No. 689,625. Patented Dec. 24, 1901.

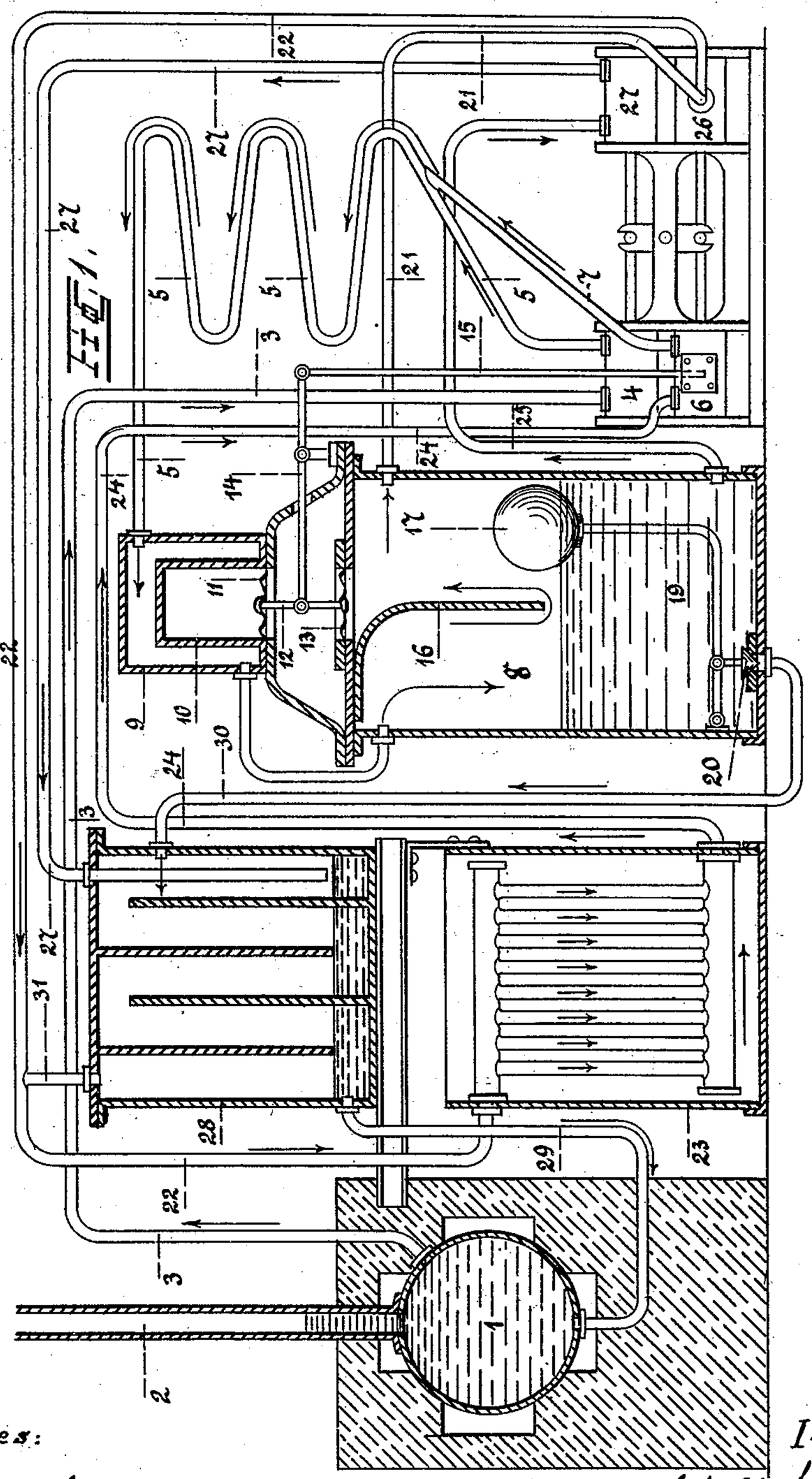
A. SCHARFFE.

VAPOR GENERATOR.

(Application filed Aug. 21, 1900.)

(No Model.) 7 Sheets—Sheet 1.

Fig. 1.



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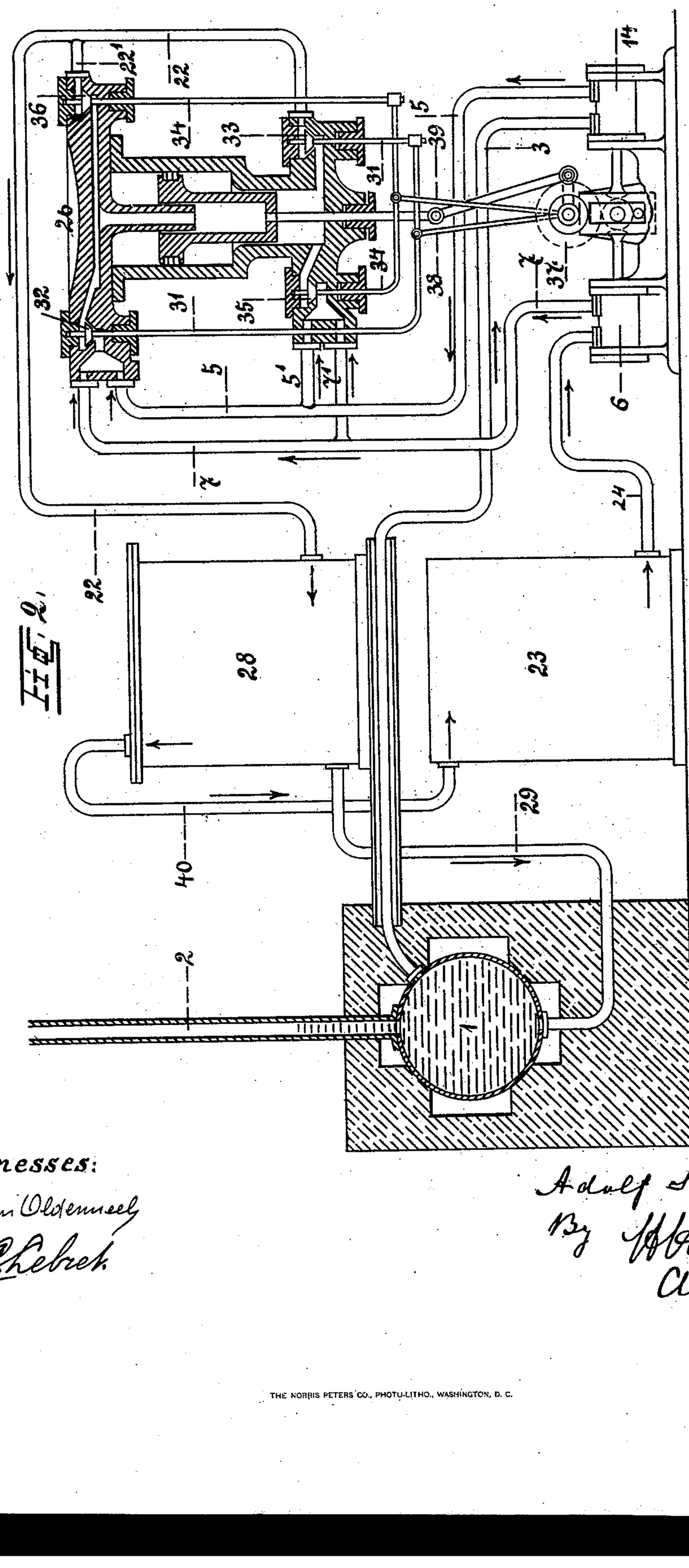

FIG. 2.

