(No Model.) 5 Sheets—Sheet 1.

C. E. EMERY.

APPARATUS FOR CONTROLLING AND INDICATING STEAM SUPPLY.

No. 473,733. Patented Apr. 26, 1892.

Fig. 1.

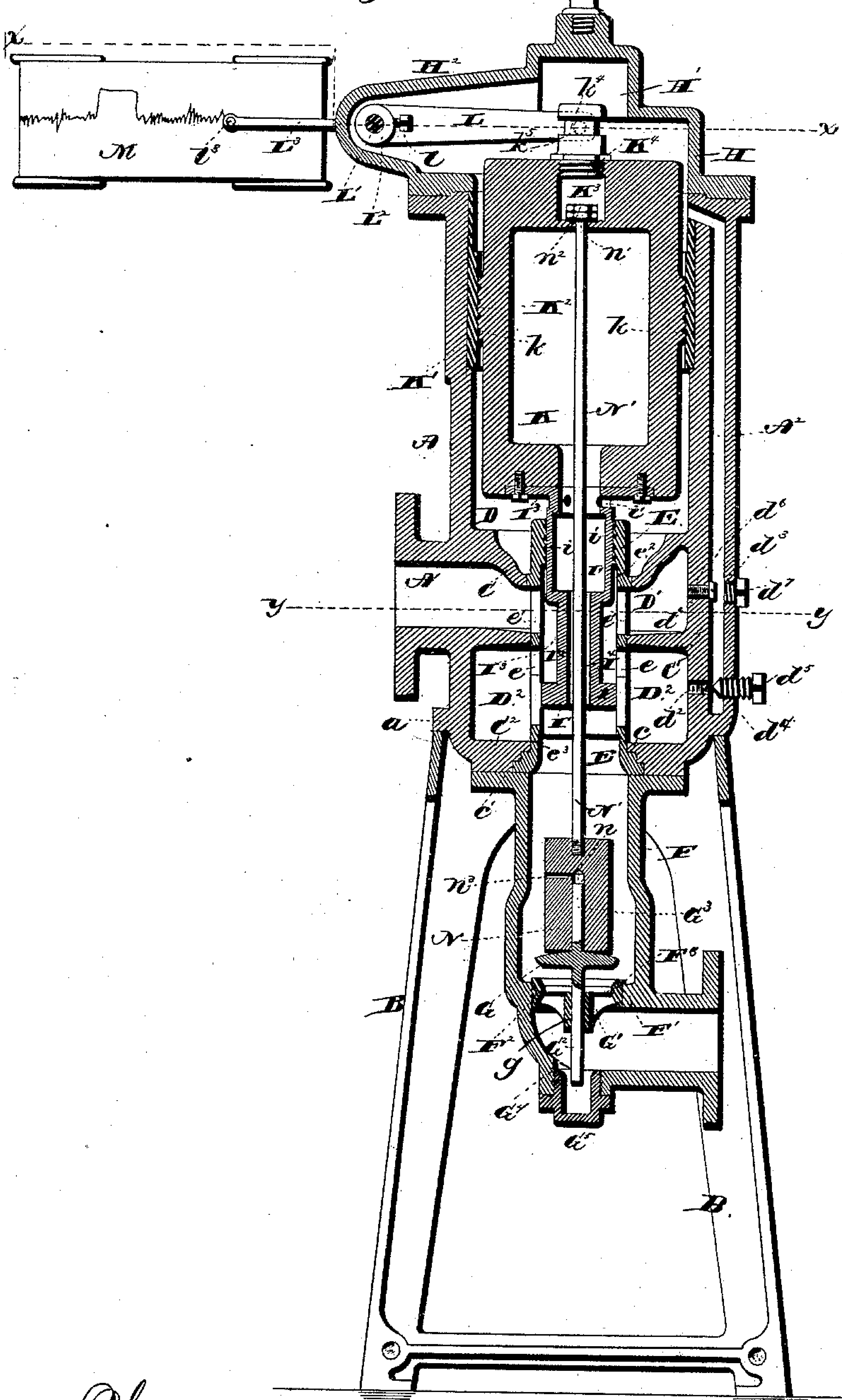

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Fig. 2.

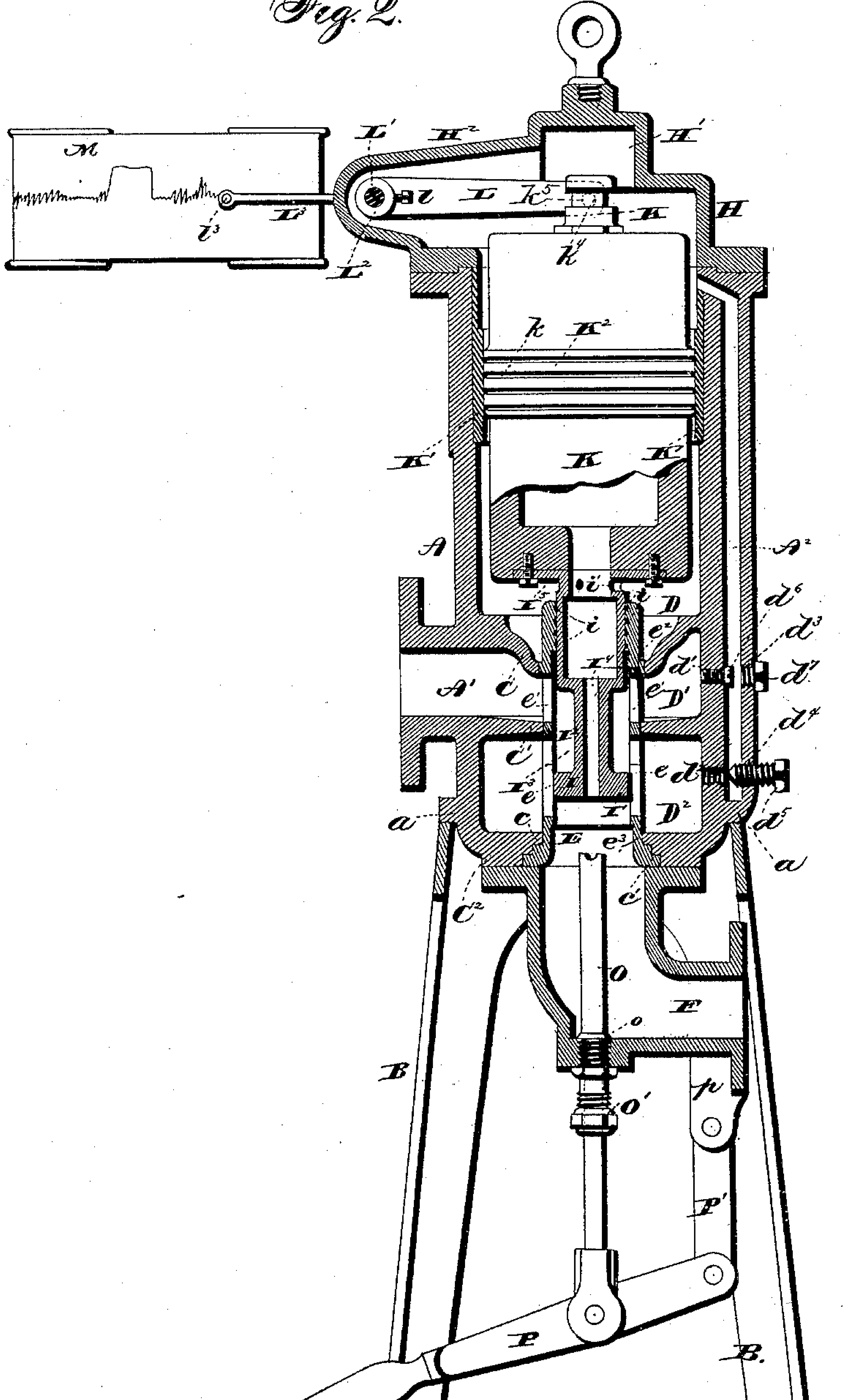

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Fig. 3.

