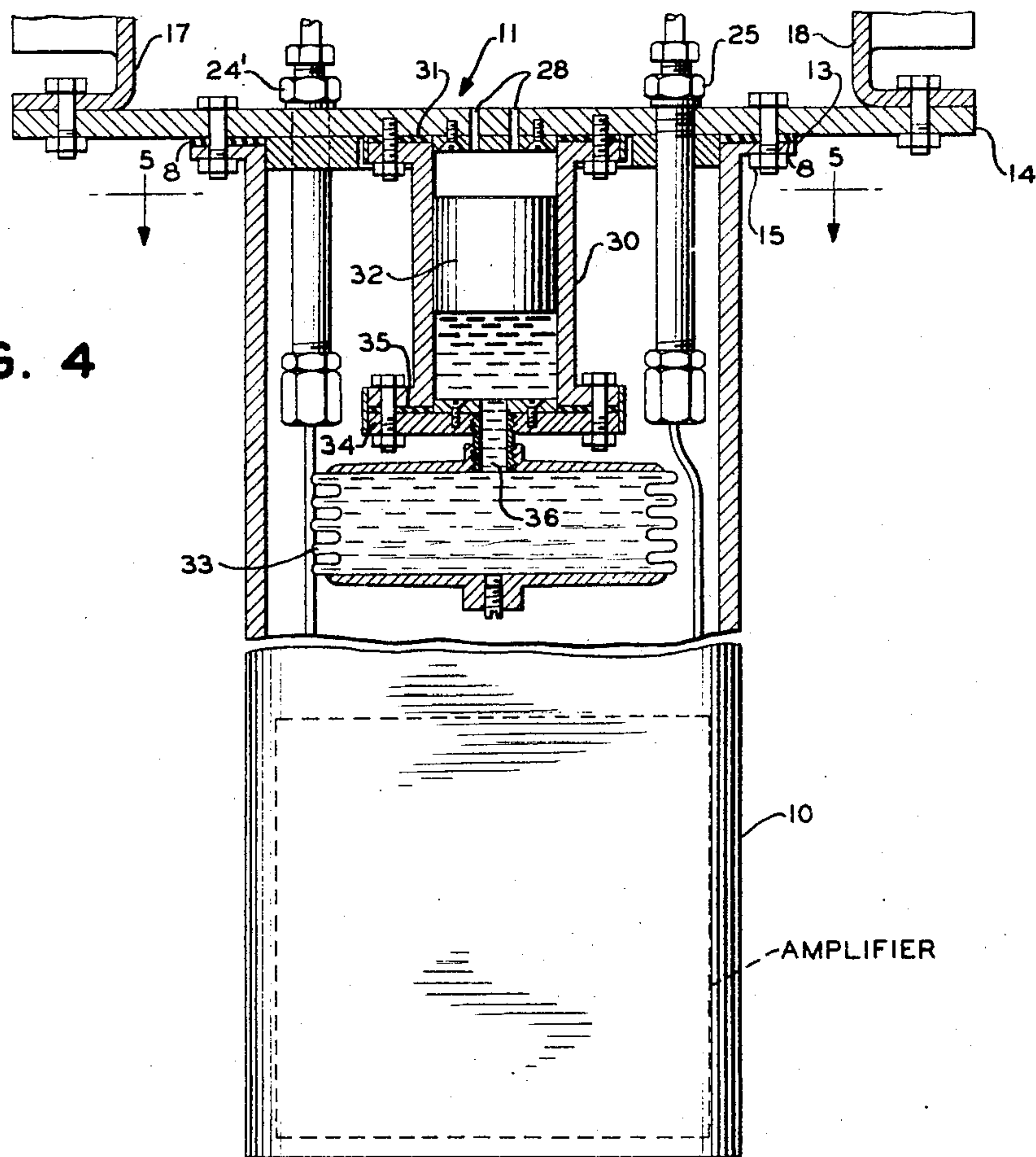
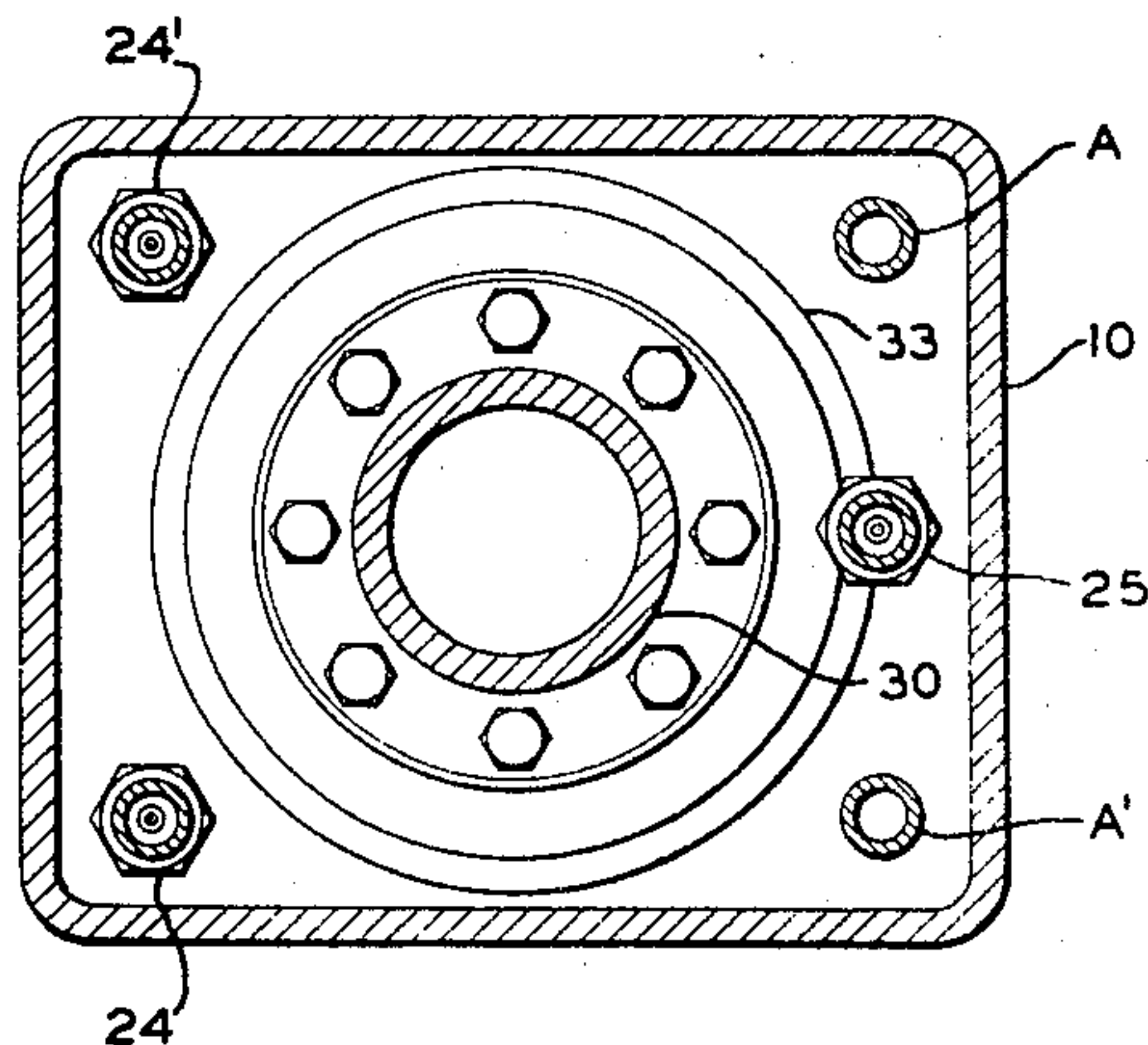


