No. 745,589. PATENTED DEC. 1, 1903.

J. C. FRALEY.

ART OF DEVELOPING AND UTILIZING FLUID PRESSURE.

APPLICATION FILED JAN. 31, 1903.

NO MODEL. 2 SHEETS—SHEET 1.

FIG. 1.

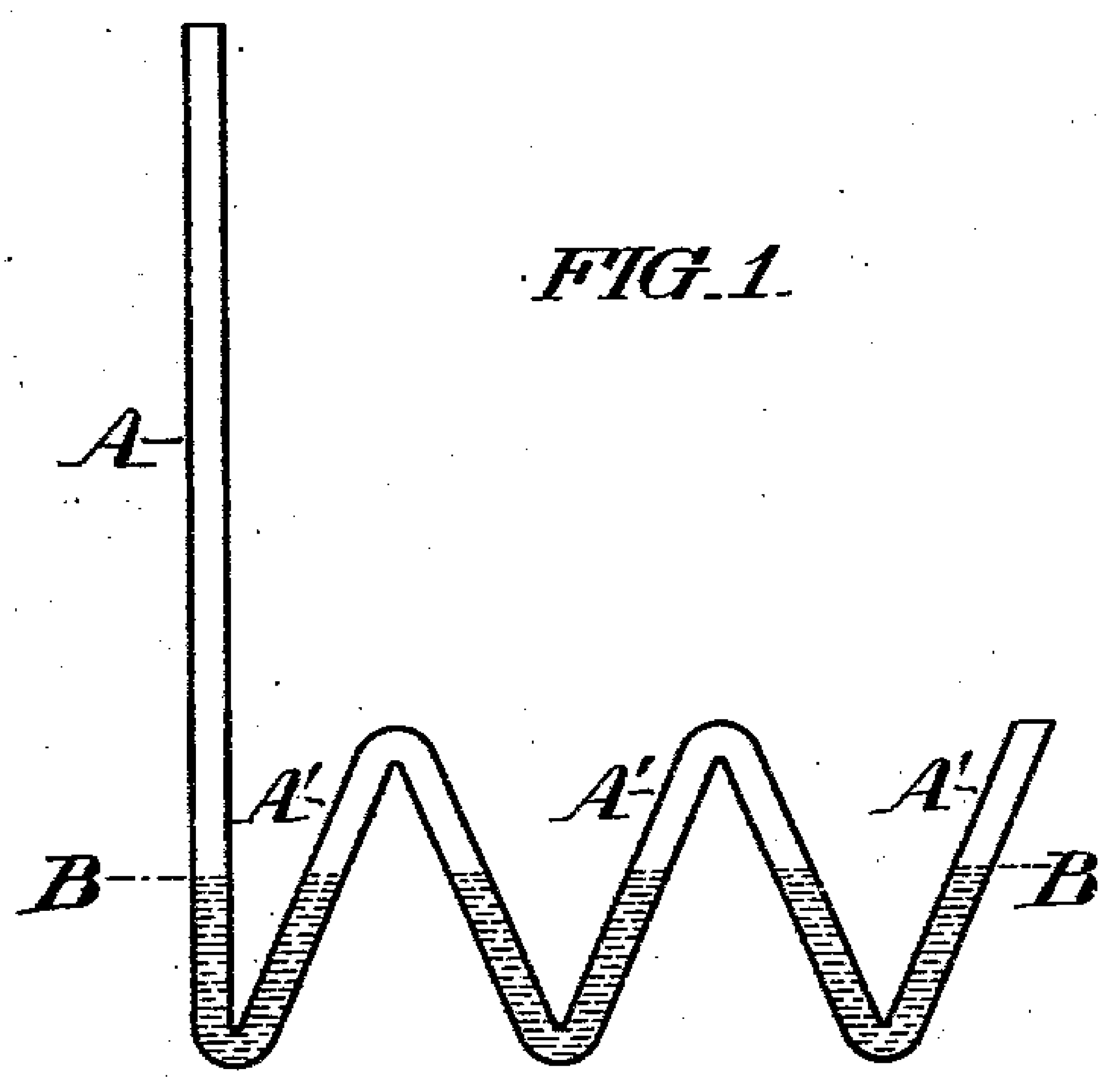


FIG. 2.