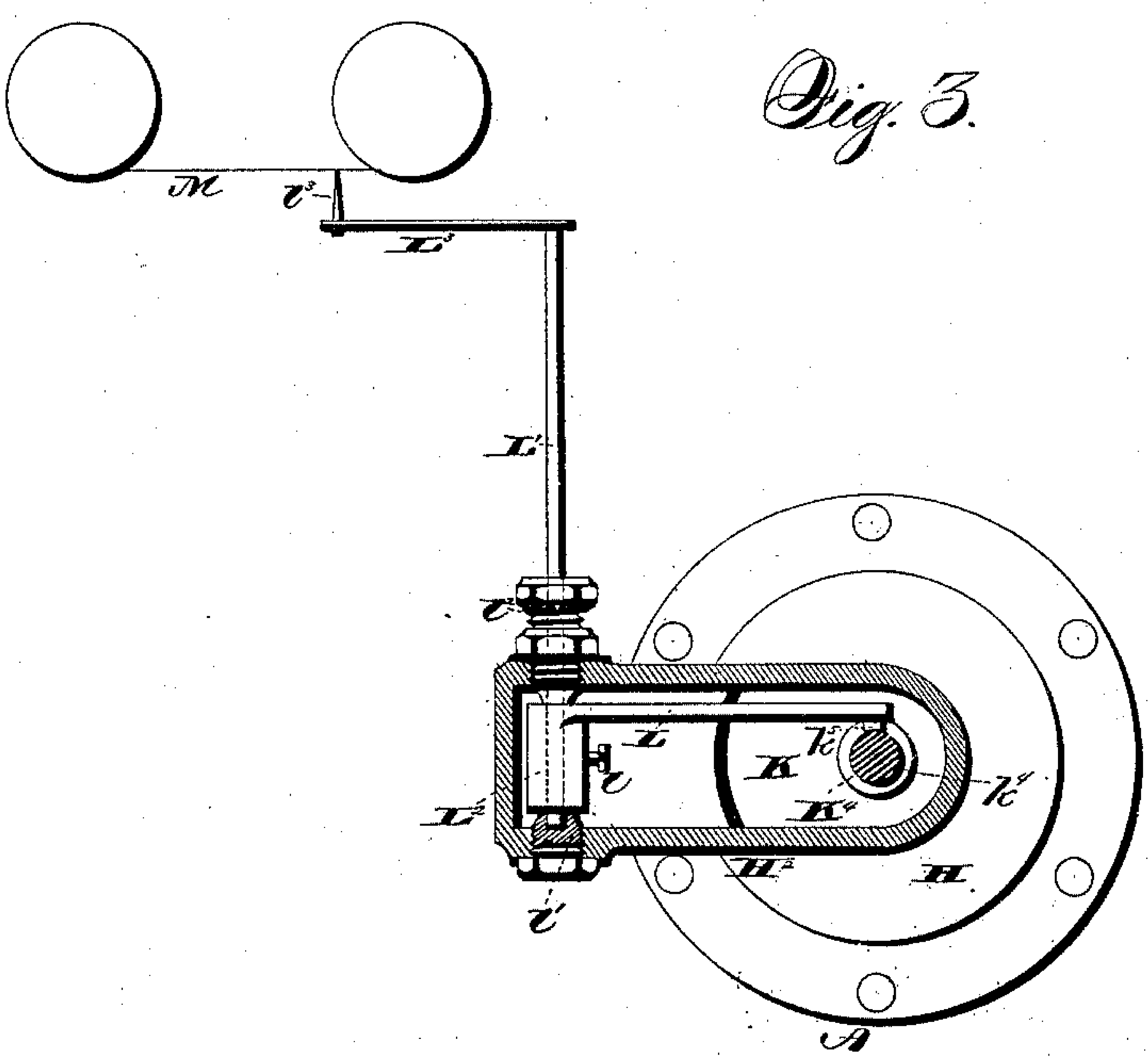

Fig. 5.

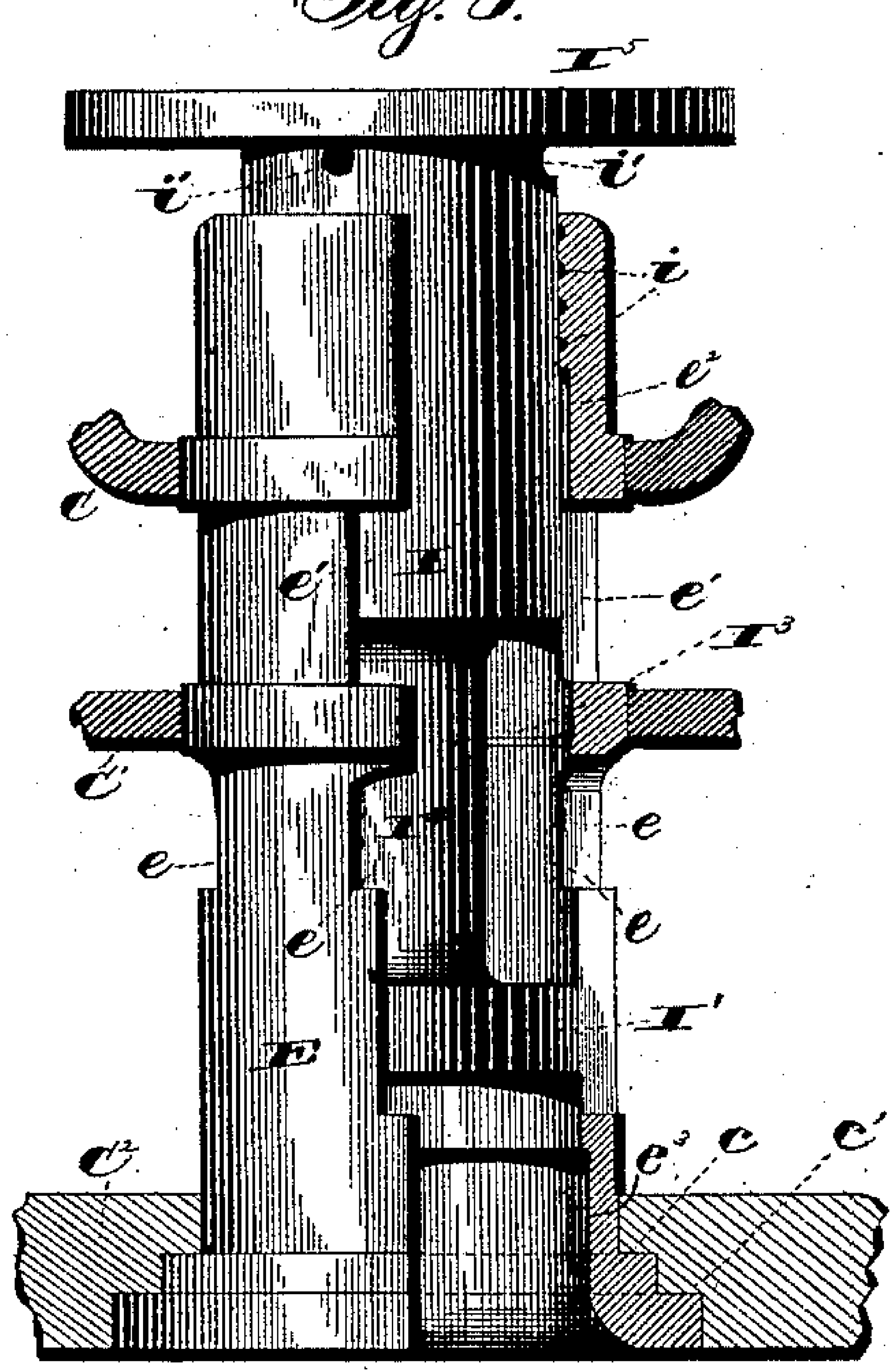

Fig. 4.

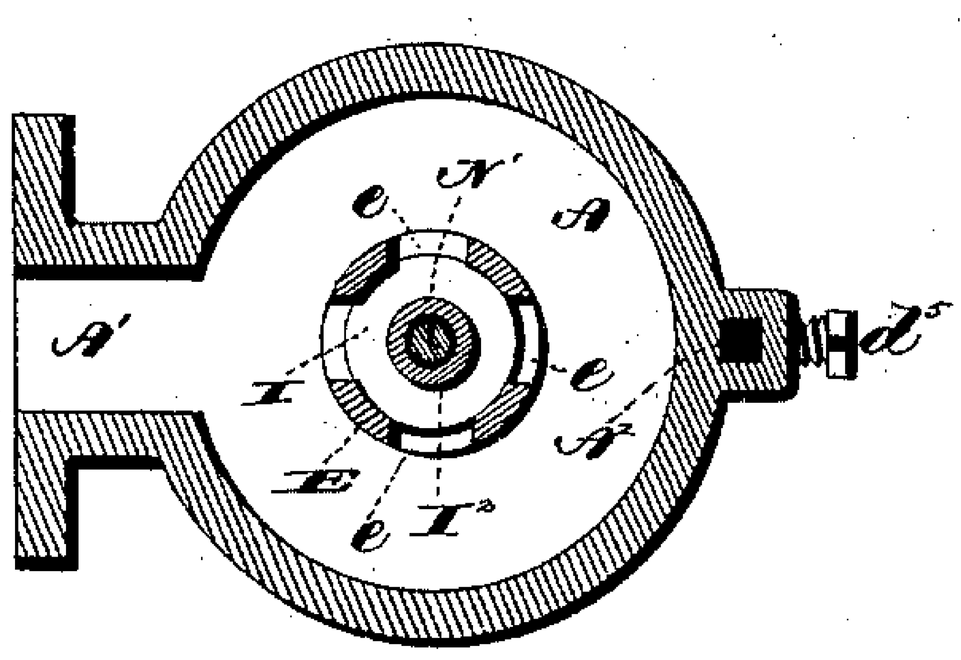

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Fig. 6.