FIG. 5



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FIG. 6

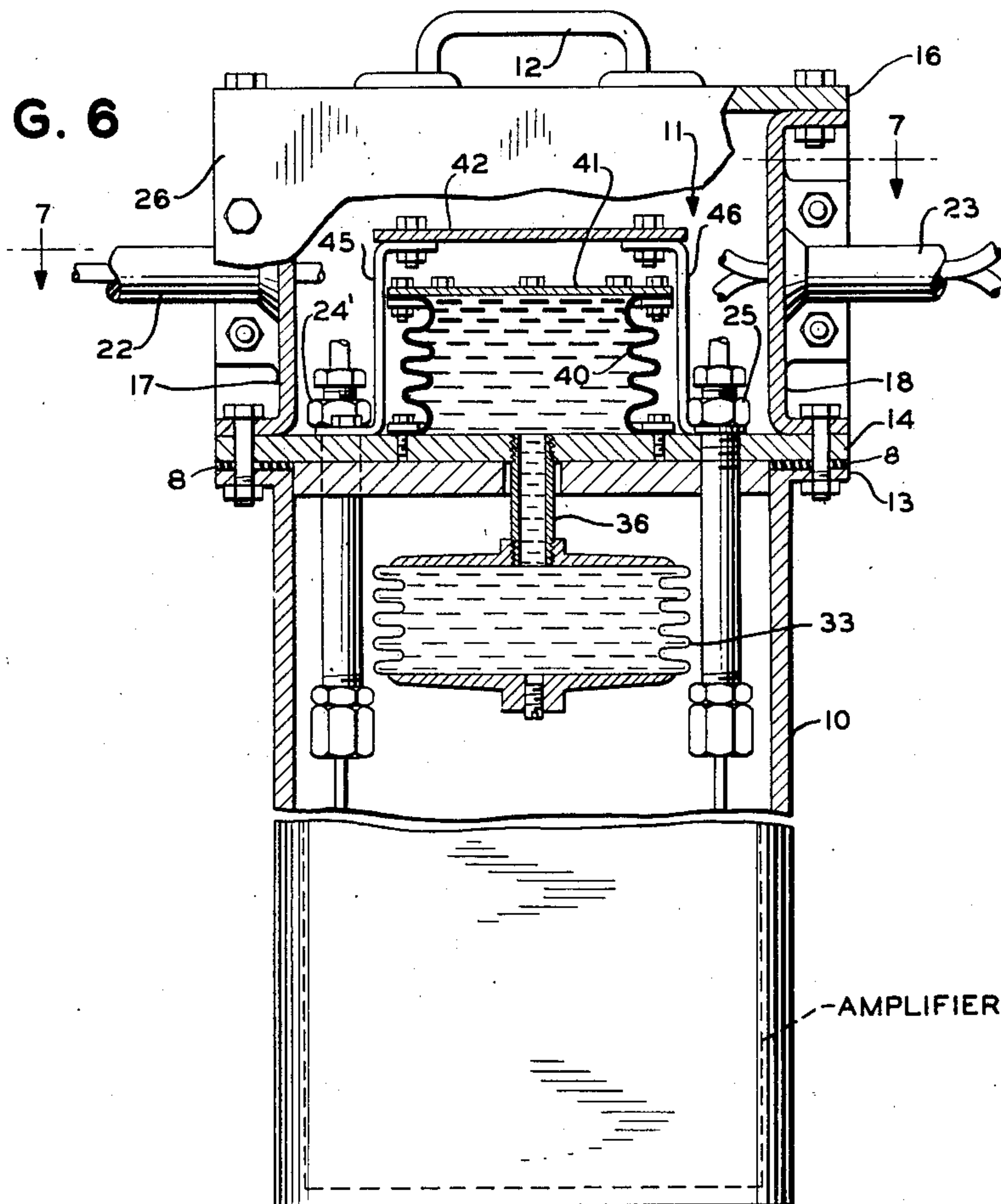
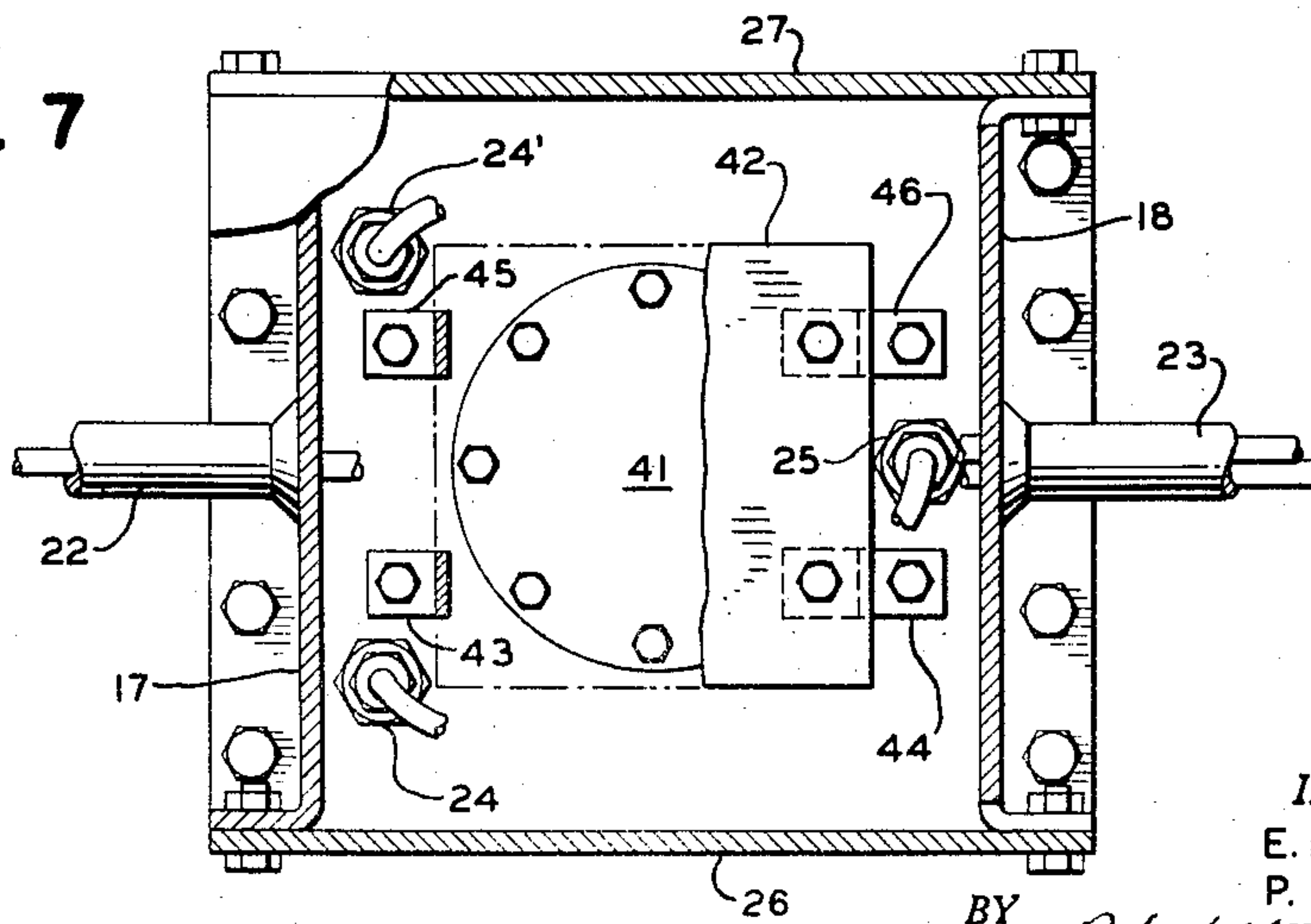