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(No Model.) 7 Sheets—Sheet 3.

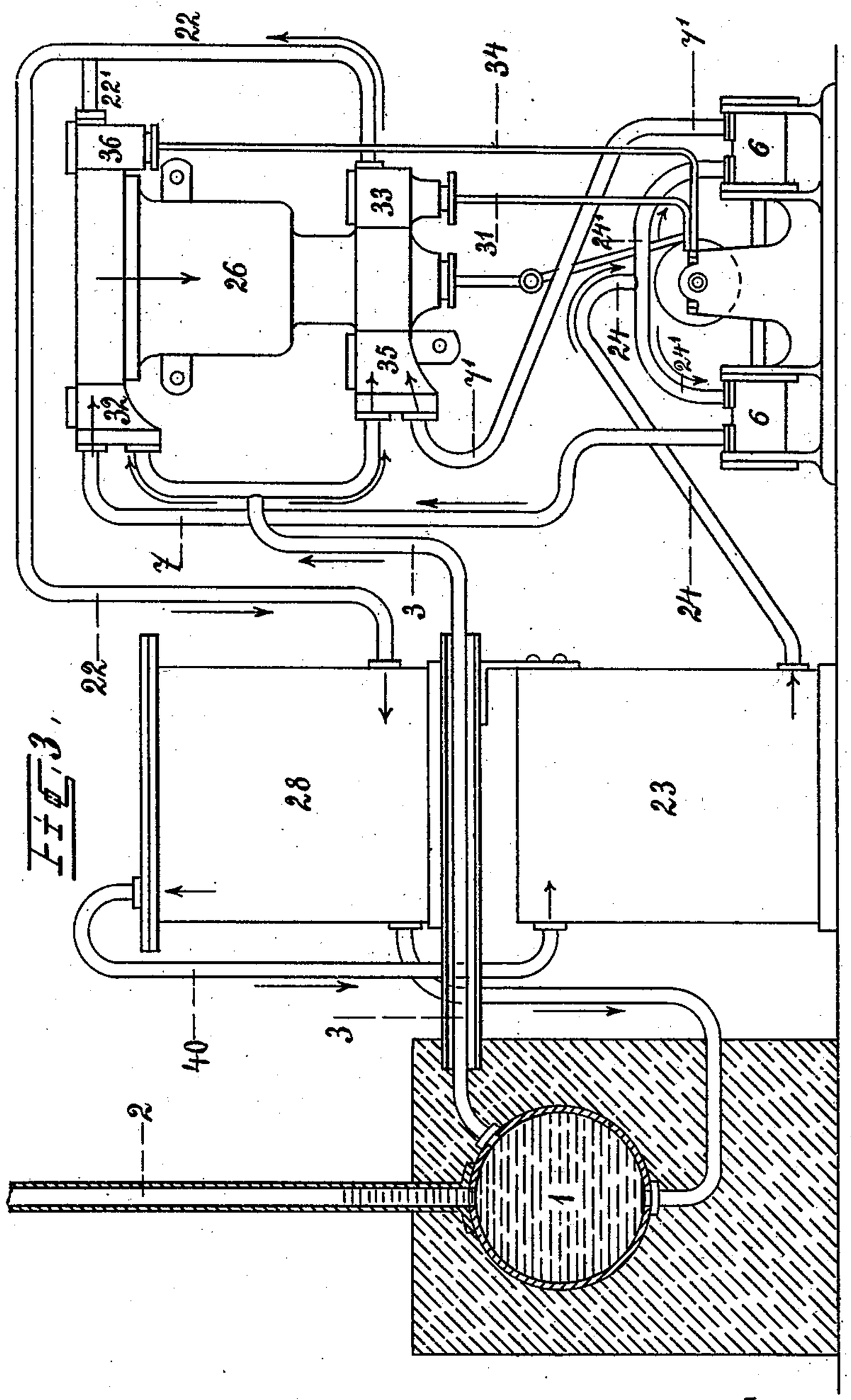

Fig. 3.

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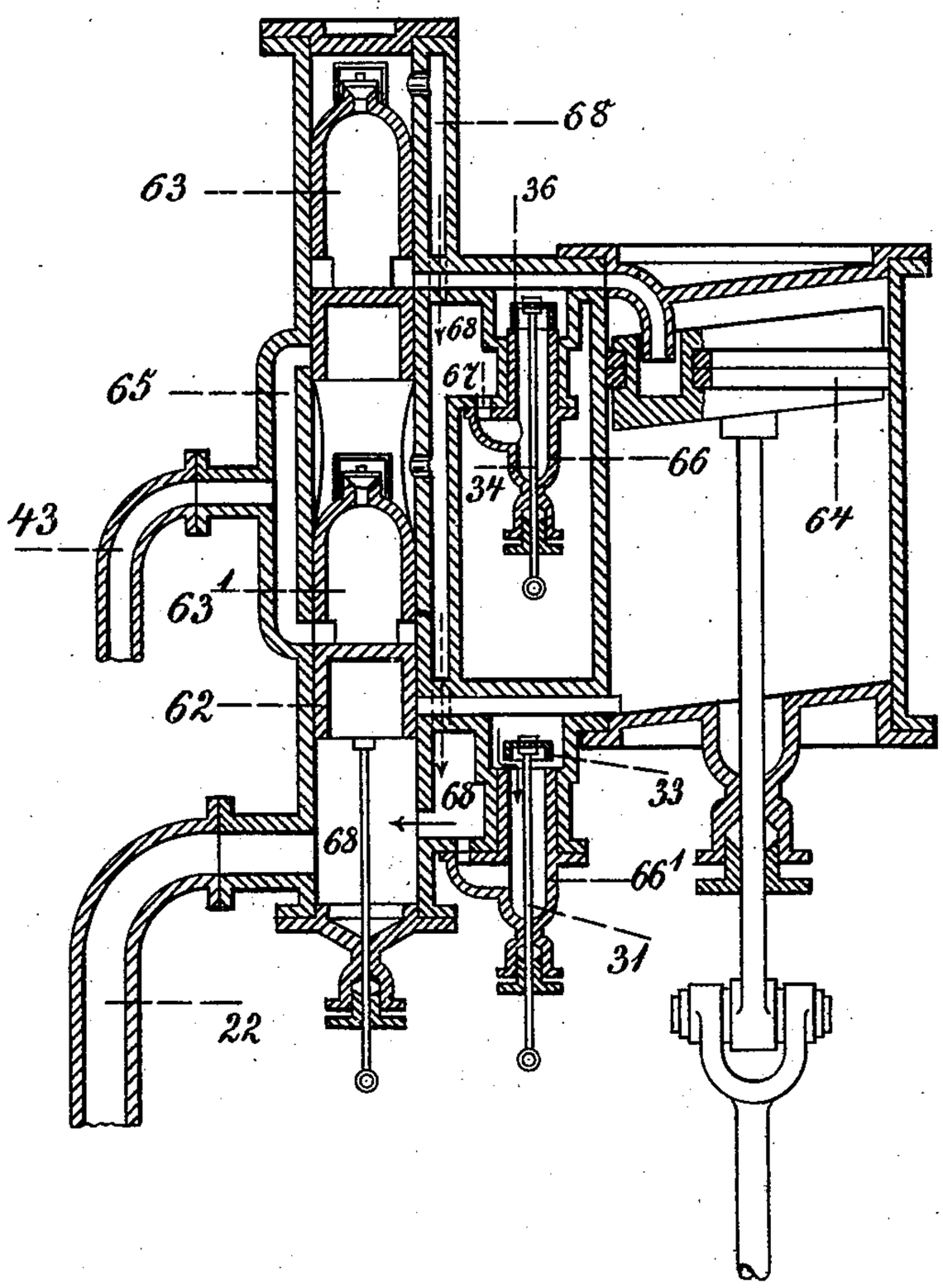
(No Model.) 7 Sheets—Sheet 4.