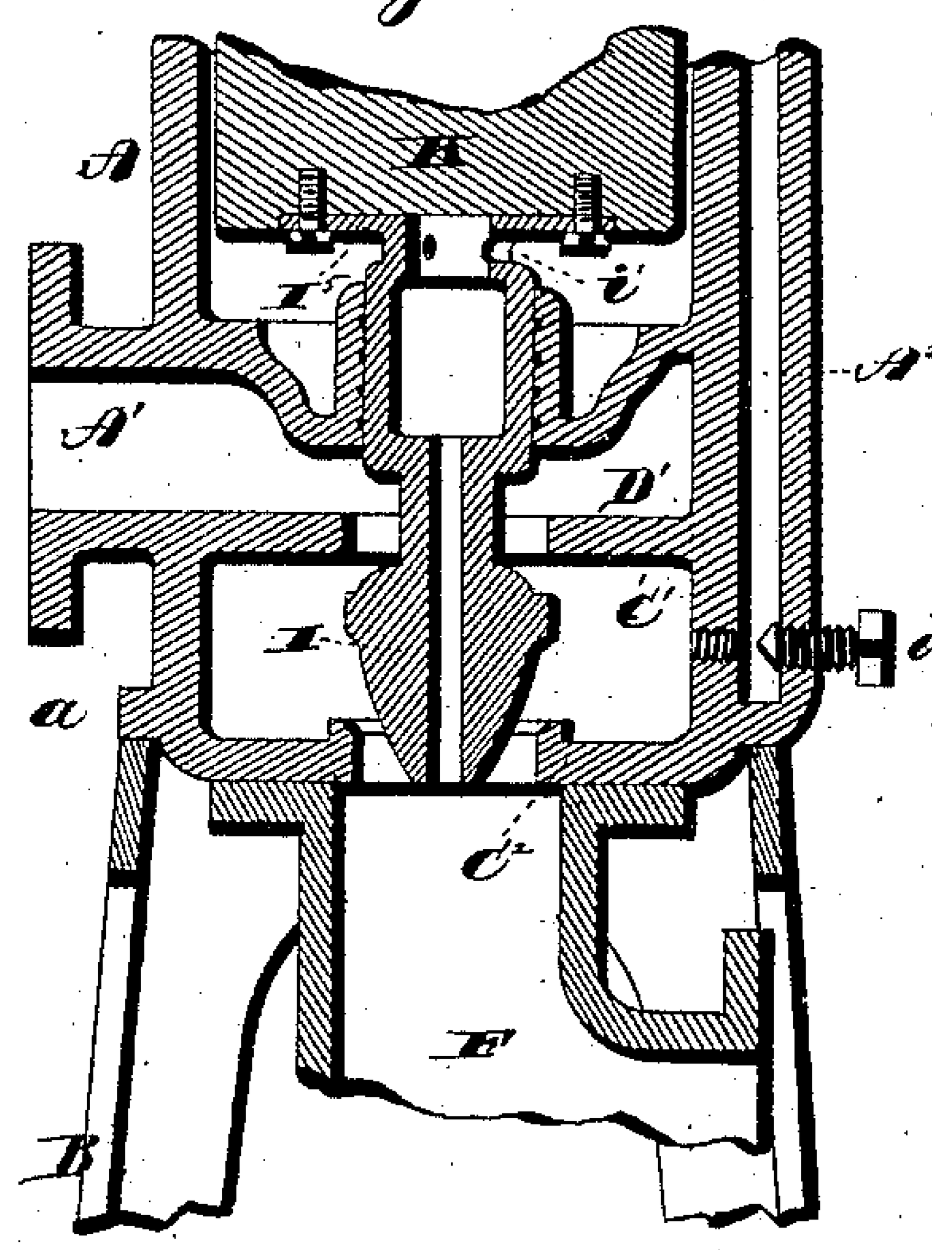

Fig. 8.

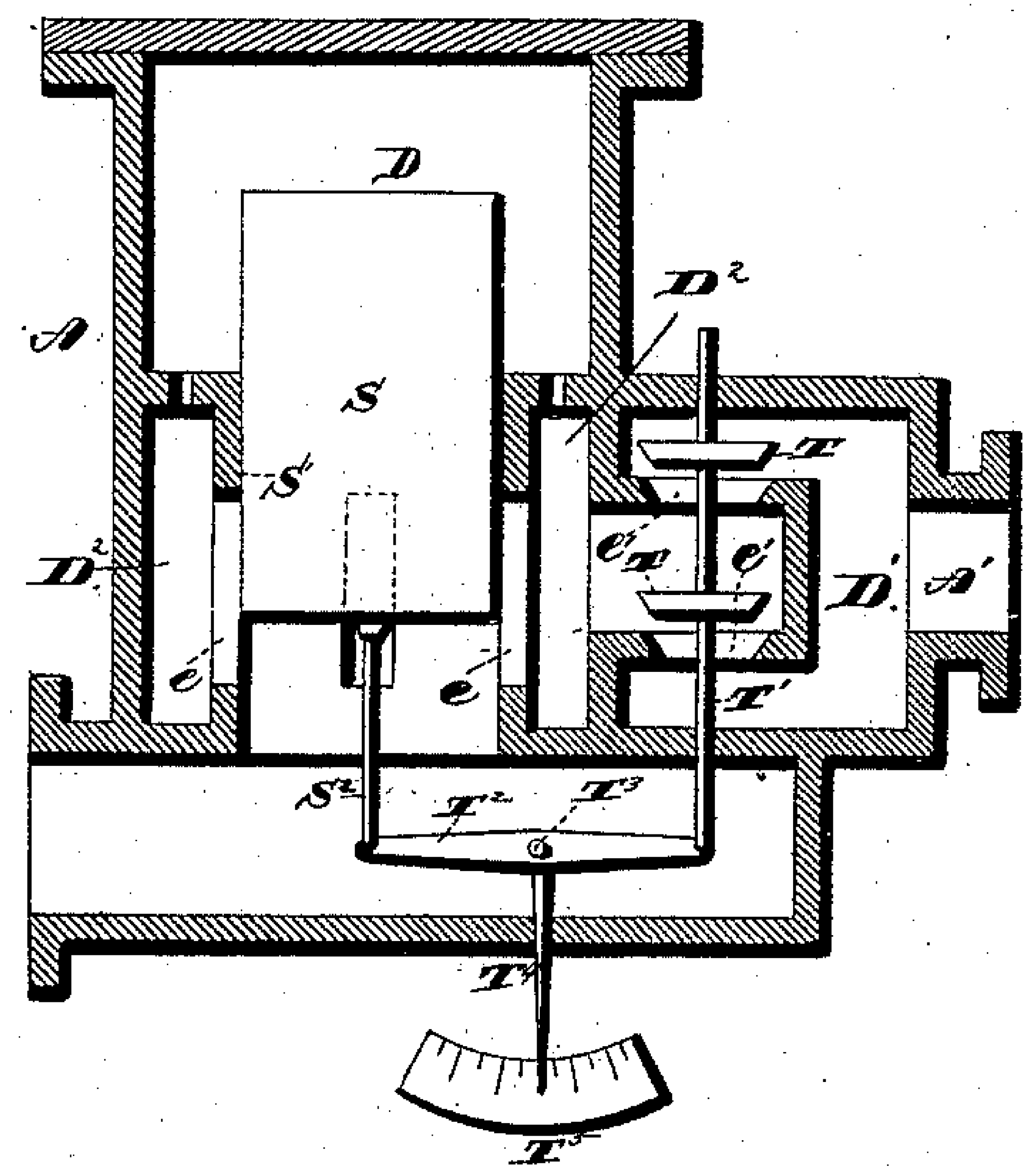

Fig. 7.

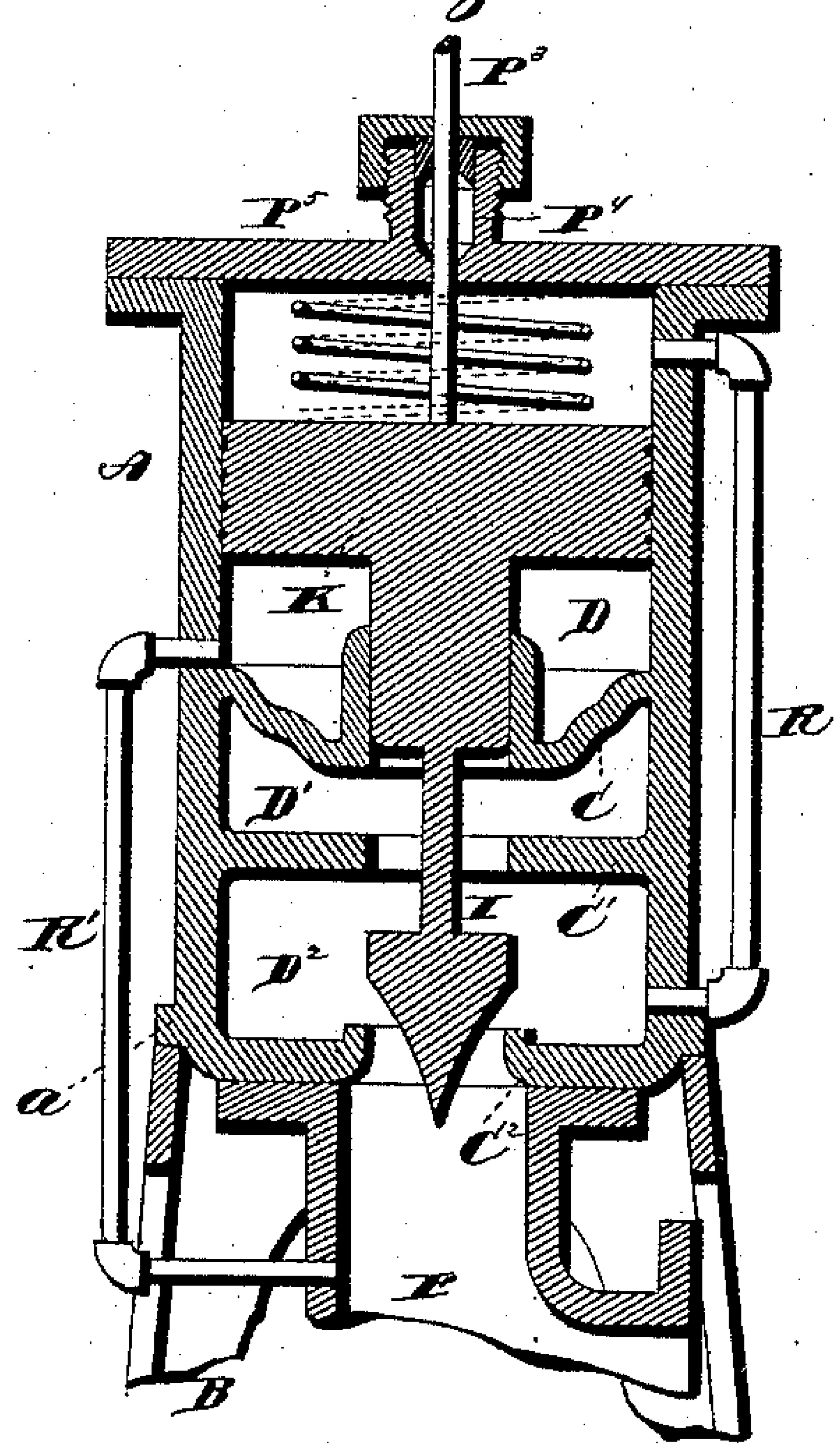

Fig. 9.