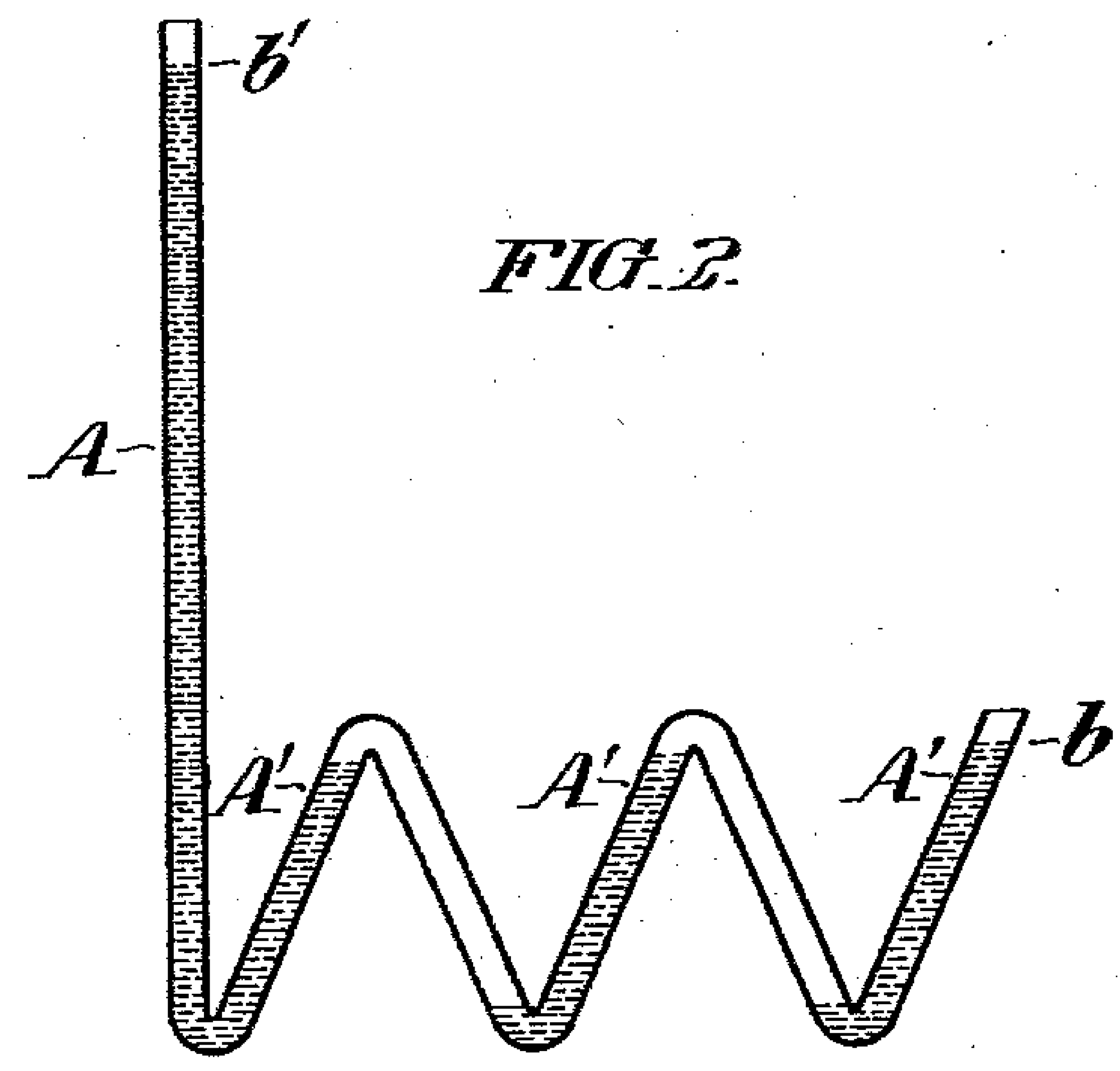