Fig. 4.



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(No Model.) 7 Sheets—Sheet 5.

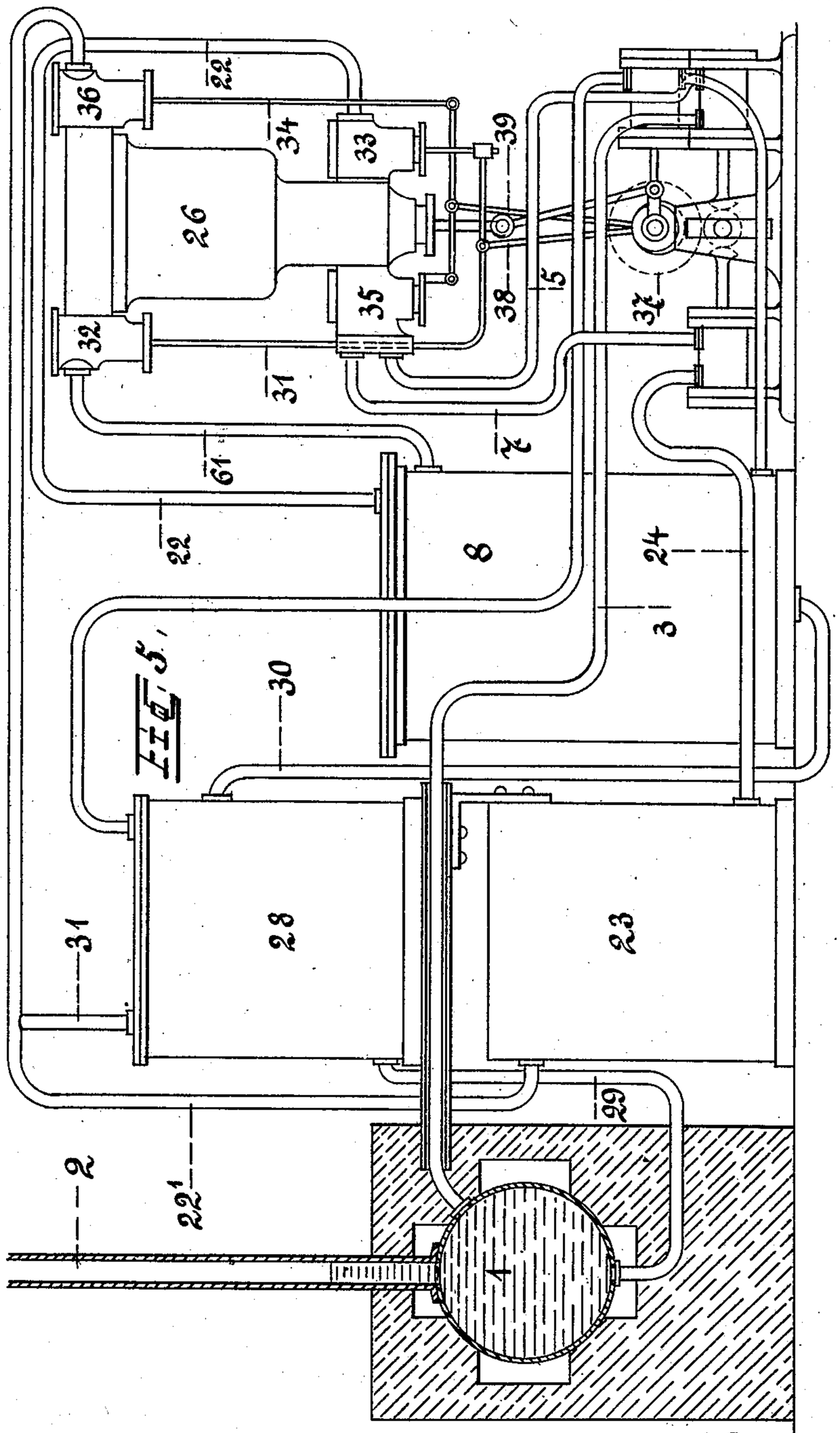

FIG. 5.

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(Application filed Aug. 21, 1900.)

(No Model.) 7 Sheets—Sheet 6.

FIG. 7.