FIG. 7



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FIG. 8

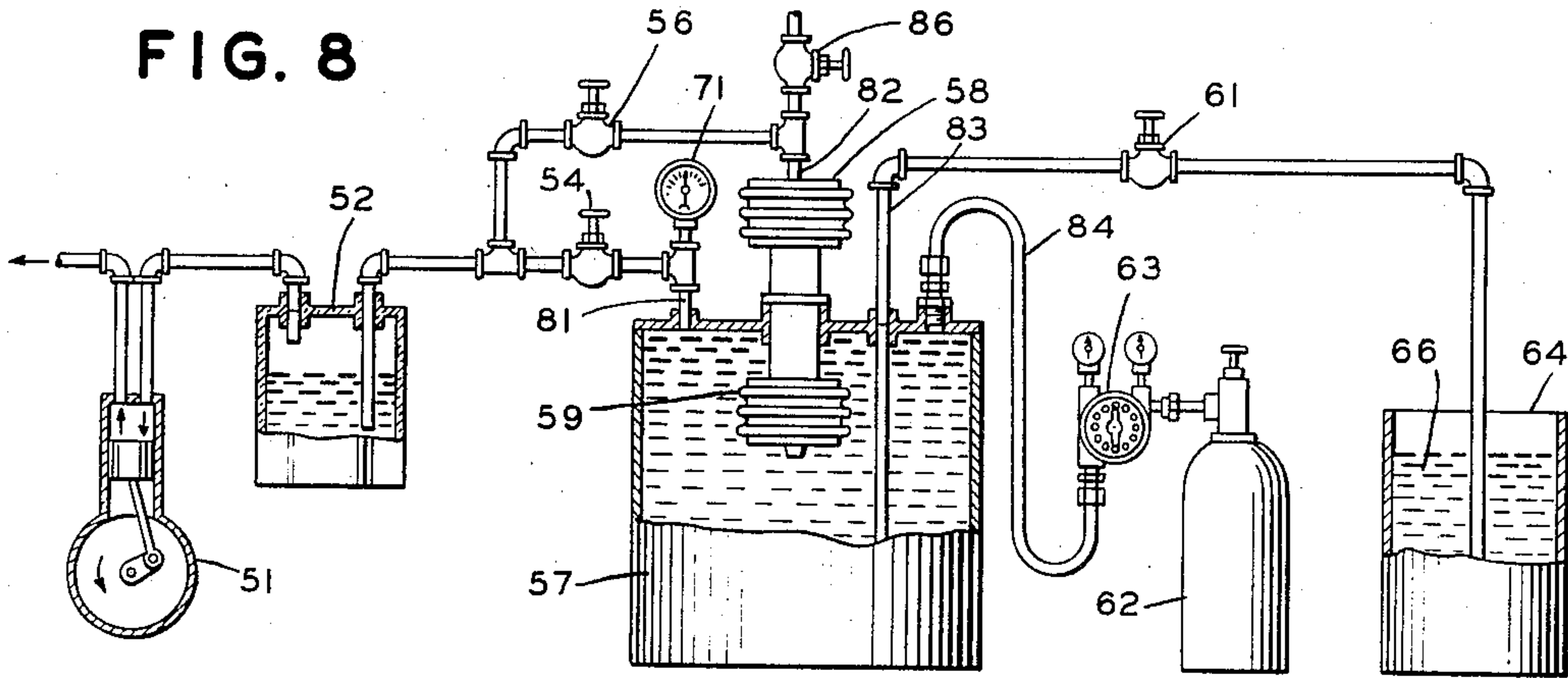


FIG. 9

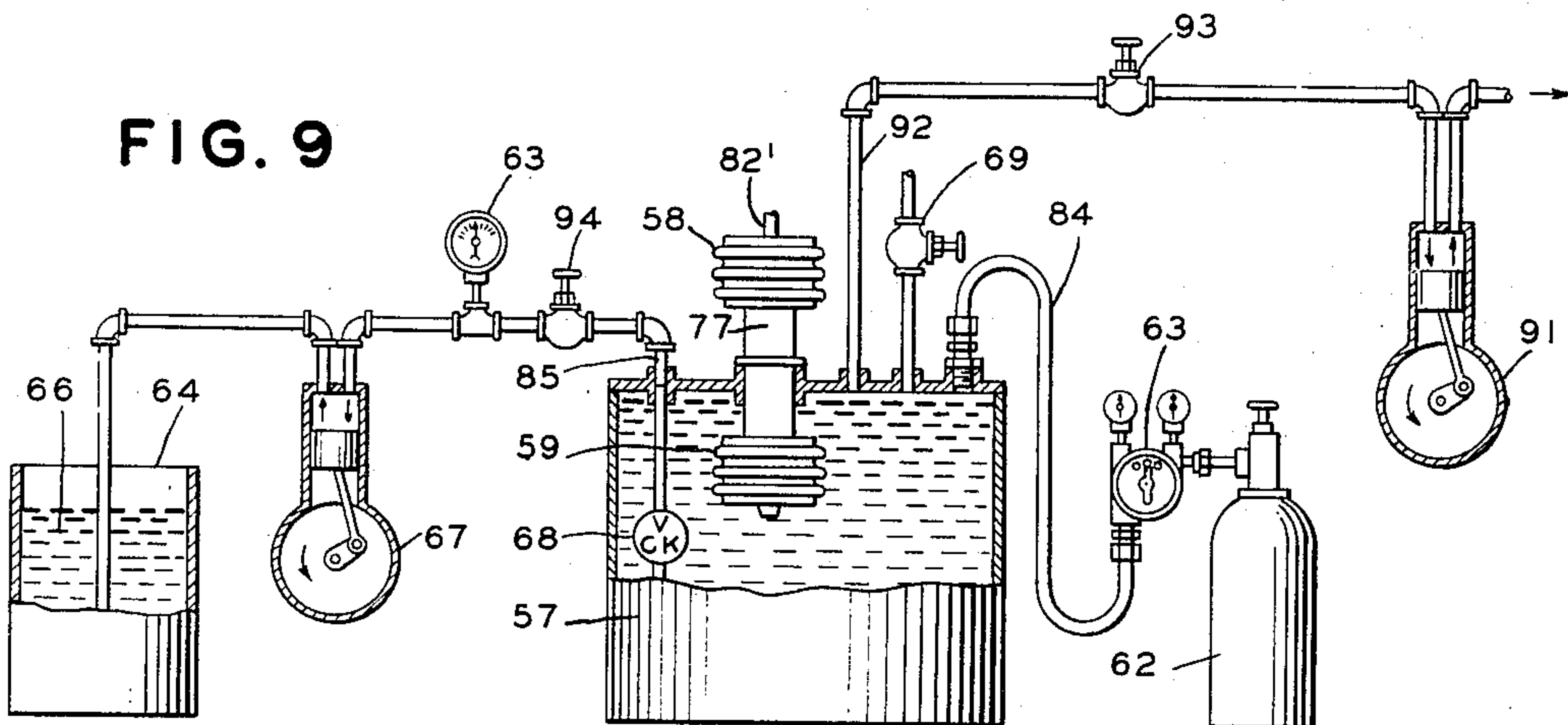
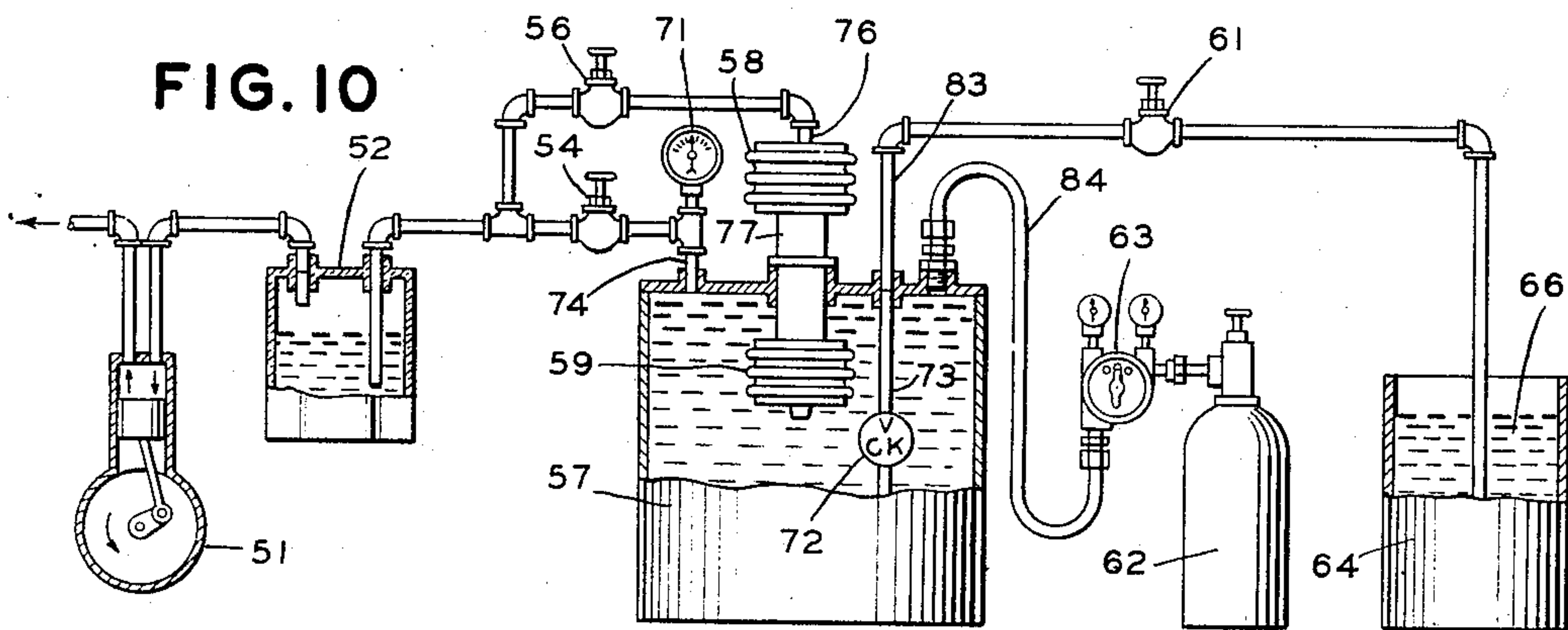


FIG. 10



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2,902,803

METHOD FOR CHARGING SUBMERSIBLE CHAMBERS

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Original application October 28, 1952, Serial No. 317,278. Divided and this application February 18, 1959, Serial No. 794,115

4 Claims. (Cl. 53—37)

The present invention relates to submersible chambers suitable for extended operation under relatively large hydrostatic pressures and more particularly to submersible chambers containing electronic apparatus and arranged to provide an internal pressure substantially equal to the external hydrostatic pressure.