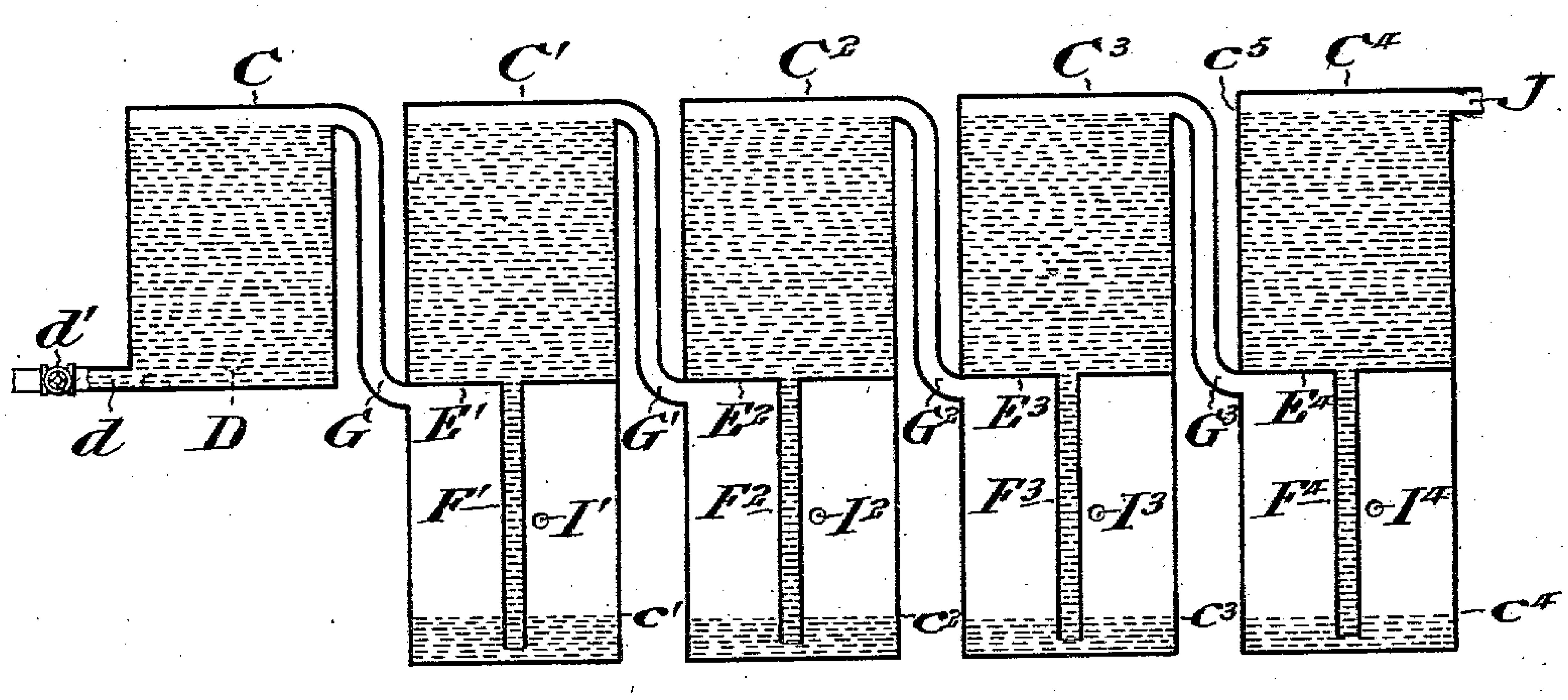