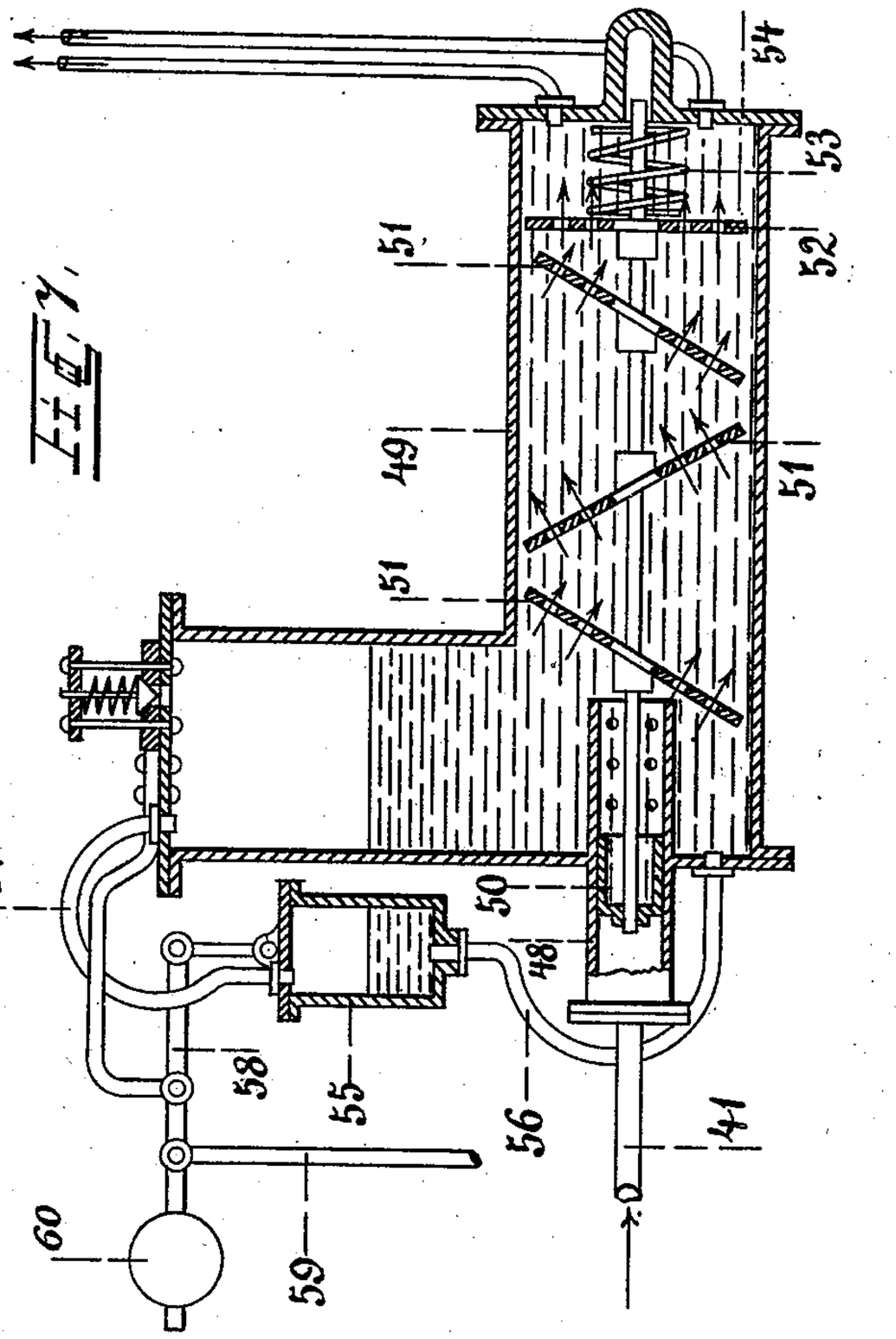
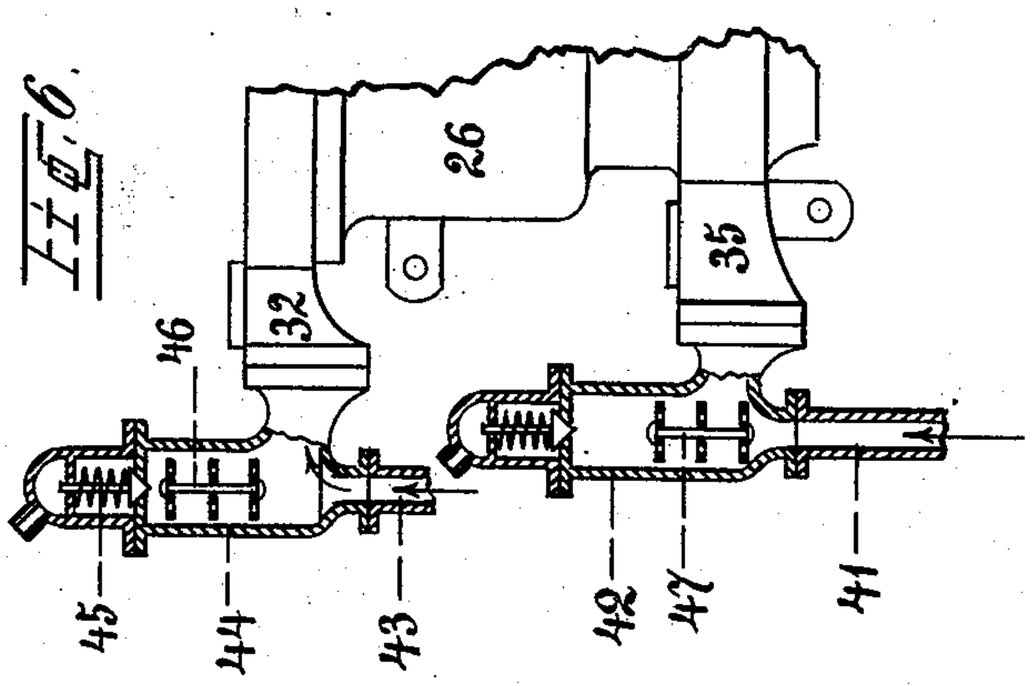


FIG. 6.



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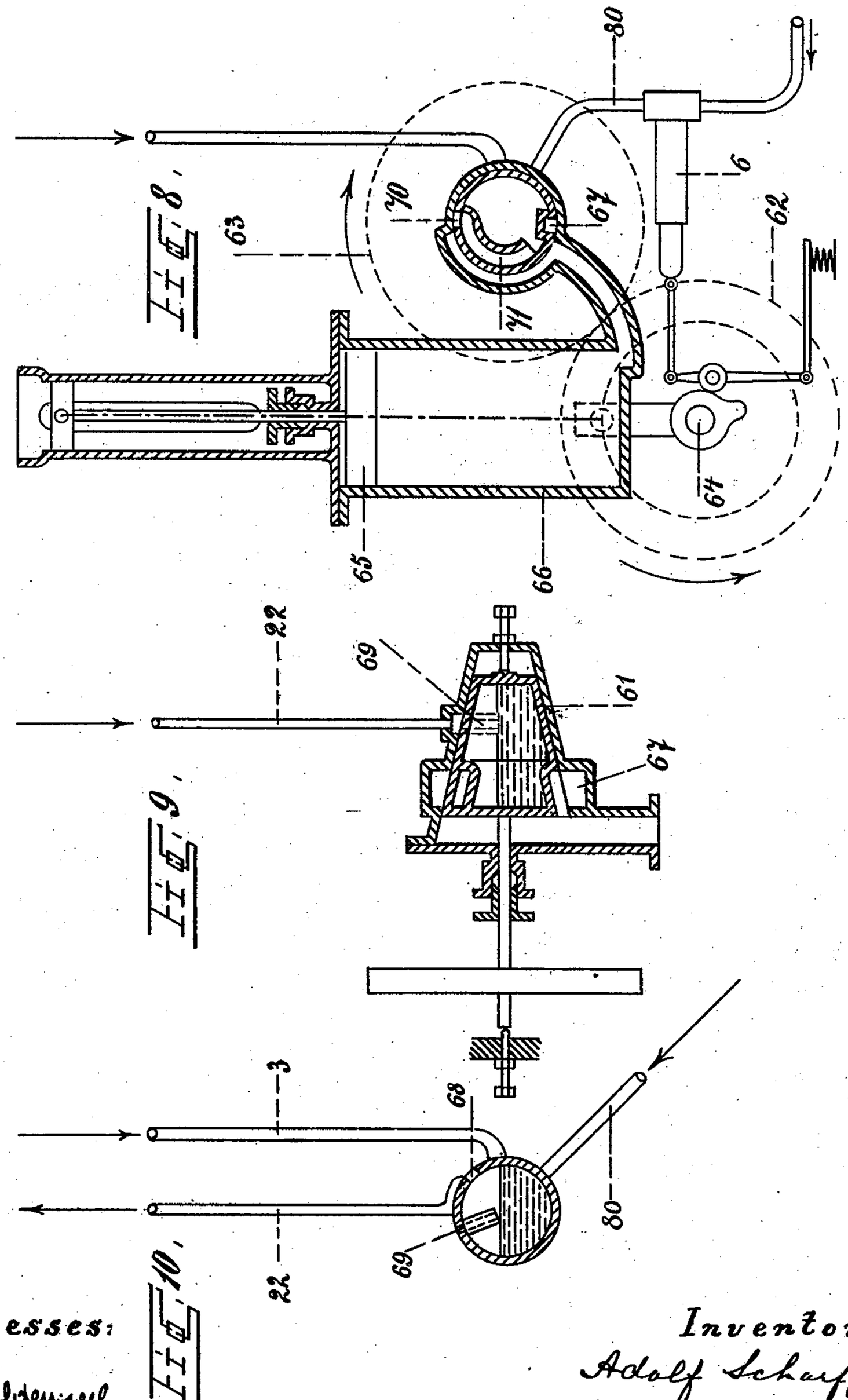