This application is a divisional application of copending application Serial No. 317,278, filed October 28, 1952, by Earl L. Newell, Philip H. Wells and Clifford H. Cramer.

As described in the copending patent application of H. F. Wilder, Serial No. 229,146, filed May 31, 1951, now U.S. Patent No. 2,637,784, many advantages are secured by providing a repeating amplifier in a submerged portion of a submarine cable circuit. Since electronic apparatus suitable for use at the low frequencies normally employed in telegraphic communication over submarine cable circuits is inherently bulky, it is impractical to provide a housing for a submerged repeating amplifier which will maintain atmospheric pressure at substantial depths. More particularly, it would be very difficult to provide a relatively large container for unattended installation over a long period of time and which would maintain a high external-internal pressure differential. For example, a typical repeater installation might be at a depth at which a hydrostatic pressure of 750 pounds per square inch would be encountered. Accordingly, the housing should have an internal pressure substantially equal to the external hydrostatic pressure.

Since it is not possible to operate electrical apparatus in sea water, the repeater housing should be filled with an insulating fluid such as oil. Delicate electronic components, such as vacuum tubes, may be encased in small sealed containers located within the housing and being designed to maintain substantially atmospheric internal pressures. A pressure equalizing mechanism must be provided to transmit to the insulating fluid the increasing hydrostatic pressures encountered as the repeater is lowered. The equalizing mechanism must also provide a reservoir to compensate for voids within the repeater housing resulting from incomplete filling thereof and for decreases in fluid volume with the temperature drop.

Bellows arrangements have heretofore been used to equalize the internal and external pressures of a submerged casing. However, arrangements heretofore employed have not been suitable for unattended use over long periods of time in deep salt water. Corrosion and mechanical failure of the bellows tend to admit sea water into the interior of the casing. Moreover, a small amount of seepage over a long period of time will permit enough water to enter the casing to seriously damage the equipment therein.

Accordingly, it is an object of the invention to provide an improved method of filling housing for a submersible repeater, the housing being arranged to provide an internal pressure substantially equal to the external hydrostatic pressure.

Still another object is to secure additional safety of

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components and reliability of operation in submerged repeaters through increasing the reserve volumetric capacity of expansible members, without increase of size, weight, or complexity of those members.

A further object is to lengthen the average service life of submerged repeaters by providing a more effective means of compensating for the occasional leakage of liquid into the hermetically sealed containers used for housing certain components such as thermionic tubes and switches operated at atmospheric pressure within the chamber.

Other objects and advantages of the invention will be apparent from the following description.

In accordance with the invention, a submersible chamber containing electronic apparatus and intended for use where subject to changes in temperature and hydrostatic pressure is filled with an electrically insulating fluid, a bellows member being included within the chamber to transmit external pressure changes to the fluid within the chamber and to compensate for voids occurring within the chamber due to temperature changes of the insulating fluid, additional pressure translating means being provided to transmit external pressure variations to the bellows member and to prevent water from reaching the bellows member.

The invention will now be described in greater detail with reference to the appended drawing in which:

Figs. 1, 2 and 3 are views of a submerged repeater housing embodying the present invention;

Figs. 4 and 5 illustrate one pressure equalizing arrangement for the housing of Figs. 1 to 3, constructed in accordance with the invention;

Figs. 6 and 7 illustrate a second form of pressure equalizing arrangement constructed in accordance with the invention;

Fig. 8 is a schematic view of a submersible repeater housing and a filling mechanism therefor employing a vacuum pump;

Fig. 9 is a schematic view of an alternative arrangement wherein a pressure pump is shown for filling insulating fluid into the housing; and

Fig. 10 is a schematic diagram showing a further arrangement for filling the repeater housing with insulating fluid, employing a vacuum pump.

Referring now to the drawing and more particularly to Fig. 1, there is shown a front view of a submerged repeater housing H comprising a hollow tank member 10, a cable entrance chamber 11 and a supporting ring 12. The structural elements of housing H are preferably composed of steel. Tank member 10 is provided with an upper flange 13 fastened to a cover plate 14 by bolts such as 15 arranged along the outer edges of flange 13. Flange 13 and cover plate 14 are separated by a gasket 8 made of a material such as synthetic rubber which resists salt water.

Cover plate 14 forms the bottom of cable entrance chamber 11. Chamber 11 is also provided with a top plate 16 and side plates 17 and 18 shown sectioned. Not shown in Fig. 1 are back and front plates which, together with side plates 17 and 18, serve to protect the cable entrance chamber. Supporting ring 12 is fastened to top plate 16 by means of a pair of nuts 19.

Repeater housing H is supported by two lengths of steel rope 20 and 21. One end of each length is formed into an eye which is secured to ring 12 by a link member. The other end of each length is spliced to the armor wires of respective cable sections 22 and 23 in such manner as to provide slack in cable sections 22 and 23 between the splices and the repeater housing. Cable sections 22 and 23 enter the cable entrance chamber through entrance ports in side plates 17 and 18, respectively. The cable armor wires are returned through peripheral holes

about the entrance ports and are fastened to the armor wires outside the ports, thereby providing a rigid mechanical coupling which will minimize strain on the cable conductors.

Cable section 23 is preferably a bicores cable so that a remote sea earth may be provided for the repeating amplifier input. The repeating amplifier output ground is preferably effected on housing H. The two cable conductors from cable section 23 are passed into tank member 10 through water-tight cable entrance glands 24 and 24'. In Fig. 1, gland 24' is hidden behind gland 24. The single cable conductor from cable section 22 is passed into tank member 10 through a water-tight cable entrance gland 25.

In Fig. 2, which is a side view of the repeater housing, there is shown tank member 10, ring 12, flange 13, cover plate 14, top plate 16, side plate 17 and cable section 22. Also shown in Fig. 2 are front and back plates 26 and 27, respectively, which were not illustrated in Fig. 1. No effort is made to make cable entrance chamber 11 water-tight, the enclosing plates being provided only to prevent mechanical injury to the cable conductors and their insulation. As is evident from Figs. 1 and 2, each of plates 17, 18, 26 and 27 is bolted to top plate 16 and to cover plate 14.

In Fig. 3, which is a sectional view of Fig. 1, taken along line 3—3, there can be seen cable entrance gland 24' which was hidden in Fig. 1. Also shown in Fig. 3 are four apertures 28 which permit entrance of sea water into a portion of tank member 10. As can be seen from Fig. 3, tank member 10 and cable entrance chamber 11 have generally rectangular cross-sections.