FIG. 3.



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NO MODEL. 2 SHEETS—SHEET 2.

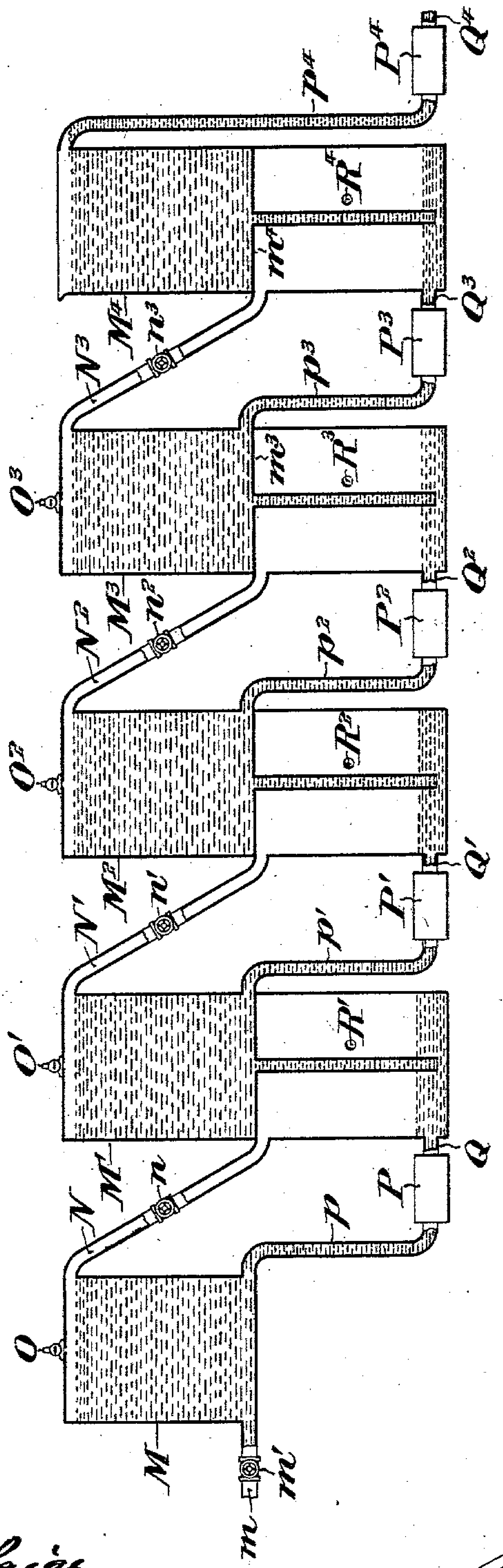

FIG.4.

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No. 745,589. Patented December 1, 1903.

UNITED STATES PATENT OFFICE.

JOSEPH C. FRALEY, OF PHILADELPHIA, PENNSYLVANIA.

ART OF DEVELOPING AND UTILIZING FLUID-PRESSURE.

SPECIFICATION forming part of Letters Patent No. 745,589, dated December 1, 1903.

Application filed January 31, 1903. Serial No. 141,251. (No model.)

To all whom it may concern:

Be it known that I, JOSEPH C. FRALEY, a citizen of the United States, residing at No. 1833 Pine street, in the city and county of Philadelphia, and State of Pennsylvania, have invented certain new and useful Improvements in the Art of Developing and Utilizing Fluid-Pressure, whereof the following is a specification, reference being had to the accompanying drawings.

It may be noted that my application, Serial No. 175,761, filed October 5, 1903, for Letters Patent of the United States for improvements in apparatus for developing and utilizing fluid-pressure, comprises claims for an apparatus which, broadly speaking, involves similar conditions to those existing in the apparatus herein set forth.

My invention relates to the development and utilization of fluid-pressure for dynamic purposes, the characteristic principle of operation being cumulative action so organized as to permit supply and withdrawal of fluid under sustained pressure. By "cumulative action" I mean the behavior of a plurality of fluid columns when so combined in series as to exert a pressure substantially equal to that of a single column whose height is represented by the sum of the heights of the individual columns.

The invention can be appropriately explained by reference to a typical instance of its practical embodiment, and I have accordingly selected as such a stand-pipe for a hydraulic system, where of course the purpose is the delivery of water under pressure. I do not, however, restrict myself to this particular application, as the invention may be utilized for other dynamic purposes.