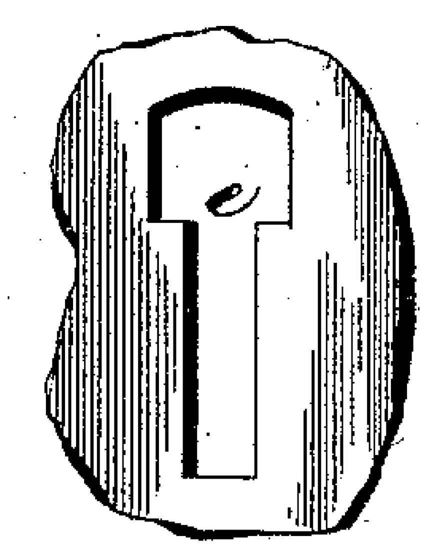

Fig. 10.

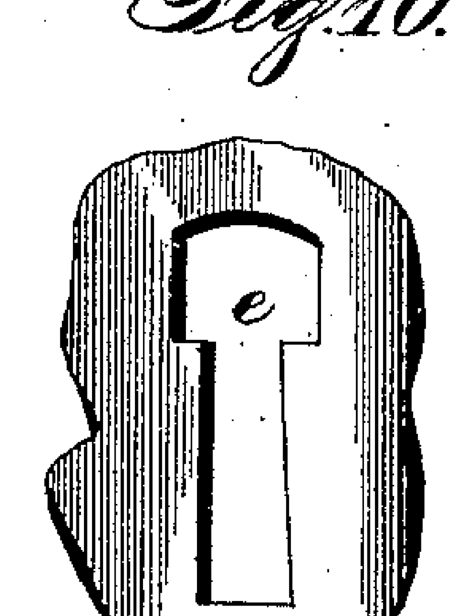

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Fig. 11.

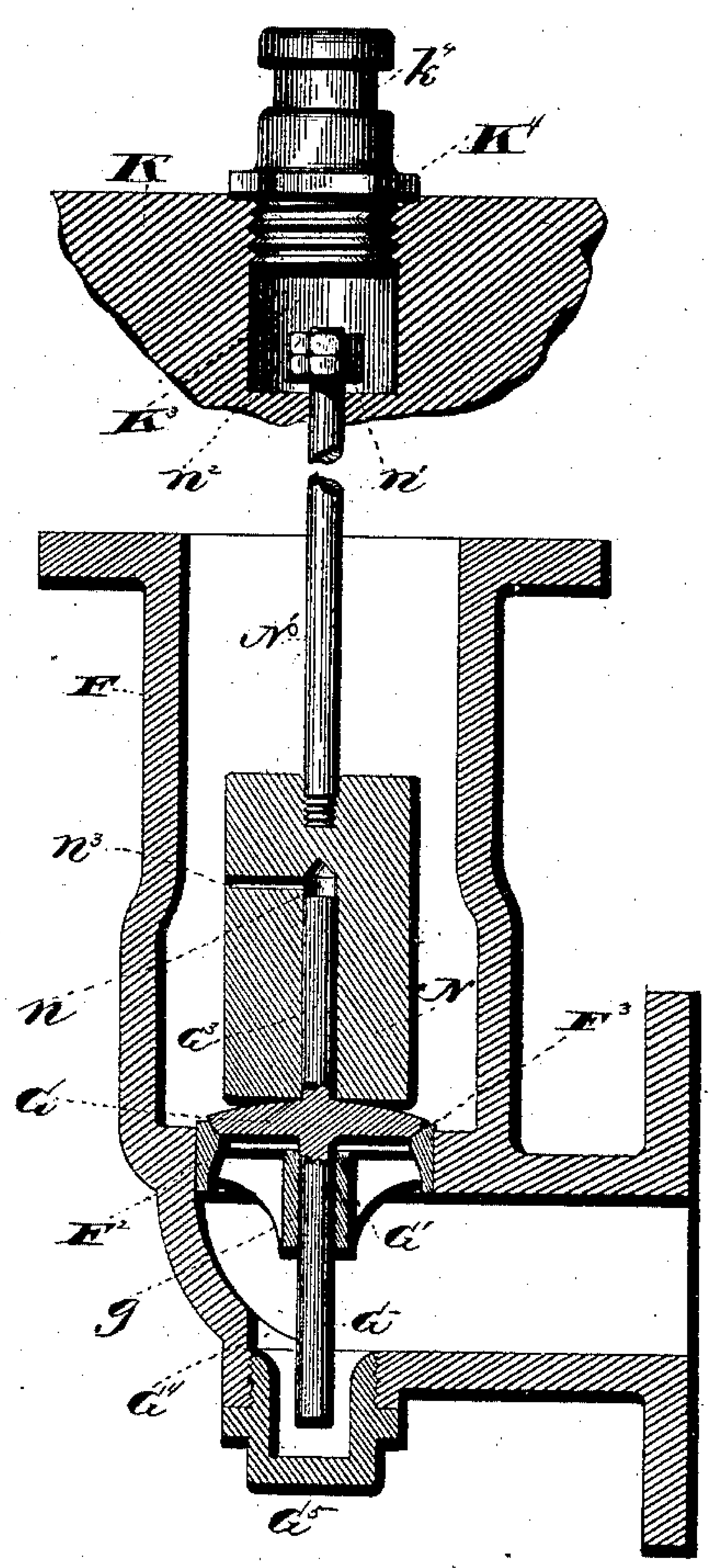
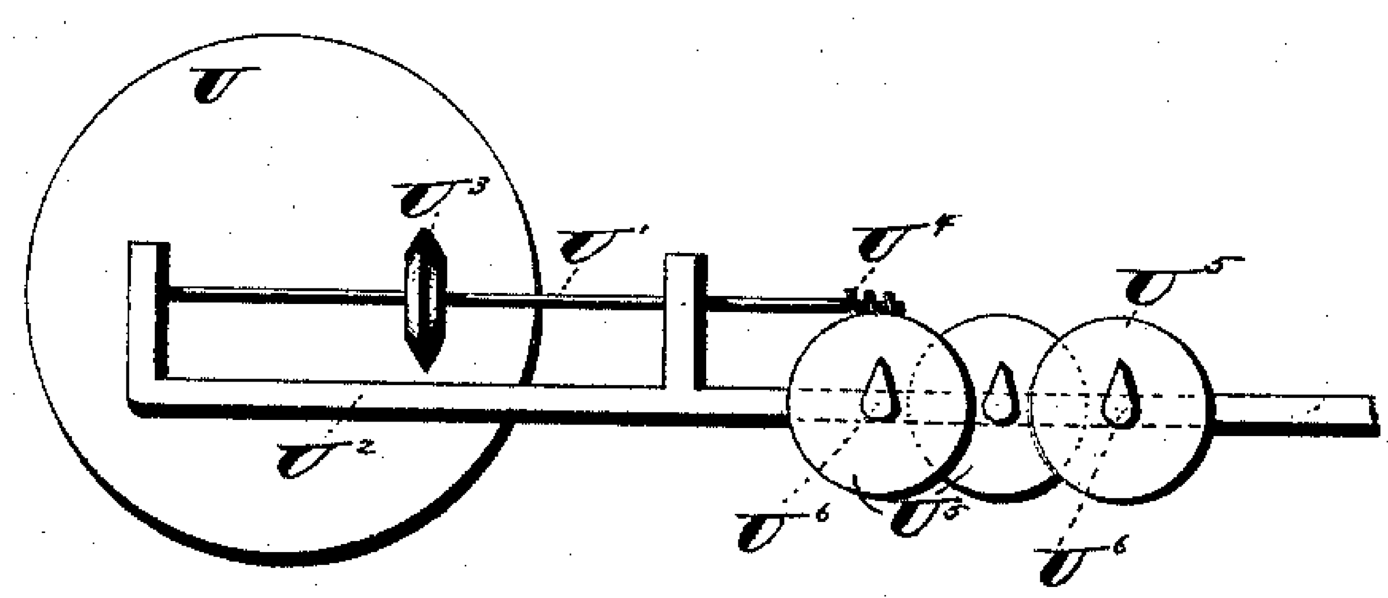


Fig. 12.



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UNITED STATES PATENT OFFICE.

CHARLES E. EMERY, OF BROOKLYN, NEW YORK.

APPARATUS FOR CONTROLLING AND INDICATING STEAM-SUPPLY.

SPECIFICATION forming part of Letters Patent No. 473,733, dated April 26, 1892.

Application filed April 18, 1884. Renewed October 13, 1891. Serial No. 408,565. (No model.)