Referring now to Fig. 4, the lower portion of cable entrance chamber 11 and the upper portion of tank member 10 are shown in cross-section. A hollow metal cylinder 30 having flanges at the upper and lower ends thereof is included within tank member 10. The upper flange of cylinder 30 is fastened to cover plate 14 by bolts, a gasket 31 being provided to insure proper sealing. Apertures 28 in cover plate 14 are arranged to admit sea water into the upper end of cylinder 30. A piston 32 is included within cylinder 30 and is arranged to prevent admission of sea water to the lower portion of cylinder 30 and to transmit the hydrostatic pressure to an oil reservoir comprising the lower end of cylinder 30 and a thin-walled cylindrical metallic bellows 33.

The lower flange of cylinder 30 is fastened to a plate 34 by bolts, a gasket 35 being employed to insure an oil-tight seal. A nipple 36 screwed into an opening in plate 34 and into an opening in the top of bellows 33 provides mechanical support for bellows 33 and serves as a channel for the transfer of oil between the lower portion of cylinder 30 and bellows 33.

As the repeater housing is lowered through water, the increasing hydrostatic pressure exerted on the top of piston 32 causes piston 32 to travel toward the bottom of cylinder 30, thereby applying a substantially equal pressure to the oil in the reservoir. Increasing pressure of oil in bellows 33 causes the walls thereof to diverge, thereby transmitting the pressure to oil within the remainder of tank 10.

The lower portion of tank 10 contains the desired electronic apparatus, portions of which may be enclosed within small sealed chambers for operation at normal surface pressures. A number of large electronic components, and in particular transformers and oil-filled capacitors, can conveniently be operated in oil at high hydrostatic pressures, the oil providing excellent insulation.

The three cable conductors referred to hereinbefore are passed through glands 24, 24' and 25 and into the lower portion of tank T for suitable connection to the electronic apparatus. A suitable electronic circuit for use in the repeater is shown in the copending patent application of P. H. Wells et al., Serial No. 229,193, filed May 31, 1951, now U. S. Patent No. 2,794,853. Additional ap-

paratus for inclusion in tank member 10 is illustrated in the copending patent application of F. B. Bramhall et al., Serial No. 229,191 filed May 31, 1951, now U.S. Patent No. 2,658,945.

Since the electronic apparatus will not completely fill the lower portion of tank member 10, and since oil has a relatively high volumetric temperature coefficient of expansion solid, light-weight inert filler material such as pieces of sheet aluminum cut to fit the space, which has a lower volumetric temperature coefficient, may be provided.

To maximize the repeater life span, it is essential that as much air as possible be excluded from tank member 10. For this purpose, it is desirable that every portion of tank member 10 not filled with apparatus or filler material be filled with oil. Any appreciable amount of air within tank member 10 will, because of the compressibility of air, greatly increase the required capacity of the pressure equalizing apparatus. Any oil having suitable insulating qualities could be employed for filling tank member 10. However, capacitor-type mineral oil is preferred for this purpose because of its excellent electrical qualities and because seepage of this type of oil into the interior of capacitive elements will produce a minimum change in the electrical characteristics thereof.

Moisture within tank member 10 will tend to shorten the life of electronic components. For this reason, all components should be thoroughly dried. Apertures A and A' in cover plate 14 are provided for evacuating and filling tank member 10. In service, these apertures are closed with suitable plugs.

When the repeater is lowered to its operating position it will be subjected to a temperature drop which may be as large as 40° F. or more. Since most oils, suitable for filling tank member 10 have a relatively large volumetric temperature coefficient, 0.00035 per degree F. being a typical value, means must be provided to fill the space left empty as the oil contracts. In addition, any portions of the tank member not initially filled should be filled when the repeater is subjected to hydrostatic pressure. This is accomplished by expansion of bellows 33 due to increasing hydrostatic pressure. If the interior of bellows 33 were filled with sea water, a thin-walled metallic bellows could not conveniently be used because of corrosion problems. However, it is desirable to employ a thin-walled metallic bellows because of its sensitive response to changes in hydrostatic pressure. Providing the tandem arrangement of piston 32 and bellows 33 permits the use of a thin-walled metallic bellows. The reservoir of oil contained in the lower portion of cylinder 30 and in bellows 33 should be sufficiently large to permit bellows 33 to expand sufficiently to compensate for all decreases in volume of oil within tank member 10.

It has been found impractical to construct a piston and cylinder assembly which will completely prevent sea water from getting past the piston. Furthermore, a substantially water-tight fit of piston and cylinder would tend to be relatively insensitive to small changes in hydrostatic pressure. In the arrangement illustrated in Fig. 4, a small amount of sea water seepage past piston 32 will not produce harmful results because the sea water will still be excluded from the portion of tank member 10 containing electronic apparatus. It is evident, however, that cylinder 30, piston 32 and bellows 33 should be constructed of corrosion resistant metal since each will be subjected to the corrosive effects of salt water.

Fig. 5, which is a section taken along line 5—5 of Fig. 4, shows the plan arrangement of tank 10, glands 24, 24' and 25, cylinder 30 and bellows 33.

For reasons set forth hereinbefore, it is desirable that thin-walled bellows 33 be not subjected directly to sea water. In the arrangement illustrated in Figs. 4 and 5, suitable separation is obtained by using the tandem arrangement of piston 32 and bellows 33. An important advantage of the tandem arrangement is that failure of either

the piston or bellows will not disable the repeater. More particularly, excessive seepage of water past piston 32 will not admit sea water to the electronic apparatus in tank 10. Similarly, a leak in bellows 33 will not allow the oil from tank 10 to escape to the sea.

An alternative arrangement and one which provides a larger oil reservoir for compensating voids in tank member 10 is illustrated in Figs. 6 and 7. Elements in Figs. 6 and 7 corresponding to elements in Figs. 1 through 5 are given like reference characters.

Referring now to Fig. 6, bellows member 33 is supported by nipple 36 screwed into an aperture in cover plate 14. A second bellows member 40 is mounted on cover plate 14. The walls of bellows member 40 should be formed of a material resistant to both oil and sea water. One suitable material is synthetic rubber. Cover plate 14 serves as the bottom member of bellows 40, the synthetic rubber walls being fastened thereto with bolts. A metal plate 41, also fastened to the walls of bellows 40 with bolts, serves as the top of bellows 40. Since bellows 40 is mounted outside tank member 10, bellows 40 will be subjected directly to hydrostatic pressure. Since both bellows 33 and 40 are filled with oil and since they are joined by nipple 36, pressure exerted on bellows 40 will be transmitted to bellows 33 which, in turn, will transmit the pressure to the oil within tank 10.