Referring now to the drawings, Figures 1 and 2 show in elevation a tube of peculiar form by means of which the underlying physical principle of the invention may conveniently be explained. In Fig. 3 I have illustrated the application of the invention for the purpose of a stand-pipe, the device being shown in vertical longitudinal section. In Fig. 4 I have again illustrated the application of the invention for the purpose of a stand-pipe, the system, however, exhibiting a further development of the main or characteristic principle.

In Figs. 1 and 2 a tube is shown, which may be supposed to be of glass for the purpose of inspection. This tube has at one extremity a long leg A, whose lower end is connected with a series of undulations A′, similar to one another, but of much less height than the leg A. If the lower half of the several undulations be filled with liquid, the upper portions thereof being occupied by air, the several columns therein contained will of course be in equilibrium with each other and will balance a similar liquid column in the long leg A. This condition is shown in Fig. 1, where the line B B indicates the general liquid-level. If, however, liquid be poured into the long leg A of the tube, it will tend to displace the immediately adjacent body of liquid in the first undulation, causing the liquid to rise therein toward the top portion, and the movement of this confined body of liquid will be transmitted by the adjacent confined body of air to the body of liquid in the next undulation, tending to similarly displace it, and so on through the series of undulations. This displacement will continue until the total height of the column in the long leg is substantially equal to the sum of the heights of the several columns in the undulations, as illustrated in Fig. 2, where the level of the liquid in the long leg is shown at *b*′, and the upper level of the series of displaced columns is shown at *b*. Air being compressible, the actual conditions will vary slightly from those which would exist if the whole movement of displacement were uniformly transmitted throughout the entire series; but for purposes of illustration this factor may be considered as negligible. By protracting the undulating portion of the conduit any desired degree of pressure may be attained at the basic end of such an apparatus.

The physical movement of the fluid in the various columns is attended by a progressively-increasing pressure, due to the fact that the displacement of the normal level has the effect of not merely lengthening that column which rises, but also of shortening to the same extent the opposing column by which it was formerly balanced. The converse of this is of course true, and hence withdrawal of fluid from the region of ultimate pressure will, unless compensated, be attended by diminishing pressure in a similar progressive ratio by reason of the tendency toward equilibrium exhibited in all the several columns.

It will be furthermore noted that the extent of the movement of the several columns is limited by the following conditions: If the body of lighter fluid be forced beyond the level where it is confined or trapped by the surface of the next adjacent column of heavier fluid, the lighter fluid will rise through the heavier one and the positions of the columns will be disturbed, resulting in disorganization, more or less complete, of the system.

Referring now to the application of the invention for the purpose of a stand-pipe, as shown in Fig. 3, C represents a closed vessel or reservoir having an inlet D, (shown in dotted lines,) connected with the delivery-pipe of the pumping system, (details not shown.) Said vessel is also provided with an outlet d, connected with the distributing system, (details not shown,) the main controlling-valve of the outlet being indicated at d'. The vessel C is the region of ultimate pressure in the system; but while it incidentally affords pressure in accordance with its own height its substantial function is to store the water in sufficient quantity to meet momentary excesses of withdrawal over supply without too great fall of the water-level within it.

Adjacent to the vessel C, I arrange a plurality of vessels C' C^2 C^3 C^4, similar to one another in height and cubic capacity, each of which, with the exception of the end one of the series, (in this instance C^4,) is closed to the atmosphere. At a level which in the present case is half the vertical height of said vessels each of them is provided with a transverse diaphragm, as indicated at E' E^2 E^3 E^4. Pipes F' F^2 F^3 F^4 lead from said diaphragm to a level close to the bottoms of the several vessels. Pipes G G' G^2 G^3 lead, respectively, from the upper portion of one vessel to a point below the diaphragm of the next vessel of the series. These diaphragms divide the vessels into upper and lower compartments, the area of cross-section of which should preferably not be less than the area of cross-section of the reservoir vessel C.

The several vessels C' to C^4, inclusive, may be provided with valve-controlled inlets I' I^2 I^3 I^4 below the level of the diaphragms, said inlets being connected with a source of supply of air under pressure. The last vessel, C^4, of the series is open to the atmosphere at the top, being shown as provided with an overflow or outlet pipe J.