FIG. 8.

FIG. 9.

FIG. 10.

FIG. 11.

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UNITED STATES PATENT OFFICE.

ADOLF SCHARFFE, OF TIENTSIN, CHINA.

VAPOR-GENERATOR.

SPECIFICATION forming part of Letters Patent No. 689,625, dated December 24, 1901.

Application filed August 21, 1900. Serial No. 27,560. (No model.)

To all whom it may concern:

Be it known that I, ADOLF SCHARFFE, civil engineer, a subject of the German Emperor, residing at Tientsin, in the Chinese Empire, have invented a certain new and useful Improvement in Vapor-Generators, of which the following is a specification.

This invention relates to the generation of motive fluids, such as steam and gases; and it consists in the hereinafter-described improvements in apparatus for generating and using the same.

It is well known that the usual apparatus for generating the motive power for driving machinery are a source of danger in all works, as the total power to be distributed to the several engines and apparatus is stored in a large quantity in one place. It is immaterial whether steam or gas pressure is used, whether the plant is large or small, or confined to a single motor. Even electricity is not excepted, if generated by means of steam. The larger the generator is the greater is the danger of explosion; but even in the smallest generator of motive power there is always stored such an excess of energy that in case of an explosion the health and life of the attendants are endangered.

The object of this invention is chiefly to remove this danger, which is effected by completely avoiding the use of stations or apparatus in which a storage of motive power takes place—as, for instance, in steam-boilers—and by generating the required motive agent for driving the engine or the like by means of the same in such small quantities only as are required for producing the power during a unit of time—for instance, one stroke of the steam-engine piston. This is done by employing two different media, one of which, hereinafter called "heating liquid," posesses a higher boiling-point than the other, hereinafter called "working medium," and heating the heating liquid in open or closed vessels to near its boiling-point, but in any case above the boiling-point of the working medium, conducting the heating liquid and working medium separately to the motor or engine, and mixing the two substances only just before or even in the engine in such small quantities that the steam or gas developed from the working medium possesses the required pressure for performing the desired amount of work, but that no storage of energy capable of causing danger takes place in the mixing-chamber for the heating fluid and working medium. The heating liquid, thereby reduced in temperature, is then returned to the heating vessel in order to be used over again, while the exhaust from the motor is condensed, and the working medium regained in this way is employed again in the manner above described. The heating liquid may be a liquid at ordinary temperatures before it is heated or may be produced for use by melting solid substances. Whether a working medium is added to the heating liquid in the form of a liquid of lower boiling-point or of a gas or a gas absorbed in a liquid is immaterial as far as this invention is concerned, as a preferably slightly-compressed gas on being mixed with the heating liquid obtains a higher pressure and can be used similarly to steam. Even salts evaporating readily without leaving a residue could be used as a working medium. For the sake of convenience the evaporated working medium is hereinafter called "steam," but may be a gas, as stated.

The mixing of the heating liquid and working medium for producing the steam can be effected, as stated above, in a separate vessel or in the engine-cylinder itself or in the piping leading to the engine. Corresponding with these different arrangements of the generators different types of apparatus for carrying out the process are represented on the drawings appended hereunto, which are successively described hereinafter.

Referring to the drawings which accompany the specification to aid the description, Figure 1 is a diagrammatic representation in section and elevation of an installation containing the invention and illustrating generally the course of the heating and the working media. Fig. 2 is a longitudinal sectional section and elevation of an installation wherein the heating and the working media are brought together in the engine-cylinder. Fig. 3 is a longitudinal vertical section and elevation of an installation wherein pumps for bringing the heating and the working media into the engine-cylinder are dispensed with, the movement of the engine-piston drawing said media into the cylinder. Fig. 4 is a ver-

tical section of an engine cylinder, piston, valves, and connected chambers arranged for the distribution of the media to each end of the said cylinder. Fig. 5 is a longitudinal vertical section and elevation of an installation wherein the invention is applied to a compound engine. Fig. 6 is a vertical sectional detail of a device for effecting an intimate admixture of the two media before they pass into the engine-cylinder. Fig. 7 is a vertical section of another device for effecting an intimate admixture of the media, combined with an automatic device for controlling the pump which delivers the media to the mixing device. Figs. 8, 9, and 10 are details of an arrangement of feed-valves for controlling the delivery of the heating medium.

Fig. 1 shows an arrangement in which the heating liquid and working medium are brought together outside the engine. The heating liquid is drawn from the heater 1, provided with a stand or safety pipe 2, by the pump 4 through the pipe 3 and forced into the pipe 5. Into the same pipe 5 the working medium to be evaporated or gasified is forced by the pump 6 through the pipe 7, so that an intimate mixing of heating liquid and working medium takes place in the pipe 5, which is preferably coiled or serpentine.