To all whom it may concern:

Be it known that I, CHARLES E. EMERY, a citizen of the United States, residing at Brooklyn, in the county of Kings and State of New York, (office in New York city,) have invented certain new and useful Improvements in Meters, of which the following, together with the accompanying drawings, is a specification.

My invention relates to improvements in meters intended more particularly for use in connection with a "district system for supplying steam in cities." Though I shall describe this meter as being used for measuring the quantity of steam passed through it under pressure, it will be understood that it is equally applicable for measuring any other gaseous fluid or liquid. Steam being an elastic fluid, its density varies very nearly with its absolute pressure. To measure steam, therefore, requires that its volume be accurately determined at a constant known pressure; or, if its pressure be variable, that the record of measurement be corrected to correspond to the changes of density. In practice the pressure at which steam is delivered varies so slightly that its density may be taken as constant at that corresponding to the average pressure at which the steam is delivered to the meter; or, if desirable, the steam may be passed through a regulating-valve, so that the pressure at which the steam enters the meter will always be constant. The rate of discharge in units of volume for a given fluid through a fixed orifice from one chamber to another at a constant difference of pressure will always be uniform, while the rate of discharge through a variable orifice will at different times be a function of and nearly proportional to the area of the orifice. By measuring the area of the orifice the exact relation between the area of the orifice and the volume discharged under given difference of pressure, having previously been determined by experiment, the rate of discharge can be determined, and from this, knowing the pressure, and therefore the density, of the steam, the quantity discharged can be computed.

The object of my invention is to provide a "steam-measuring" apparatus which will receive steam under pressure and will discharge it into a delivery-pipe at a different pressure, which will automatically maintain a uniform difference between the pressure of the steam received and that of the steam discharged, will automatically register the amount of steam discharged, and will automatically throttle the flow of steam when the difference between the pressure on the inlet and discharge sides becomes too great.

To this end my invention consists in the construction, arrangement, and combination of parts, combined and operating as hereinafter specified.

In the accompanying drawings, Figure 1 shows a vertical sectional view of my apparatus; Fig. 2, a similar view of the same with the weighted piston partly in section and partly in elevation and with the supplemental leak-preventing valve removed; Fig. 3, a horizontal section of the apparatus on line $x\,x$ of Fig. 1; Fig. 4, a similar view of the same on line $y\,y$ of Fig. 1; Fig. 5, an enlarged detail view, partly in section and partly in elevation, of a portion of the casing, the bushing with its ports, and the main valve therein; Fig. 6, a detail vertical sectional view of a modified form of the main valve; Fig. 7, a vertical central sectional view of a modification of my apparatus; Fig. 8, a similar view of a still further modification of the apparatus; Figs. 9 and 10, detail views showing different shapes for the ports in the bushing in my apparatus; Fig. 11, an enlarged detail sectional view showing the construction of the supplemental leak-preventing valve, and Fig. 12 a detail view of a form of integrating mechanism which can be used with my apparatus.

Letters of like name and kind refer to like parts in each of the figures.

The main portion A of the casing of my apparatus is, as shown, supported upon and attached to a suitable frame B. At one side is the discharge-pipe A′, communicating with the casing-interior and to be connected with a delivery-pipe. On the opposite side of casing A is the passage A^2, extending from near its lower end upward and communicating at its upper end with the space within the casing. As shown best in Fig. 4, this passage extends up through a longitudinal and vertical offset or enlargement of the casing. At its extreme lower end the casing A is contracted horizontally, and above this contraction are the two horizontal partitions C C′. The space within casing A is thus divided up into the large upper chamber D and the two smaller chambers D′ and D^2. The chamber D^2, as shown, is intermediate between the outlet-chamber D′ and the inlet, as hereinafter described. The discharge-pipe A′, described above, communicates directly with chamber D′. A screw-threaded opening d' extends through the casing side from the passage A^2 into the chamber D′, and a similar one d^2 puts the intermediate chamber D^2 into communication with the same passage. Through the outer wall of passage A^2 are two larger threaded openings d^3 d^4 opposite openings d' d^2.

In Fig. 1 a screw d^5 is shown screwed into opening d^4 and having a conical end adapted as the screw is screwed in or out to close the opening d^2, more or less, or leave it open or unobstructed, as desired. In the same figure the opening d' is shown as closed by a screw d^6 and the opening d^3 by another screw d^7. With this construction and arrangement the intermediate chamber D^2 is in communication with passage A^2, the extent of the communication being capable of regulation by screw d^5 and the communication between chamber D′ and the passage is closed.

If, for a purpose to be hereinafter described, it be desired to put chamber D′ into communication with passage A^2 instead of intermediate chamber D^2, the various screws d^5, d^6, and d^7 are removed, the stop-screw d^6 is screwed into the opening d^2, and the stop-screw d^7 into opening d^4, and the adjusting-screw d^5 is screwed through opening d^3. The openings d^3 and d^4 are larger than openings d' and d^2, so that the stop-screw d^6 can be passed in through either of them and readily inserted in or removed from either of openings d' and d^2.

Down through the partitions C, C′, and C^2, the last formed by the contraction of the casing, there are central openings all of equal size and in line with each other. On the under side of the lowest partition C^2 around the central opening therein, are the annular rabbets c c', two in number, the lower one c' being of greater diameter than the upper one. The cylindrical bushing E, of such diameter as to fit very closely the central openings in the partitions and of such length as to extend above the upper partition, as shown, has its upper end formed with collars or annular shoulders adapted to fit the rabbets c and c' around the opening in the lowest partition. In the sides of the bushing are ports e e, communicating with the chamber intermediate D^2, and the ports e' e', communicating with the chamber D′. There can be any desired number of ports in each set; but I prefer four.

To the bottom of casing A and against partition C^2 is clamped, bolted, or otherwise fastened the flanged upper end of the elbow F, having its bore in direct communication with that of the bushing E. The upper end of this elbow bears against the lower end of the bushing and serves to hold it with its collars described fitting closely in the corresponding rabbets around the opening in the lowest partition C^2 of the casing A, so as to make a steam-tight joint. The outer end of the horizontal portion of the elbow is flanged, as shown, so as to adapt it to be coupled to a steam-supply main or a pipe therefrom. This elbow is just above its angle provided within with a rigid horizontal partition F′, having an opening in line with the bore of the bushing E above. Fitting in this opening is the short bushing F^2, formed at its upper end with the conical seat F^3 for the valve G. Within the bushing is the spider G′, having the central vertical opening g, in which fits and slides the stem G^2, extending down from the lower side of the valve G. From the upper side of the valve extends the vertical central stem G^3. Directly below the center of the valve G is an opening G^4 in the lower side of the elbow F, closed by the screw-plug G^5, made concave or cup-shaped on its upper side to allow vertical play of the lower valve-stem.

Upon the top of casing A is fastened the hood H, having the central elevation or vertical offset H′ in its top and the horizontal extension or offset H^2 for purposes to be hereinafter set forth fully.

Within the bushing E slides the hollow-piston valve I, having its lower portion I′ made to fit closely within the bushing and above such portion contracted to form the neck I^2, between which and the sides of the bushing is the annular space I^3. The valve I near its upper end and above the neck I^2 is made cylindrical to fit closely the upper portion of the bushing E. The bearing for this part of the valve on the inner side of the upper portion of the bushing is provided with the annular grooves i i, in which water condensed from the steam can collect and act as packing. The bushing E is made thin at e^2 and e^3, as shown in the drawings, in order to allow for any unequal expansion of the valve I, the bushing E, and the iron casing A, and thus prevent binding or sticking of the lower and upper portions of the valve, which are necessarily made to fit the bushing very closely. At its extreme upper end the piston-valve I is provided with the disk-shaped horizontal enlargement or head I^3, to which is bolted the lower end of the piston K, made quite large, so as to have considerable weight, to force the valve I downward. The valve I, being then loaded by the piston, is formed with a longitudinal passage I^4, extending up axially through it, and just below the disk-like head I^3 the valve is provided with one or more openings i', connecting the passage I^4 within the valve with the space in chamber D below piston K. Said piston may be made hollow, as shown, by which means the weight may be adjusted as desired.

The cylindrical chamber D within casing A is larger in diameter than the main portion of the piston K. Within its upper portion is fitted a cylindrical bushing K', preferably of brass, within which fits the cylindrical enlargement K^2 around the piston and forming the bearing-surface thereof. This bearing-surface of the piston is preferably provided with the series of annular grooves k k for the same purpose as the grooves i i in the bushing E, as described above. As the portion of the latter above the enlargement is smaller than casing A or the bushing K' therein, it will not prevent free communication between the passage A^2 and the space within the casing above the piston.

In the upper end of piston K is a central recess K^3, into which is screwed the lower end of the plug or block K^4, which near its upper end is formed with the annular groove k^4, which is engaged by the pin k^5 on the lever-arm L, which is sleeved upon the horizontal rock-shaft L', journaled transversely within the outer end of the offset or arm H^2 of the casing cap or bonnet H. The said arm is fixed to the shaft by means of the set-screw l, tapped through the sleeve L^2 and bearing against the shaft. The shaft is journaled at one end in a bearing-block l', screwed into the side of the cap or bonnet extension H^2, and at the other passes through and is journaled in the stuffing-box l^2 on the other side of the bonnet extension. To the outer end of the shaft is fixed the arm L^3, carrying the pencil or other marker l^3, adapted to mark on the recording-strip M, which is to be moved continuously by suitable clock-work in some one of the well-known ways. With this construction the pencil or marker will be moved up and down as the piston K falls and rises, and will, therefore, indicate by the marks it makes on the record-strip the position of the piston at any time. The continuous mark on the strip will then form a permanent and continuous record of the movements of the piston and valve. If desired, the motions of the piston and valve could be communicated to a recording appaartus by a rod attached to the piston and passing dirictly up through a stuffing-box in the top of the casing, as shown in Fig. 7; but I prefer the construction just described above and shown in Fig. 1, as there is with such construction less friction.