At the commencement of the operation let it be supposed that the outlet d, leading to distributing system, is closed by means of the valve d'. The pump is actuated to force water into the apparatus through the inlet D. As soon as the reservoir vessel C is filled to the level of the pipe G the water will overflow and pass down said pipe into the lower compartment of the vessel C', where it will rise until its level seals the bottom of the pipe F'. As the air can no longer escape from said compartment, the further entry of water will result in the compression of the confined body of air below the diaphragm E' until a degree of tension has been reached which will compel the water thereafter entering to rise through the pipe F' into the upper compartment of the vessel C' above the diaphragm E', where it will accumulate until said upper compartment of the vessel is filled with water to the level of the pipe G'. Thereupon the water will overflow down said pipe and into the closed vessel C^2, where a similar action will take place, resulting in the overflow of the water into the next vessel C^3, and so on throughout the series until the water has filled the upper portion of the last vessel thereof, when it may overflow into any desired waste-channel. Under these conditions the air in the lower compartment of the last vessel, C^4, below the diaphragm E^4, will be under a pressure equal to the height of the column of water from the level c^4 of the water in said lower compartment to the level c^5 of the surface in the upper compartment. The confined body of air below the diaphragm E^4 will communicate this pressure through the pipe G^3 to the top of the water column in the vessel C^3. Consequently the confined body of air beneath the diaphragm E^3 of said vessel C^3 will be under a pressure equal to that transmitted from the vessel C^4 plus the pressure due to the water column in the vessel C^3 itself, said column extending from the upper water-level down to the level c^3 of the water in its lower portion. Similarly the double pressure thus developed will be transmitted by the confined body of air through the pipe G^2 to the top of the next water column in the vessel C^2, and said column in C^2 will exert a threefold pressure upon the confined body of air below the diaphragm E^2, said pressure being thence transmitted by said body of air through the pipe G' to the top of the column in the vessel C', at whose base a further increment of pressure will be exerted, and finally the sum of all the pressures thus cumulatively developed will by means of the confined body of air below the diaphragm E' be transmitted to and exerted upon the water in the vessel C. Said vessel C may therefore be considered as the reservoir portion of a stand-pipe containing water at a pressure equal to the sum of the series of individual pressures and by proper maintenance of the water-level through the action of the pumping system may be utilized for the distributing of water, just as in the case of an ordinary stand-pipe.

One factor which should be noted in the operation of an apparatus of this character is the compressibility of the air confined between the base of one column and the top of the next and the consequent diminution of its bulk, which permits the rise of water in the bottom portion of a vessel to a level somewhat above the lower extremity of the pipe leading down from its diaphragm. This rise of the water-level is progressive through the series, and it is conventionally indicated in Fig. 3. To the extent that the water thus rises in the lower part of the vessel it balances a certain portion of the total column, and thereby detracts from the theoretical degree of pressure which could be developed. Where the total pressure is not high, the effect due to the diminution in bulk of the confined air may be negligible; but should its elimination be deemed desirable this can be accomplished by pumping air under pressure into the lower portions of the several vessels. For this purpose I have indicated as adjunctive features the air-inlet pipes I′ I^2 I^3 I^4. It will be obvious that by forcing a sufficient quantity of air into the lower portions of the several vessels a degree of tension can readily be attained which will insure the minimum water-level therein under normal conditions.

Of course if the demand upon the reservoir vessel C substantially exceeds the supply pumped into the same the water-level therein will fall, and a corresponding fall will occur in the upper compartment of each one of the vessels of the series, accompanied by a rise of the water-level in the lower compartments of said vessels and a corresponding reduction of the total pressure developed by the system. It is therefore important in the practical operation of such a device that the normal level of the water in the reservoir C should be maintained as far as possible, since otherwise the efficient pressure of the whole system will tend to fall more and more rapidly unless artificially maintained, as by pumping air into the lower portion of the vessel C′.

As a feature of practical value I would call attention to the fact that such a system of storage of water under pressure may be placed at or below the level of the earth, and thus the unsightliness of an ordinary stand-pipe structure and other practical objections to the use thereof can be avoided.