For mechanical protection of bellows 40, a metal plate 42 is disposed above plate 41 and supported by four metal straps 43, 44, 45 and 46, of which only straps 43 and 44 are visible in Fig. 6, all four being shown in Fig. 7.

In Fig. 6 the connections of the cable conductors of cable 23 to glands 24 and 24' and the connections of the cable conductor of cable 22 to gland 25 have been omitted for clarity. It is evident that cable entrance chamber 11 of Fig. 6 must be larger than cable entrance chamber 11 of Fig. 1 because of the inclusion of bellows 40 in cable entrance 11 of Fig. 6.

Fig. 7 is a section of Fig. 6 taken along line 7—7 and shows a plan view of the cable entrance and bellows 40.

As in the case of the tandem piston-bellows arrangement of Figs. 4 and 5, failure of either bellows 33 or bellows 40 of Figs. 6 and 7 will not result in admission of sea water to the electronic apparatus of tank 10. An additional advantage of the double bellows arrangement is that virtually no sea water will be admitted to bellows 33 because the synthetic rubber walls of bellows 40 act as an effective gasket.

The procedures pointed out, together with the construction referred to in the foregoing are adequate to provide a satisfactory range of pressure equalizing capacity in reasonable depths of water and under reasonable changes of temperature, a typical situation being 750 pounds per square inch hydrostatic pressure and a typical temperature being 40° F.

Referring to Fig. 8, it is seen that by the use of a vacuum pump 51, a reduced pressure can be attained in chamber 57, when the valve 54 is open, the valve 56 closed, and the valve 61 closed. Indicator 52 consisting of a closed transparent vessel containing fluid and an inlet dip tube, provides a convenient means of observing the progress of evacuation from the size and frequency of the bubbles which appear therein. When a vacuum in the neighborhood of 15 inches of mercury, as shown on gauge 71, has been obtained, regulating valve 63 is opened to introduce dry nitrogen from the flask 62 into the chamber 57. This process, when repeated several times, is effective in removing air, moisture and moisture vapor from the equipment enclosed in the container. Immediately after the last introduction of nitrogen, pipe 84 is removed, and the opening left in chamber 57 is plugged. When sufficiently dehydrated, chamber 57 may be connected to container 64 of oil 66 by opening valve 61. Application of vacuum from pump 51 will then cause chamber 57 to fill with oil. It is advantageous to

arrest this process at intervals by closing valve 61 and allowing pump 51 to run, so that air confined or trapped in the interstices in the equipment contained in chamber 57 may be expanded and removed while near the surface of the oil without being subjected to hydrostatic pressure from an excessive head of contained insulating oil standing above it in the chamber 57, which would limit the effectiveness of the pump 51 in removing it. When chamber 57 is filled, valve 54 is closed, valve 61 is closed, pipe 81 removed, and the opening thus left in chamber 57 is plugged. Valves 56 and 61 are then opened, valve 86 closed, and pump 51 is operated, a vacuum being thereby applied to the space enclosed between the bellows 58 and 59, causing bellows 59 to contract, and drawing further oil 66 from container 64 into chamber 57. Pipe 83 connected to chamber 57 may then be removed and the opening plugged, after which the vacuum previously applied between diaphragms 58 and 59 may be released and the pipe 82 connected thereto removed. The inter-bellows chamber is now filled by pouring oil into it through the opening in the top plate of diaphragm 58 left by the removal of pipe 82, while the upper bellows is distended by a lifting force applied to the top plate, and that opening is then plugged. By this technique air and moisture are removed from the chamber, and the bellows 58 and 59 are sufficiently flexed in an outward direction to provide increased volumetric capacity in order to accommodate later contraction due to the pressure of great depths of sea water acting on the contents of the chamber.

Fig. 9 illustrates another method of filling chamber 57 wherein a pressure pump 67 is used to remove insulating oil 66 from the container 64 and apply it under a pressure indicated by gauge 63 through the check valve 68 into chamber 57. Dry nitrogen gas from flask 62 is first applied through regulating valve 63 to the chamber 57 prior to filling the same with oil, and is exhausted therefrom by vacuum pump 91 having valve 93 open and valves 94 and 69 closed, after a slight pressure has been developed in chamber 57, the process being repeated slowly several times. This accomplishes drying of the interior of chamber 57 and removal of air therefrom, as previously explained. When the dehydration and deaeration are completed, pipe 84 is disconnected and the opening thereby left in chamber 57 is plugged. With valve 69 open, and acting as a vent, oil is forced by pump 67 into chamber 57 until it is partly filled. With valve 94 closed, valve 69 closed and valve 93 open, vacuum pump 91 is operated to remove entrapped gases. The last two steps are repeated until chamber 57 is filled. Pipe 92 and valve 69 are then removed and the openings in chamber 57 plugged. Additional oil is supplied by pump 67 until diaphragm 59 is sufficiently compressed. Pump 67 may then be stopped, the piping 85 between it and chamber 57 removed, and the opening therein plugged, while check valve 68 prevents leakage of oil during that process, and also during any temporary interruptions which may occur in the pumping due to breakage or failure of equipment. The chamber between diaphragms 58 and 59 is then poured full of oil through opening 82' while diaphragm 58 is distended mechanically, and opening 82' is then plugged.

In Fig. 10 is shown an arrangement for filling chamber 57 with insulating oil 66 from container 64, which presents advantages sufficient to render it the method of choice. Vacuum pump 51 is connected to chamber 57 through indicator 52, valve 54 and pipe 74 with gauge 71 attached thereto, all previously described. After removal of air, moisture, and moisture vapor from chamber 57, with the aid of nitrogen flask 62, and regulator valve 63, as described for Fig. 8, the pipe 84 is removed, and the opening left thereby in chamber 57 is plugged. The valve 61 is then opened to permit an inflow of oil 66 from container 64 to chamber 57 as vacuum pump 51 is operated with valve 54 open. Check valve 72 is

located at the foot of dip tube 73 in the path of this oil, and closes to prevent its escape from the tank 57. At the completion of pumping and filling and the removal of entrapped air, as previously described for Fig. 8, valve 54 is closed, pipe 74 removed and the opening left thereby in chamber 57 plugged. Valve 56 is then opened and the pump 51 operated to collapse bellows 59, valve 61 remaining open, thereby withdrawing an additional quantity of oil 66 from container 64 into chamber 57. Pipes 76 and 83 are then disconnected and the opening in chamber 57 left by the removal of pipe 83 is plugged. The inter-bellows chamber 77 is poured full of oil through the opening from which pipe 76 was removed, while bellows 58 is distended by an upwardly applied force to its upper surface. The opening in bellows 58 is then plugged.