A weight N, provided on its under side with an axial socket n to receive the stem extending upward from valve G, is screwed onto the lower end of the rod N', which passes up through the hollow-piston valve I and the piston K, and has screwed upon its lower end within the recess in the upper end of the piston the nut n', adapted to engage the bottom of recess K^3 when piston K is raised. A jam-nut n^2 above nut n serves to lock it as adjusted on the rod. The socket n in weight N fits the valve-stem G^3 loosely, so as to allow the weight to rise and fall independently of the valve. A vent-passage n^3 is bored inward through the side of the weight communicating with the upper end of socket n, so as to prevent the formation of vacuum in the socket above the valve-stem.

To determine readily and at any time whether the valve I and piston K are freely movable or not, I provide the rod O, (shown in Fig. 2,) passing up through a stuffing-box O' in the lower side of the horizontal portion of elbow. Such rod is provided with a shoulder or collar o, adapted to rest upon the upper side of the bottom of the elbow, as shown, when the rod is down. Said rod is at its upper end adapted to engage the lower end of valve I, so as to raise such valve when the rod is pushed up. For raising and lowering such rod I provide the lever P, pivotally connected with the lower end of the rod and having its outer end pivoted to a fulcrum-link P', depending from a lug or ear p on the elbow.

Where the supplemental leak-preventing valve is used, as described, and as shown in Fig. 1, the end of rod O is to be arranged to engage the lower end of the stem G^2, extending down from the valve. With this construction as the rod O is forced up it will raise valve G and valve I, with its weighted piston K. When it is lowered again, both valves will drop and it can be ascertained by the movement of the marker over the record-strip whether valve K falls freely to its proper position again or is clogged or otherwise prevented from moving freely.

The ports e e are T-shaped, as shown in Fig. 9. The bottom and sides of the ports are accurately faced to gage and are made with square clear-cut corners and the sides of the ports are made parallel. The upper ends of the ports are enlarged, as shown, so as to allow free and unobstructed passage from intermediate chamber D^2 into the annular space I^3 around piston-valve I within bushing E for all the steam which can enter chamber D^2 through the lower portions of the ports. The position of the lower edge of the portion I' of the piston-valve I with relation to the lower ends of ports e e determines the area of the openings through which the steam can flow into intermediate chamber D^2, and as the sides of the ports are parallel and at right angles to the bottoms of the ports and the lower edge of the piston-valve is horizontal and parallel to the lower ends of the ports the openings through which the steam can pass will always be rectangular and their areas will be exactly proportional to the amount of rise or fall of the piston. The areas of the openings or portions of the ports through which steam may be flowing into intermediate chamber D^2 at any time will then, obviously, be accurately indicated by the position of the marker l^3, connected as described hereinbefore and moved by the motions of the piston-valve and its weighted piston.

The operation of my apparatus, constructed and arranged as described, is as follows: I will first describe the operation of the apparatus without the supplemental leak-preventing valve and its weighted rod. While the loaded-piston valve is down, being held so by the weighted piston K, it closes the ports e e against the passage of steam from the elbow into intermediate chamber D^2. The steam passes up through the interior of the hollow-piston valve and out through the small ports i' i' into the portion of the chamber D below the lower end of weighted piston K. As the pressure increases enough to overcome the weight of the piston and valve, said piston will be forced upward, raising the valve so that the lower edge of the latter no longer closes ports e e. The steam then passes through such ports into intermediate chamber D^2, then inward into and through the annular space, around the reduced portion or stem of the piston-valve, and from there through ports e' e' in bushing E out into chamber D′, and thence out through the pipe A′. As the upper portions of ports e e are, as described, made quite large, so as to offer little or no obstruction to the passage of any amount of steam, which can flow into intermediate chamber D^2 through their lower portions, and the ports e' e' are also large, the pressure in chambers D^2 and D′ and in the discharge or delivery connecting-pipe A′ will be substantially the same, except when the valve rises and throttles the flow of steam through the upper portions of the parts, as hereinafter set forth. Through the opening d^2 some of the steam in intermediate chamber D^2 will pass into passage A^2, then up through the same, and into the portion of chamber D around and above the upper end of piston K. With this construction a pressure equal to that of the steam in intermediate chamber D^2 will be brought to bear upon piston K to force it down against the pressure of the steam from the supply-main. This pressure on the top of piston K then tends, together with the weight of the piston and valve, to lower the piston-valve to close the ports e e between the supply-pipe or inlet-chamber in the pipe connection and intermediate chamber D^2 between such supply-pipe and chamber D′. When, therefore, the weight of the piston and piston-valve and the pressure in intermediate chamber D^2, which is the same as that upon the upper end of piston K, added together, becomes greater than the pressure of the steam from the inlet-chamber in the elbow upon the lower side of the piston-valve and the weighted piston, the valve will be forced down to partially or entirely shut off the steam-chamber D^2 until the pressure therein has fallen again. When the pressure in chamber D^2 and the discharge-chamber D′, and so in the space above the piston K, has fallen, so that, added to the weight of valve and piston, it is less than the pressure of the inlet-steam on the lower end of piston-valve and weighted piston, the piston and valve will be forced up to open ports e e and admit more steam into intermediate chamber D^2. Thus a certain difference between the pressure on the inlet and outlet sides of the valve will be constantly maintained and such difference will always be equal to the weight of the piston-valve and weighted piston—that is, the pressure of steam as flowing into the service-pipes from the outlet-chamber of the apparatus will normally be less than that in the supply-mains by an amount of pressure equal to the weight of the valve and weighted piston. This difference would be exactly equal to such weight but for the loss of pressure on the valve when the steam is flowing at high velocity. The position of the valve will, however, always be the same for the same quantity discharged. As the difference of the pressures in the inlet and intermediate chambers is thus kept substantially constant, the rate of discharge of steam in units of volume through the ports connecting such chambers will be substantially proportional to the areas of the openings through which the steam passes. As described hereinbefore, the areas of the portions of ports e e, through which the steam can pass into intermediate chamber D^2, is determined by the position of the lower edge of piston-valve and is directly proportional to the height of such lower edge with reference to the lower ends of the ports. The quantity of steam discharged from the inlet-chamber through ports e e into intermediate chamber D^2 will then be in units of volume proportional to the height of the lower edge of the piston with relation to the lower ends of the ports. In other words, the quantity discharged through the ports will vary with the movements of the piston, and therefore from the motions of the marker l^3 over the recording-strip, such marker being actuated, as described, by connections with the weighted piston and piston-valve, the quantity of steam discharged from the inlet into the intermediate chamber and into the outlet-chamber at any time can be readily determined. The pencil or marker will in its markings on the record-strip leave a permanent record of the positions and change of positions of the valve from which the areas of the openings through which the steam has flowed into intermediate chamber D^2 and the quantity discharged can be computed. As the rate of flow of steam from one chamber into another at a constant difference of pressure in the two chambers and through openings of a known area is known, the entire amount of steam delivered for any length of time can readily be computed. Since the rate of flow or the flow per unit of area through a graduated opening becomes slightly less as the valve is partially closed, for the reason that there is more frictional surface in proportion to the area. This law being known, the amount of steam passing through the ports e e, when made with their sides parallel, as indicated hereinbefore, can be readily computed from the indications of the marker, which records the movements of the piston-valve, and so indicates, as described, the areas of the port-openings.