Referring to the application of the invention illustrated in Fig. 4, I have there shown a system which in one aspect is similar to the system shown in Fig. 3, but possesses further capacities. The structure of Fig. 4 is also a stand-pipe system, having a reservoir vessel M for the distribution of water through the pipe m, said reservoir communicating with a series of vessels M′ M^2 M^3 M^4, constructed and combined as previously described. Instead, however, of relying upon or requiring a supply-pump capable of delivering water directly to the reservoir vessel M against the ultimate high pressure existing therein the water-supply throughout the system may be maintained by the use of a plurality of pumps, each one of which need only have the capacity of delivering water at a pressure equivalent to that of an individual column of the series.

It is not deemed necessary to redescribe those portions of the apparatus which correspond directly with the portions shown in Fig. 3, so that I shall now proceed to indicate only the further features of importance, which are as follows: A pump P^4, having its intake Q^4 in communication with the source of water-supply, is arranged to deliver water through the pipe P^4 to the upper portion of the vessel M^4. A second pump, P^3, is arranged with its intake Q^3 leading from the lower portion of the vessel M^4 and its delivery-pipe p^3 leading to a point in the vessel M^3 above the diaphragm m^3 thereof. Similar pumps, P^2, P′, and P, are interposed between the remaining vessels and connect each with the next throughout the series, the intake and delivery pipes of said pumps being indicated by letters of reference in accordance with the distinctions previously employed, so that further detailed description is unnecessary. The communication between the several vessels of the series through the pipes N N′ N^2 N^3 is controlled by means of valves n, n', n^2, and n^3, so that said vessels may be isolated from one another. The upper portion of each of the closed vessels is provided with a valve-controlled air-outlet, as indicated at O O′ O^2 O^3, respectively. At the commencement of the operation when it is desired to charge the whole system with water the valves n n' n^2 n^3 are closed, so as to cut off communication between the vessels, and the air-outlets at O O′ O^2 O^3 are opened. If now the pump P^4 be actuated, the vessel M^4 can be filled to the top, since the water cannot descend beyond the limit of compressibility of the air confined below the diaphragm m^4, owing to the fact that the valve n^3 is closed, and the piston of the pump P^3 may also be considered as closing the intake Q^3. When the water has accumulated in the vessel M^4 to the desired extent, the pump P^3 is actuated and will fill up the vessel M^3 by drawing off the water from the lower portion of the vessel M^4, the action of the pump P^4 being, of course, continued to maintain the water-level in the vessel M^4. Similarly the pumps P^2, P′, and P being successively thrown into action, all the remaining vessels will be filled. When the operation has proceeded as thus described and the system is fully charged with water, it is obvious that the pressure in each one of the vessels will be simply that which corresponds to the height of the individual water column therein, since said vessels are not yet so connected as to cumulatively transmit the pressure from one to another. If now the air-outlets O O′ O^2 O^3 be closed and the valves n n' n^2 n^3 be opened, the cumulative transmission of pressure from vessel to vessel will take place exactly as in the apparatus shown in Fig. 3 and the water in the reservoir vessel M will be under a pressure equal to the sum of the individual pressures of the series. As in the instance previously described, air may be forced in through the inlet-pipes R′ R^2 R^3 R^4 to compensate the loss of bulk due to compression, if desired; but this is obviously an adjunctive and not an essential feature. The valve *m′* controlling the delivery of water to the distributing system being opened, it is of course necessary that the demand upon the reservoir vessel M should be supplied by pumping water thereto in order to maintain the efficient water-level throughout the apparatus. For this purpose the series of pumps P P′ P^2 P^3 P^4 is actuated, and a continuous stream of water will then be forced through the apparatus from end to end, being finally delivered at the pressure characteristic of the vessel M. It will be seen, however, that no one of the pumps in said series need be capable of exerting any greater pressure than is represented by the height of one of the individual columns of the series, since the water at the intake of each pump is under a pressure corresponding to its position in the series, and the only effort required of the pump is to lift the water to the height of the next column.