It is seen that both bellows 58 and 59 are left in an upwardly flexed condition, providing them with substantially full travel available for the compensation of compressive volume changes due to pressure of sea water at great depths. Moreover, the provision of check valve 72 in the oil dip tube 73 prevents any outflow of oil from occurring due to an accidental or temporary interruption in the operation of vacuum pump 51. In addition, when valve 61 and its associated piping 83 is disconnected preparatory to plugging the opening therefor in chamber 57, the level of oil at that opening is not dependent upon the degree of pressure in tank 57, but is fixed and stable such that a plug readily can be inserted in the opening without danger of loss of oil from or of entrance of air into tank 57. Since the use of vacuum pump 51 is desirable in order to remove entrapped air from the chamber 57 in any event, the further advantages of the arrangement of Fig. 10 already mentioned are attained without the use of additional pumping equipment.

In Figs. 8 to 10 we have shown means associated with the container by which voids internal to chamber 57 are substantially reduced or eliminated and the deleterious effects thereof obviated when the chamber is subjected to conditions of high hydrostatic pressure such as occur at depths from 600 fathoms to over 1000 fathoms. It has been found to be advantageous to operate submarine cable repeaters at such greater depths in order to amplify the incoming signals before they encounter interference produced by another cable which the operating cable may parallel or cross, for the purpose of reducing cross-talk or mutual interference between the signal currents traveling within the cables. Hydrostatic pressures from approximately 1800 pounds to over 3000 pounds per square inch are encountered in such cases and are successfully accommodated hereby.

While the invention has been described in particular embodiments thereof and in particular uses, it is not desired that it be limited thereto for obvious modifications thereof will occur to those skilled in the art without departing from the spirit and the scope of the invention as set forth in the appended claims.

What is claimed is:

1. In a submersible device comprising apparatus enclosed in a casing filled with an insulating liquid for operation in an ocean or other body of deep water, and in which an extensible structure is mounted in a wall of the casing for changing the volumetric capacity of the casing in accordance with the hydrostatic pressure encountered; the method of increasing the maximum pressure which said extensible structure will exert on the liquid within the casing to increase the range of depths of water in which the apparatus can operate comprising the steps of alternately evacuating said casing to a pressure less than atmospheric pressure and filling the evacuated casing with an anhydrous inert gas throughout at least one cycle of such alternations, thereafter alternately inserting into the said casing an insulating liquid in the amount of a fractional part of the volu-

metric capacity of the said casing and evacuating the space above the liquid in said casing throughout a plurality of such alternations until the casing is filled with the said insulating liquid, causing the said extensible structure to deform in a direction to enlarge the volumetric capacity of said casing, further filling said casing to an increased maximum capacity thereof with said liquid, and sealing the casing.

2. In a submersible device comprising apparatus enclosed in a casing filled with an insulating liquid for operation in an ocean or other body of deep water, and in which a bellows structure is mounted in a wall of the casing and located entirely within the casing, a second bellows structure similarly mounted is located without the casing and communicates with the first said bellows structure to form a cavity common thereto, and a liquid fills said cavity for transmitting pressure to the insulating liquid within the casing in accordance with the external hydrostatic pressure encountered; the method of increasing the maximum pressure which said bellows structure will exert on the liquid within the casing to increase the range of depths of water in which the apparatus can operate comprising the steps of alternately evacuating said casing to a pressure less than atmospheric pressure and filling the evacuated casing with an anhydrous inert gas throughout at least one cycle of such alternations, thereafter alternately inserting into the said casing an insulating liquid in the amount of a fractional part of the volumetric capacity of the said casing and applying a vacuum to the space above the liquid in said casing throughout a plurality of such alternations until the casing is filled with the said insulating liquid, evacuating the said cavity to compress the first of said bellows structures and further filling the said casing with the said insulating liquid, sealing the casing, distending the second bellows, filling the said cavity with a liquid while the said first bellows member remains in a compressed condition, and while the said second bellows member is distended, and sealing the said cavity.

3. In a submersible device comprising apparatus enclosed in a casing having therein a filling pipe with a check valve closing outwardly, filled with an insulating liquid for operation in an ocean or other body of deep water, and in which a bellows structure is mounted in a wall of the casing and located entirely within the casing, a second bellows structure similarly mounted is located without the casing, and communicates with the first said bellows structure to form a cavity common thereto, and a liquid fills said cavity, for transmitting pressure to the insulating liquid within the casing in accordance with the external hydrostatic pressure encountered; the method of increasing the maximum pressure which said bellows structure will exert on the liquid within the casing to increase the range of depths of water in which the apparatus can operate comprising the steps of alternately filling the said casing with an anhydrous inert gas and removing the said gas from the casing through at least one cycle of such alternations, thereafter filling the said casing with an insulating liquid, forcing a further amount of said liquid into said casing under pressure thereby to compress said second bellows structure, and filling the said cavity with liquid under pressure thereby to distend the said second bellows structure, and sealing said casing and said cavity.

4. In a submersible device comprising apparatus enclosed in a casing having therein a filling pipe with a check valve closing outwardly, filled with an insulating liquid for operation in an ocean or other body of deep water, and in which a bellows structure is mounted in a wall of the casing and located entirely within the casing, a second bellows structure similarly mounted is located without the casing and communicates with the first said bellows structure to form a cavity therebetween, and a liquid fills said cavity for transmitting pressure to the insulating liquid within the casing in accordance

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with the hydrostatic pressure encountered; the method of increasing the maximum pressure which said bellows structure will exert on the liquid within the casing to increase the range of depths of water in which the apparatus can operate comprising the steps of alternately evacuating said casing to a pressure less than atmospheric pressure and filling the evacuated casing with an anhydrous inert gas throughout at least one cycle of such alternations, thereafter alternately inserting into the said casing an insulating liquid in the amount of a fractional part of the volumetric capacity of the said casing and evacuating the space above the liquid in said

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5 casing throughout a plurality of such alternations until the casing is filled with the said insulating liquid, evacuating the said cavity to compress the first said bellows structure and further filling the said casing with the said insulating liquid, sealing the casing, distending the second bellows member, filling the said cavity with a liquid while the said first bellows member remains in a compressed condition and while the said second bellows member is distended, and sealing the said cavity.

10 No references cited.