As the heating liquid, as explained above, possesses a much higher boiling-point than the working medium and so high a temperature that on mixing the two substances the working medium is evaporated or gasified, there will be in the pipe 5 a mixture of the heating liquid reduced in temperature and of the steam or gas under pressure produced from the working medium. This mixture is conducted to the separator 8, preferably after passing through a pressure-regulator 9. This regulator in the example represented consists of a casing surrounding the closed chamber 10, the bottom of which is formed by a membrane 11. The chamber 10 incloses a certain quantity of the working medium, to be determined by experiment. As the temperature in the chamber 10 increases with the temperature of the surrounding mixture of heating liquid and steam the pressure upon the membrane 11 will be altered correspondingly. The membrane 11 is connected by a rod 12 to a membrane 13 in the top cover of the separator 8, and a beam-lever 14 is connected to the rod 12. The motion of the outer end of the lever is transferred by the rod 15 to a valve or its equivalent, regulating the pump in such a manner that when the pressure in the separator 8 falls the pump 6 will forward working medium, but will stop when the pressure in the chamber 10 and separator 8 are equal. This stopping and starting mechanism may be arranged in any suitable known manner used for this purpose.

The heating liquid, with the steam, flows from the pressure-regulator 9 into the separator 8, in which the separation of the steam and the heating liquid is effected. For this purpose obstacles, such as the partition-plate 16, are placed in the way of the passage of the steam by which in the known manner the separation of the gaseous and liquid substances is effected. The heating liquid settling to the bottom of the separator is drawn off by the continually-working pump 27 through the pipe 25 and forced through the pipe 27′ into the collector 28, whence it passes through the pipe 29 again to the heater 1. In the separator 8 preferably a float 17 is arranged, which is attached to the lever 19 and acts upon the outlet-valve 20, and thus regulates the level of the heating liquid collected in the separator in such a way that when the float is raised by the liquid and lifts the valve 20 the liquid is forced by the pressure of the steam out of the separator into the collector 28 and thence into the heater 1. Obviously the utilized heating liquid could be forwarded to the collector 28 or heater 1 by the valve 20 only, or only by the pump 27, or by any other suitable means. The steam under pressure flows through the pipe 21 to the engine 26 and the exhaust-steam through the pipe 22 into a condenser 23 of any suitable construction. It is there condensed and drawn through the pipe 24 by the pump 6, which forces it again into the mixing-pipe 5, where it is again mixed with heating liquid and evaporated and passes again through the same cycle of actions. The heating liquid performs a similar cycle as the working medium, in which provision is made to separate from the exhausted steam any heating liquid that may be carried over notwithstanding the arrangement of the separator hereinbefore described and to return it to heater. This is effected by the collector 28, preferably formed as a separator, as shown, with partitions alternately open at the top and bottom, into which the heating liquid passes when it accumulates in excess in the separator 8 and the float 17 opens the valve 20. The pressure of the steam existing in the separator 8 then presses the excess of heating liquid through pipe 30 into the collector 28 till the sinking float closes the valve 20 and transfers the duty of returning the heating fluid to the collector exclusively to the pump 27; but as the steam may carry over particles of the heating medium which then pass on with the exhaust the exhaust-pipe 22 is connected by the pipe 31 with the collector, so that such particles of heating liquid likewise flow into the collector 28 and are returned to the heater 1, while the exhaust travels on to the condenser 23. Preferably a non-return valve is inserted into the pipe 22 in front of the condenser 23, so that the exhaust-steam cannot return from the condenser, while if the pipe 31 is made wide enough any exhaust collecting in the separator can pass likewise into the condenser notwithstanding the liquid flowing down the wall of the pipe.

The pipes and various receptacles are

placed as shown on Fig. 1 only for the sake of clearness, while in practice they would be partly behind each other and not visible.

In the arrangement represented by Fig. 2 the heating liquid and working agent are brought together in the engine-cylinder, so that the motive power is only generated within the same. From the heater 1, provided with the stand-pipe 2, the liquid, as in the arrangement hereinbefore described, is drawn through the pipe 3 by the pump 4 and pressed through the pipe 5, with branch pipe 5′, into the valve-chambers arranged at the upper and lower ends of the engine 26. At the same time the working medium is drawn through the pipe 24 from the condenser 23 by the pump 6 and forced through the pipe 7, with branch pipe 7′, into the same chambers of the engine arranged, as an instance, as a wall-engine. The evaporation of the working medium commences in these chambers, and the valves 32 35, operated by suitable gear, admit the mixture, according to the position of the piston above or below the same, while the exhaust, with the heating liquid, passes through the valves 33 36 and the pipe 22, with branch 22′, to the collector and separator. The heating liquid collected at the bottom of the latter flows back through the pipe 29 to the heater 1, while the exhaust passes through the pipe 40 to the condenser 23 in order to be condensed and again supplied to the engine 26 by the pump 6. The valve-gear for actuating the valves 32, 35, 33, and 36 may be of any known suitable construction. In the example represented the valves 32 and 33 are connected to the frame of rods 31, which by the eccentric-rod 38 are connected to an eccentric on the crank-shaft of the engine. In the same manner the valves 35 and 36 are connected to the frame of rods 34, which by the eccentric-rod 39 is connected to an eccentric on the crank-shaft. The eccentrics actuating the inlet and outlet valves are arranged in the known manner, so that the inlet-valve 32 and the outlet-valve 33, for instance, are open, while the valves 35 and 36 remain closed. The mixture of heating liquid and steam under pressure will then enter the hollow cylinder-cover 26, provided with a hollow trunk entering the hollow piston, and drives the piston downward, which expels the mixture of heating liquid and steam in front of it through the open exhaust-valve 33 into the pipe 22 and thence into the separator. When the piston has attained its lowest position, the valves 35 and 36 are opened, the mixture of heating liquid and steam passes under the piston, and it moves upward, while the exhaust and used heating liquid escape through the valve 36, and thence pass through pipes 22′ and 22 to the separator. The two pumps 4 and 6 are shown actuated in the known manner from the engine-shaft. To avoid losses of working medium, the stuffing-boxes for the valve-rods are preferably arranged, as shown by Fig. 2, so that they are always covered by heating liquid.

The arrangement represented by Fig. 3 in general is the same as that herein last described, but shows an example in which the heating and working medium are brought together in the engine-cylinder, but without the use of a pump for the heating liquid. The engine being the same as that shown by Fig. 2, it is only shown in outline on Fig. 3. The heating liquid in this arrangement is drawn directly by the engine-piston through the bifurcated pipe 3, while the pump 6 6′ draws the working medium from the condenser 23 through the bifurcated pipe 24 and 24′ and forwards it through the delivery-pipes 7 7′ to both ends of the cylinder, so that the mixing of the heating and the working medium takes place as in the arrangement described with reference to Fig. 2. In the arrangement according to Fig. 3 it is only necessary to govern the exhaust-valves 33 and 36, while the inlet-valves 32 and 35 act as automatic suction-valves. As the piston descends it opens by its sucking action the inlet-valve 32 and draws in heating liquid. Following quickly upon this the pump 6 forwards working medium through the pipe 7 to the engine-cylinder, and the evaporation of the working medium drives the piston farther down. During the downstroke of course the outlet-valve 33, governed by the rod 31, is open, so that the mixture of working medium and heating liquid below the piston is forwarded through the pipe 22 into the separator, from which the heating liquid is returned through pipe 29 to the heater 1, while the exhaust passes through the pipe 40 into the condenser 23, and is drawn from it again by the pumps 6 6′. The inlet-valve 35 remains closed during this operation in consequence of the pressure of the mixture underneath the piston. The valve 36 likewise remains closed, as the valve-rod 34 is not actuated until the piston has reached its lowest position, when the valves 33 and 36 are reversed by the action of the valve-gear and the valves 32 and 35 by the upward movement of the piston. The piston then draws through the raised valve 35 fresh heating liquid into the cylinder, and the pump-cylinder 6 delivers a little later working medium, so that the process just described with reference to the downstroke is repeated for the upstroke, the valve 32 being closed and the previously-used mixture of working medium and heating liquid being forced through the opened valve 36 and branch 22′ into the pipe 22.