For convenience of illustration and in order to fully explain the principle of operation I have shown as many pumps as there are vessels; but it is obvious that such a multiplication of pumps is not essential, since a less number of pumps of proper pressure capacity could convey water from any part of the system to any other region of higher pressure.

As the claims in this particular application are not addressed to the apparatus itself, I do not deem it necessary to describe such modifications thereof, but only advert to their possibility in order that I may avoid any seeming limitation. The characteristic feature of the system shown in Fig. 4 is that it permits a step-by-step transference of the fluid under pressure throughout the apparatus without requiring a pump capable of sustaining the total pressure of the system, and whether the steps be relatively large or small the principle remains the same.

I would further state in order to avoid misunderstanding that the use of the air-outlets O O′, &c., and valves *n n′*, &c., is not essential to the system, as the results which are obtained by these elements could obviously be otherwise attained.

Having thus described my invention, I desire to point out that its essential principle is the combination of a plurality of fluid columns in such relation to one another that the base of one column is operatively connected with the upper portion of the next column by an interposed and confined body of a lighter fluid in such an organized relation throughout the whole system as to permit the supply and discharge of fluid under the ultimate pressure thus obtained, while maintaining the series of columns in unstable equilibrium. The use of a plurality of fluid columns for purely static purposes, such as a gage for the mere exhibition of a degree of pressure exerted upon the fluid itself, is not within the scope of my claims; nor do I claim, broadly, the employment of an interposed body of light fluid, such as air, for the purpose of transmitting hydraulic pressure to the surface of heavier fluid, such as water. It must, furthermore, be borne in mind that while the ultimate body of fluid upon which the cumulative pressure is exerted may incidentally add to the total pressure of discharge because of its own vertical height, yet its essential function need not extend substantially beyond the provision of a reservoir from which the dynamic discharge takes place and to which fluid is to be supplied in order to maintain the essential condition of unstable equilibrium throughout the series proper. Hence the body of fluid in such reservoir is not necessarily to be considered as one of the series of pressure-producing columns, although it may be so organized as to become part thereof, provided the other essential conditions are present.

While I have in the accompanying illustrations shown four columns whose cumulative pressure is transmitted to the reservoir and have employed the term "series" in describing the same, I do not thereby imply that the method requires the use of such number or any particular number, provided there be such a plurality as will substantially embody the principle of cumulative action as hereinbefore set forth.

I would also state that in describing the system shown in Fig. 4 and the step-by-step conveyance of fluid under pressure thus effected I have set forth that the several vessels may at the outset be separately charged and then thrown into combination. I do not, however, limit my claim in this connection to such mode of initially establishing the columns. Moreover, in so far as concerns the separate establishment of a plurality of columns and their subsequent connection in series I have in an application of even date herewith (Serial No. 141,252) set forth and claimed a method of developing pressure which, broadly speaking, involves similar conditions, and consequently I do not specifically claim it herein.

I claim—

1. The hereinbefore-described method of developing, cumulatively transmitting and maintaining pressure, which consists in establishing a plurality of fluid columns, connected in series by interposed confined bodies of lighter fluid, extending from the base of each column of heavier fluid to the upper portion of the next column of such heavier fluid in the series; utilizing the cumulative pressure for the discharge of fluid from the region of ultimate pressure; supplying fluid to said region; and maintaining said columns in unstable equilibrium.

2. The hereinbefore-described method of

developing, cumulatively transmitting, and maintaining pressure, which consists in establishing a plurality of fluid columns, connected in series by interposed confined bodies of lighter fluid, extending from the base of each column of heavier fluid to the upper portion of the next column of such heavier fluid in the series; withdrawing fluid from the region of ultimate pressure; and progressively conveying fluid thereto from a region of lower pressure in the series itself; while maintaining said columns in unstable equilibrium.

In testimony whereof I have signed my name to this specification, this 30th day of January, 1903, in the presence of two subscribing witnesses.

JOSEPH C. FRALEY.

Witnesses:
JAMES H. BELL,
C. BRADFORD FRALEY.