To simplify the computation of the volume of the steam, I prefer to make the lower portions of ports *e e* wider at one part than another, so that the rate of flow of steam through them will be directly proportional to the height of the valve with reference to the lower ends of the ports. I therefore make the ports, as shown in Fig. 10, T-shaped in general outline, but having the lower end of the upright portion of the T wider than the upper end of such portion. The ports *i' i'* in the upper end of the piston-valve I and the passage A^2, I make quite small, in order that the valve may not be too sensitive to changes in pressure in the inlet or the connected intermediate and outlet chambers, but will respond readily to any continued change in the pressure. The weight of the piston-valve and weighted piston can obviously be adjusted so as to maintain any desired difference between the pressure on the inlet and outlet sides of the valve. Where several meters are used, I prefer to make the difference in such pressures the same in all by having the weights of the pistons and valves all the same, so that the volume of steam flowing through the valve-ports in the several meters can be readily and quickly computed, as such flow is influenced in all the meters by the same difference in pressures on the inlet and outlet sides of the ports. In practice I prefer to make this difference of pressure equal to about two pounds per square inch to measure steam delivered at an average pressure of about seventy pounds to the square inch. In each meter, as the difference in pressures on the inlet and outlet sides of the valve increases or diminishes, the valve will rise or fall to admit more or less steam into the chamber on the outlet side, so as to bring the difference in the pressure back to its normal desired amount again. If the demand for steam be reduced, the pressure in the outlet-chamber will rise slightly, thus reducing the difference of pressure, when the loaded valve will fall until the demand for steam is such that the difference in pressure corresponds to that due to the weight of the valve and its operating-piston when the valve will become stationary, and so remain as long as the difference in pressure is constant. If the discharge be shut off entirely, the pressure will accumulate in the discharge-chamber and the valve will drop down, closing the ports entirely. If, however, the demand for steam be great, the pressure will fall in the discharge and intermediate chambers and the valve will rise, and if the demand be sufficiently great continue rising until the ports are nearly open, when, as the pressure can no longer be kept up by the admission of a greater quantity of steam, the apparatus is so arranged that the upper edge of the lower portion of head of valve will commence throttling the communication through the T-heads of the ports between the intermediate and outlet chambers, and thus maintain a constant difference of pressure between the intermediate and inlet chambers. When the valve is raised so as to throttle the steam passing through these openings, the pressure in the discharge-chamber may fall to any extent, depending entirely upon the demand. This does not affect the accuracy of the meter for the reason that the calculations are based on the flow through the ports from the inlet to intermediate chambers at a constant difference of pressure, which latter is maintained when the valve is down, so that the T-headed ports are open by opening the lower end of the ports wider as the demand becomes greater, and when the valve is up by throttling the discharge through the T-heads of the ports. If the recording mechanism be omitted, my meter may then be used simply as a regulator to prevent the passage of steam into the delivery-pipe in excess of a certain established rate. If the passage A^4, communicating at its upper end with the space above the upper end of the weighted piston be, by changing the top screws d^6 d^7 and regulating-screw d^5, as described hereinbefore, put into communication with the outlet-chamber D′, instead of intermediate chamber D^2, should the difference of the pressures in the inlet and outlet chambers become greater than the weight of the piston and piston-valve, the piston will rise until the difference of pressure is brought back to its normal amount by the increased flow of steam through ports *e e*. With this construction, should any break occur in the delivery-pipe or the difference in pressure in the inlet and outlet chambers become too great from any other cause, the valve will fly up until its upper edge cuts off communication from intermediate chamber D^2 to outlet-chamber D′, and will continue so to throttle the steam and keep it cut off from the delivery-pipe until the supply of the steam to the meter is cut off or until the pressure in the discharge-chamber accumulates, so as to decrease the difference of pressure to that at which the apparatus is adjusted. This accumulation of pressure in the discharge-chamber can occur when the demand is cut off by the small leaks permitted by the apparatus. As soon as the supply is cut off, or as soon as the pressure in the discharge-chamber accumulates, as stated, the valve will fall and resume its normal action again. My apparatus constructed and arranged in this way will then act as a combined meter and safety-valve. It not only maintains a constant difference between the steam in the supply-main and that flowing into the delivery-pipe and makes a record from which the amount of steam in units of volume can be ascertained, but it also throttles the steam and cuts it off from the delivery-pipe if a leak should occur in the latter. If desired, the cylindrical bearing around the piston K may be omitted, so that said piston will act merely as a weight. The ports *i i* will then be omitted. The upper bearing of the piston-valve will then form the piston upon which steam from the outlet-chamber, passing up through passage A^2 into chamber D will press downward. The valve will then be operated by the difference of the pressure upon it acting to move it in opposite directions. In practice it is found not desirable to fit the piston-valve very closely in the bushing, as the valve is not then sufficiently sensitive to changes in the difference of pressure. I therefore fit the valve loosely within the bushing, so as to leave a slight space between the valve and bushing and to prevent leakage through the constant opening so formed when the valve is at its lowest point, which leakage would, of course, not be recorded. I provide the supplemental valve G with its weight and weight-rod, as hereinbefore described. When the difference of pressure in the inlet and intermediate or outlet chambers falls below an amount equal to the weight of the piston and piston-valve and so below the desired normal amount, and the piston-valve therefore descends, as described hereinbefore, the weight N rests upon the supplemental check-valve G′ and holds it shut. Said weight is made sufficiently large to hold the valve G down until the pressure on its upper side in the intermediate chamber D^2 is less than that on its lower side by an amount somewhat greater than the difference which the meter is set to maintain between the pressures of the steam from the supply-main and of that in the delivery-pipe. When the valve is thus held closed by the weight, equilibrium of pressure on the inlet and outlet sides of the main valve will be established and maintained because there is a communication between the chambers around the loosely-fitted valve and the bushing. As long as the pressure on the upper side of the supplemental valve, when added to the weight of the valve, the rod N′ and the weight N overbalances the pressure from the inlet-pipe upon the under side of the valve, said valve will of course remain closed—that is, if the difference of pressure on the upper and lower sides of the valve is less than the weight of valve weight and rod, the valve will stay closed. If the difference of such pressures should be greater than such aggregate weight, the valve will be raised to admit steam into the space below the main valve. By properly adjusting the weight of the valve, rod, and weight the supplemental valve can then, as desired, be set so as to open when the difference of pressure above and below it is somewhat greater than the difference of pressures at which the main valve of the meter is set to act. As when the supplemental valve is used the valve I is preferably, as described, fitted in its bushing, allowance must be made in the computation of the amount of steam passing through the meter for the amount which can pass between the valve I and its bushing when the meter is in operation. When the pressure in the space below the main valve I and above the supplemental valve falls below that at which the supplemental valve is set to act, such valve rises, as described, to admit steam from the source of supply to the inlet-chamber below the piston-valve. By the pressure thus produced on the under side of the piston-valve it will be caused to rise to cause the marker to make a record-mark on the strip M. As the piston-valve and piston K rise, the bottom of recess K^3 in the upper end of the piston engages the nut n on the upper end of rod N′ and so lifts the weight N to remove it from the supplemental valve. The meter then operates in the way as described hereinbefore. When the quantity of steam supplied is limited, the steam will pass through the meter in a series of puffs. The diagram then marked on the record sheet or strip will then show that the meter is running on its constant opening. When the difference of the pressures on the inlet and outlet sides of the main valve becomes too little, such valve descends, as described hereinbefore, and thus lets the weight down upon the valve again to close it, so as to prevent the passage of any steam which would not be recorded.

In Fig. 6 is shown a modified form of the main valve I of the meter. In this modification the valve-seat around the upper edge of the opening in the lowest partition C^2 is made conical, as shown, and the lower end of the valve I is made of a conoidal shape, with its apex downward, so that the area of the portion of the opening through which the steam can pass up at any time will be directly proportional to the height of the valve. If desired, the valve can be so shaped that the area of the valve-opening, through which the same can pass at any time, will be such that steam passing through it will be directly proportional to the amount of rise of the valve. The upper end of this conoidal portion of this modified form of valve acts in connection with the edge of the opening in partition C′ to diminish or cut off the flow of steam into the outlet-chamber at the higher lifts of the valve and piston.

In Fig. 7 I show a modified form of my meter in which the piston is pressed downward by a spring instead of a weight, and from the piston a rod P^3 extends vertically upward through a stuffing-box P^4 on the top of the cap or cover P^5 and is adapted to be connected at its upper end with a suitable indicator or recorder. In this modified form I use, instead of the passage A^2, as shown in Fig. 1, extending up through a portion of the casing, the pipe R, connecting the chamber D^2 with the space above the piston K, and instead of making the valve I hollow and having the passage up through it connected with the space in chamber D below piston K by one or more parts, as shown in Fig. 1, I use the outside pipe R′, connecting the space on the inlet side of the valve with the space in chamber D below the piston. When a spring is used, as in this modification, to load the valve or force it down, the stress of the spring obviously must increase as the valve and piston rise. In order that the pressure on the inlet side of the valve shall counterbalance the weight of the valve and piston and the stress of the spring added to the pressure on the outlet side of the valve or in the intermediate chamber D^2, the difference between such pressures must increase as the spring is compressed by the rising of the valve and piston. The steam passes then through the valve-opening under the influence of a changing difference of pressure on the inlet and outlet sides and not under a fixed or constant difference, as in my other form of meter, where a weight is used. As the conditions of the passage of the steam through the port or valve opening are thus changed at each change of position of the valve, if the ordinary form of piston-valve were used the quantity of steam discharged would not be proportional to the height of the valve or the size of the valve or port opening, but would vary very materially from such proportion. I contemplate, therefore, when this modified form of meter is used making the valve of a different shape from that shown and described as being used in the other forms of my meter. The shape of the lower portion of the valve is then to be, as shown in Fig. 7, made such that the change in the difference of pressures as the valve rises and falls will be in a measure or entirely compensated for by changes in the size of the opening or port through which the steam passes, so that the rate of flow and the amount in units of volume of the same may be computed by some known law for the positions of the valve, which will, as suggested, be indicated by a diagram marked on a record-strip.