Fig. 4 shows an engine with a modified arrangement for the distribution of heating liquid and working medium to each end of the cylinder, which may be applied with the arrangement represented by Fig. 2. This distribution is effected by a piston-valve or an equivalent flat slide-valve. The valve 62 contains for each cylinder end a chamber (63 and

63′) provided with an escape-valve. In the position shown on Fig. 4 the cylinder-piston 64 moves downward. The valve 62 lags behind the piston 64 by the width of the inlet-port, so that when the piston has reached its lowest position the valve just begins to open the lower inlet-port. In the position shown by Fig. 4 the mixing-chamber 63 of the valve 62 is fully opened, so that the mixture of heating liquid and working medium can pass into the engine-cylinder above the piston, while the lower mixing-chamber 63′ is in open communication with the port 65 and is filled through the pipe 43 with a mixture of heating liquid and working medium. While the piston is propelled downward by the steam developed from the mixture, the piston-valve 62 likewise moves downward, the chamber 63 cuts off the supply of mixture to the cylinder, and while the upper end of the port 65 opens to the emptied chamber 63 the lower end of the port 65 is closed by the filled chamber 63′. In the lowest position of the piston 64 the valve 62 has moved so far downward that the mixture then enters into the cylinder below the piston 64 from the chamber 63′. In the lowest position of the piston 64 the outlet-valve 36 is lifted and opened by the valve-rod 34, which is actuated in any suitable way, while the previously-open lower outlet-valve 33 is closed, the valve 36 remaining open till the piston 64 reaches the end of its upstroke. The exhaust and used heating liquid are during the upstroke of the piston expelled and passing through the open valve 36 enter the chamber 66, whence they flow through the opening 67 into the communicating ports 68 and thence to the separator. When the piston has again reached its highest position, the upper chamber 63 is opened, the lower one 63′ closed, the valve 36 closed, valve 33 opened, and the used power mixture under the piston 64 passes as the piston descends into the lower chamber 66′ and thence to the ports 68 and to the pipe 22.

When using the motors shown as examples by Figs. 2 to 4, compression in the engine-cylinder must be omitted in order not to obtain liquid-hammer blows. The motors represented by Figs. 2 to 4 and 6 to 10 contain a source of loss of heat by exhausting the steam or gas used in the cylinder, together with the heating liquid, in consequence of which the latter again uselessly heats the exhaust without producing any power thereby. It is therefore preferable not to completely utilize the steam or its equivalent, and work engines arranged according to Figs. 2 to 4 and 6 to 10 as high-pressure engines only or with little expansion, then conducting the heating liquid and steam into a receiver or separator and separating therein the liquid from the steam, and then utilizing the steam fully in one or more steam-engine cylinders of ordinary construction. This in its essence is a combination of one of the engines, Figs. 2 to to 4 and 6 to 10, with that shown by Fig. 1 in the manner represented by Fig. 5, for instance. The engine 26 in this arrangement is constructed as a compound engine, and the used mixture of heating liquid and exhaust-steam issuing through the valve 33 passes through the pipe 22 into the separator 8, Fig. 5. Thence the pipe 61 after the valve 32 has opened conducts the exhaust, still possessing pressure, above the large piston of the compound engine, whence after performing its work it will pass through valve 36 and pipe 22′ to the condenser.

In all the apparatus in which the working steam is only generated in the engine it is very important that the heating liquid and working medium, notwithstanding the short way passed through by the mixture, should be most intimately mixed. This may be effected by placing suitable obstacles in the inlet-ports of the cylinder which the mixture of heating liquid and working medium has to pass before entering the cylinder. In some cases, however, it is preferable to employ separate mixing-chambers in front of the steam-ports. The mixing-chambers are refilled with heating liquid and working medium directly after they have emptied the fluid mixture into the cylinder. Fig. 6 shows an arrangement of this kind which can be applied to the engine 26, Fig. 2, or used for the chambers 63 63′ of the engine, Fig. 4. Assuming the working medium to have arrived with the heating liquid at the mixing-chamber 42 and to move the engine-piston upward in consequence of the generation of steam after the valve 35 is opened, heating liquid and working medium have flowed through the pipe 43 into the mixing-chamber 44 and have filled it, while the valve 32 remains closed, which is rendered possible by the arrangement of an air or safety valve 45. In this chamber 44 the mixer 46 is movable, consisting of a number of finely-perforated plates fixed to a common spindle, and is lifted while the heating liquid and working medium flows into the chamber, as shown by Fig. 6. During the time the engine-piston makes its stroke the mixer 46 sinks down, and the mixture of fluids passes through the fine perforations of the plates, so that an intimate mixture of the heating liquid and working medium, as well as a better equalization of the temperature, is effected. As the mixing-chamber 44 is entirely closed, working steam cannot be generated, but is produced only when the piston has completed its upstroke and the valves are reversed. The evaporation of the working medium will then take place almost instantaneously, as the medium is heated above its boiling-point, while steam could not be generated for want of space, which is only formed by the opening of the valve 32 and the movement of the piston. The latter is thus propelled downward, and while the valve 35 is closed the mixing-chamber 42 is filled through the pipe 41 with heating liquid and working medium, the mixer 47 is lifted up, and the

play just described with reference to the chamber 44 will be repeated for the mixing-chamber 42.

In the arrangement represented by Fig. 6 for the intimate mixing of the heating liquid and working medium only one mixing-chamber 42 or 44 is provided for each end of the cylinder; but two or more such chambers may be arranged for each end of the cylinder, coming into action successively, so that one of the mixing-chambers is filled and respectively emptied for each stroke of the piston. By this multiplication of the mixing-chambers the time for exchanging the heat is prolonged in each chamber and the complete utilization of the working medium further assured. Instead of these the apparatus shown by Fig. 7 in longitudinal section may be used, which at the same time is provided with a stop-motion for the pumps delivering the heating liquid and working medium to the mixing apparatus. The pipe 41, delivering the mixture of heating liquid and working medium, opens into the cylinder 48, which with its perforated end protrudes into the mixing-chamber 49 and contains an easily-moving piston 50, to the end of which a series of inclined perforated plates 51 are fixed, behind which a similarly-perforated vertical plate 52 is arranged. Against this plate presses a spring 53, abutting against the end 54, from which the mixture is conveyed to the upper and lower end of the engine-cylinder. The heating liquid forced by the pumps into the pipe 41 presses the piston 50 back against the spring-pressure, whereby the perforated plates 50 51 effect an intimate mixture of the working medium and heating liquid in the mixing apparatus. The piston 50 is pushed back till the perforations of the cylinder 48 are uncovered, when a quantity of roughly-mixed heating liquid and working medium corresponding with the stroke of the pumps enters the mixing apparatus 49. If the level of the liquid in the apparatus is raised thereby, it is equally raised in the laterally-arranged vessel 55, which is connected by a flexible pipe 56 with the lower part and by a flexible pipe 57 with the upper part of the mixing apparatus. The vessel 55 is suspended at one end of a balance-lever 58, the other end of which is weighted by a weight 60 and connected to the rod 59, actuating the stopping apparatus of the pumps. The vessel 55 thus forms an automatically-varying load on the lever 50, so that it descends and lifts the stop-rod 59 when the pumps deliver more mixture of heating liquid and working medium to the mixing apparatus than is consumed for feeding the engine. The pumps are then stopped by the rod 59, the level of liquid in the mixing apparatus sinks in consequence of the continued consumption by the motor, the vessel 55 becomes lighter, and the weight 60 sinks down and lifts the vessel 55 again, whereby the stop-rod 59 is moved downward and the pumps are restarted. During the time in which the pumps do not supply any liquid to the mixing apparatus, and consequently also at the change of stroke of the pumps, the previously-compressed spring 53 pushes the perforated plate 52 and the piston-rod and piston 50, with the perforated plates 51, to the left, whereby a renewed mixing of the heating liquid and working fluid is produced, the play of the parts being repeated when the pumps start again. By adjusting the weight 60 on the lever 58 the supply by the pumps can thus be adjusted to the consumption by the engine.

With all the examples of arrangements of apparatus hereinbefore described pumps were used for delivering the heating liquid. The employment of pumps, however, is not necessary, for feed-cocks or, in combination with suitable governing-gear, feed-chambers may be used for this purpose.

Fig. 8 represents a single-acting motor operated by means of a feed-cock. The plug 61 of the cock is rotated by means of the spur-wheels 62 and 63 (indicated by dotted lines) from the engine crank-shaft 64. The piston 65 is shown in its highest position on Fig. 8, and immediately afterward the cock opens the exhaust from the cylinder through the port 67. The piston 65 then moves downward, while heating liquid flows into the hollow plug 61 through the port 68 and pipe 3 from the heater 1, Figs. 1, 2, and 3. (Not shown on Sheet 7.) The steam present in the interior of the plug 61 escapes through the port 69, Figs. 9 and 10, into the pipe 22 and the condenser 23, Fig. 1. The heating liquid cannot entirely fill the plug, but will do so only to the lower edge of the slit-shaped port 69. The turning of the plug meanwhile having so far progressed that the inlet-port 68 for the heating liquid is cut off and the port 69 closed, the pump 6 for the working medium injects through the pipe 80 and port 68 working medium into the plug 61. As the piston moves farther down and reaches its lowest position the outlet-opening 67 of the turning plug is closed, and immediately after the port 70 from the plug to the cylinder is opened, so that the mixture of heating liquid and working medium can pass through the passage 71, arranged in the plug, into the cylinder below the piston, only steam remaining in the plug. The piston is now pushed upward by the steam generated from the working medium, and when it has reached the end of its upstroke the rotation of the plug has closed the port 70 and the play of the parts described is repeated. The feed-cock in the example shown has only one chamber; but two or more such chambers may be arranged acting successively by means of a suitable arrangement of the ports and the relative speed of rotation. Obviously the engine could also be made double-acting by arranging cocks acting in opposite ways at the top and bottom end of the cylinder.

When the motor is a steam-turbine, the heating liquid and working medium are sim-

ply pumped into the pipe leading to the nozzle. The generated steam may be used by itself or mixed with the heating liquid. The arrangements for this purpose are obvious from the previous descriptions and drawings.

It is advantageous to surround the delivery-pipes, as well as the engine-cylinder, with the heating liquid in order to obtain a supplementary heating of the mixture of heating liquid and working medium, which naturally has a lower temperature than the unmixed heating liquid. This is done by providing the pipes and vessels containing the mixture with jackets through which the heating liquid circulates.

The speed of the motor is regulated in all the arrangements hereinbefore described by varying the quantity of the working medium or of the working medium and the heating liquid supplied to the motor or in any other suitable way. Naturally the use of the novel method is not confined to the examples hereinbefore described, but it may be adapted to any other motors or power-engines driven directly by steam or gas under pressure.

In describing the novel method and its application the source of power has hereinbefore been designated by the general term of "working medium," because the latter may be a liquid or a gas or even a salt evaporating without residue. When compressed or liquefied gases are used as working medium, they are condensed by a special pump after passing through the condenser or the heater and condenser, or the latter only are arranged to be under the pressure of the compressed or liquefied gas. The compression of the gas naturally is only small, as the working pressure of the same is only produced at or in the motor by mixing the compressed gas with the heating liquids. The object of the compression is only to obtain a larger effect with small quantities of the working medium, for in the engine only the difference in the pressures of the cold and heated gas is utilized.

The special result of the novel method consists in the removal of all danger of explosion, and while in practice hitherto an excessively high pressure of steam had to be avoided chiefly in consequence of the insecurity of the dangerous boilers this danger is entirely obviated by the use of the new process. The heater 1 can have any size, as there is no pressure in it likely to become dangerous, while the parts in which pressure is produced can be made of so small a diameter that they are perfectly safe against explosion under the highest pressure. If, nevertheless, an explosion should occur through insufficient strength of the walls, it can act destructively only to a very small degree, as only small quantities of steam are present.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim, and desire to secure by Letters Patent of the United States, is—

1. The combination in apparatus for generating steam for driving motors without high-pressure boilers, of pumps for feeding a heating and a working liquid, a heater for heating the heating liquid, devices for regulating said pumps, and membranes for operating said devices, one membrane being actuated by the varying pressure of the working liquid as its temperature varies, and the other membrane being actuated by the varying pressure of the mixed liquids, substantially as described.

2. In apparatus for generating steam for driving motors without high-pressure boilers, the combination with a heater and motor, of valves at the motor equipped with chambers for the liquids, and escape and safety valves at said chambers, substantially as described.

3. In apparatus for generating steam for driving motors without high-pressure boilers, the combination of a heater for heating the heating liquid, means for mixing the working liquid with the heating liquid, a motor and means for feeding the mixed liquids into the motor, substantially as described.

In witness whereof I have hereunto set my hand in presence of two witnesses.

ADOLF SCHARFFE.

Witnesses:

HENRY HASPER,

W. RUTZKE.