In Fig. 8 is shown a still further modification of my meter. In this the heavy piston S, fitting and sliding vertically within the bushing or inner cylinder S′ within the casing A, acts not only as the weighted piston in the other forms of meter described and shown, but its lower edge operates as a piston-valve, in connection with the ports *e e* in the bushing or cylinder, to either close them or regulate the area of them, through which steam can pass from the inlet-pipe and inner side of the lower portion of the bushing into the space between the bushing and the casing A. This space, corresponding with intermediate chamber D^2 in the form of meter shown in Fig. 1, is in communication with the space D within the casing above the piston and with the outlet-chamber D′ through the ports *e′ e′*. The two disks or heads T T on the vertical rod T′ form a double-puppet balance-valve, operating to regulate and close these ports when the rod is pulled downward. The piston S is connected by means of rod S^2 with the end of the lever T^2, attached to a rock-shaft T^3, journaled in the casing of the meter and at one end extending through the same, and having an index-arm T^4 attached to it and swinging over an index-scale T^5. The outer end of lever T^2 is connected, as shown, with the valve-rod T′. With this construction, as piston S rises or falls to open or close the ports *e e*, the valve-rod T′ will correspondingly fall and rise to close or open the valve-openings *e′ e′*. If the difference of pressure of the steam below the piston S from the supply-main and in the intermediate chamber D^2 becomes less than the weight of the piston S, minus that of the valves T T and valve-rod—that is, if the pressure of the steam in the intermediate chamber D^2, and consequently of that let into the delivery-pipes connected with outlet-chamber, tends to become greater than that for which the meter is set—the piston S will be forced down by pressure on its upper end and will partially or entirely close the ports *e e* until the pressure in chamber D^2 is reduced to the proper point again. If by reason of too great demand or a break in the delivery-pipe the pressure in the intermediate chamber D should fall too low, so that the difference between the pressures in the inlet-chamber and chamber D^2 becomes greater than the weight of the piston, minus the valves and the rod—that is, greater than that for which the meter is set to act—the piston will be forced up and the rod T′ through the connections with the piston will be drawn down to bring the valve-heads T T closer to their valve-seats around openings *e′ e′*. With this construction the valves T T are brought into operation to throttle the flow of steam through ports *e′ e′* when the full capacity of the meter is approached and reached, just as the valve shown in Fig. 1 operates to throttle the flow through the valve-ports by closing the upper ends of the ports or openings between the intermediate chamber D^2 and the outlet-chamber D′. In one form, as already indicated, where the space above the weighted piston is put in communication with the outlet-chamber D′, if the pressure in the latter should fall too low, as if a break should occur in the delivery-pipe, the valve will with its upper edge close the upper ends of ports *e e* entirely, thus throttling the steam and cutting off all communication between the intermediate chamber D^2 and the delivery pipe or pipes until the supply of steam in the meter has been cut off.

In Fig. 12 of the drawings I show a well-known form of integrating mechanism which is capable of use with any of the forms of meter in which the rate of flow of the steam is directly proportional to the height of the valve. This consists of the disk U to be rotated at the desired rate of speed by clock-work, the shaft U′, journaled in a suitable frame U^2 and extending radially over the disk, the friction wheel or pinion U^3 capable of sliding endwise on the shaft, but turning with it, the worm U^4 on the shaft, and the series of indicator-wheels U^5 U^5 U^5, coupled or geared together in the ordinary and well-known way and provided with index-pointers U^6 U^6. The worm U^4 meshes with and drives the first of these wheels, as indicated.

The pinion U^3 is to be so connected with the piston or valve of the meter that it will be moved along on the shaft U′ toward the perimeter of the disk U or toward its center as the piston or valve rises or falls, the movement of the wheel being proportional to that of the valve. When the valve is down, the piston will be at the center of the disk, so that the rotation of the latter will not cause the pinion to revolve. As the pinion is moved outward, so as to be nearer the perimeter of the disk, obviously the pinion will be caused to revolve faster. As the valve rises to open the ports wider, the pinion will then be moved away from the center of the disk U and will be rotated faster to actuate the indicator or register mechanism more rapidly. As the rate of flow of the steam through the meter is, as described, proportional to the height of the valve, the integrating mechanism will register directly with its indices the quantity of steam passed through the meter in a given time.

Any of the improvements in steam-meters set forth in Letters Patent No. 242,521, granted to me June 7, 1881, can be applied to this form of meter.

Having thus described my invention, what I claim is—

1. In an apparatus for controlling and indicating steam-supply, in combination with a supply-pipe for supplying steam or other fluid under pressure and a delivery-pipe, valve mechanism adapted to maintain a substantially constant difference between the pressure of the steam supplied and that delivered and to throttle the flow of the steam or fluid when the difference in such pressures becomes too great, all substantially as and for the purpose described.

2. In combination with the inlet and outlet chambers connected, respectively, with the supply and delivery pipes, valve mechanism controlling the communication between the inlet and outlet chambers, adapted to diminish the area of the communication between the two chambers as the difference between the pressures in the two chambers diminishes, and to shut off the communication between the chambers when the difference between such pressures tends to become too great, substantially as and for the purpose described.

3. In an apparatus adapted to regulate the pressure of steam in a delivery-pipe, in combination with the inlet and outlet chambers, valve mechanism, substantially as described, adapted to diminish the communication between the chambers as the difference in pressures in the two chambers diminishes, and to increase or enlarge such communication as the difference in the pressures increases up to a certain point, and as the pressure tends to rise above such point to diminish or throttle the communication with the outlet-chamber, substantially as and for the purpose described.

4. In combination with the inlet, intermediate, and outlet chambers, the valve mechanism adapted automatically to lessen or increase the communication between the inlet and intermediate chambers as the difference between the pressures in such chambers diminishes or increases and to throttle or close the communication between the intermediate and outlet chambers when the difference between the pressures in the inlet and outlet chambers becomes too great, and means, substantially as described, for indicating the position or movements of the valve, substantialy as and for the purpose described.

5. In combination with the inlet, the intermediate, and the outlet chambers connected by suitable valve openings or passages, the loaded valve actuated to fall and rise as the difference between the pressure in the inlet and outlet chambers diminishes or increases, adapted to close the communication between the inlet and intermediate chambers as it descends and the communication between the intermediate and outlet chambers as it ascends, substantially as and for the purpose described.

6. In combination with the intermediate chamber communicating with the inlet and outlet chambers, the valve-head adapted to diminish or close the communication between the intermediate and inlet chambers when it is moved in one direction and that between the intermediate and the outlet chambers when it is moved in the other direction, substantially as and for the purpose described.

7. In combination with the intermediate chamber and the inlet and outlet chambers connected therewith by suitable ports or passages, the valve adapted to regulate the communication between the inlet and intermediate chambers, and the valve connected therewith, adapted to regulate the communication between the intermediate and the outlet chambers, substantially as and for the purpose described.

8. In combination with the intermediate chamber connected with the inlet and outlet chambers by suitable ports, the loaded valve actuated by the difference between the pressures in the inlet and outlet chambers to close or open the port between the inlet and intermediate chambers as the difference in the pressures tends to diminish or increase, and the valve connected therewith, adapted to close the port between the intermediate and outlet chambers when the pressure in the outlet-chamber falls too low and the difference in pressures becomes too great, substantially as and for the purpose described.

9. In combination with the inlet and outlet chambers and the intermediate chamber connected therewith by suitable ports or passages, the loaded valve adapted to be actuated by the difference of pressures in the inlet and intermediate or the inlet and outlet chambers to open or close the port or passage between the inlet and intermediate chambers, and the valve connected therewith, adapted to close the connection between the intermediate

chamber and the outlet-chamber when the difference in pressures becomes too great, substantially as and for the purpose described.

10. In combination with the valve controlling communication between the intermediate and the inlet and outlet chambers, a loaded piston actuated by the difference in the pressures in the inlet and intermediate chambers, substantially as and for the purpose described.

11. In combination with the intermediate and the inlet and outlet chambers connected therewith by suitable ports or passages, the valve controlling and regulating the communication between the inlet and intermediate chambers, the loaded piston fitted and moving in a cylinder, a port or passage connecting the space below the piston with the inlet-passage, and a port or passage adapted to connect the outlet-chamber with the space above the piston, substantially as and for the purpose described.

12. In combination with a valve controlling the communication between the inlet and the intermediate chambers and between the intermediate and the outlet chambers, the loaded piston fitting in a cylinder, the port connecting the space in the cylinder below the piston with the inlet-chamber, and the passage opening into the space within the cylinder above the piston, adapted to be connected with the intermediate or outlet chambers, substantially as and for the purpose described.

13. In combination with the bushing connected with the inlet and outlet chambers, and provided with ports connecting with the intermediate chamber, the loaded valve adapted to close the lower portion of the ports with its lower edge as it descends and the upper portions of the ports with its upper edge as it ascends, substantially as and for the purpose described.

14. In combination with the inlet, the intermediate, and the outlet chambers, the bushing connected with the inlet-chamber and provided with ports opening into the intermediate and outlet chambers, the piston-valve having a head fitting in the lower portion of the bushing, the reduced shank or neck above such end, and the head at its upper end fitting the bushing and the weighted piston attached to the valve, substantially as and for the purpose described.

15. In combination with the bushing connected with the inlet-chamber and provided with ports connecting with the intermediate and outlet chambers, the piston-valve having the head at its lower end fitting the bushing and the reduced portion or neck above such head, the loaded piston fitting in a cylinder and means for connecting the inlet-chamber with the space in the cylinder below the piston, and means, substantially as described, for connecting the space above the piston with the intermediate or outlet chamber, substantially as and for the purpose described.

16. In combination with the casing and the weighted piston fitting and sliding in a chamber therein, the inlet, intermediate, and outlet chambers, the bushing connected with the inlet-chamber and provided with ports opening into the intermediate and outlet chambers, the piston-valve having the head on its lower end controlling the ports communicating with the intermediate chamber, the reduced shank or neck above such head, and the port or passage connecting the inlet-chamber with the space below the weighted piston, and means, substantially as described, for connecting the space above the weighted piston with the intermediate or outlet chamber, as desired, substantially as and for the purpose described.

17. In combination with the bushing communicating with the inlet-chamber and having one or more ports opening into the intermediate chamber made larger at their upper ends and one or more ports opening into the outlet-chamber, the piston-valve having the head fitting in the bushing, adapted as it is moved downward to close the lower ends of the ports opening into the intermediate chamber and as it is moved upward to close the upper ends of the same, the reduced shank or neck, and the head at its upper end fitting the bushing, substantially as and for the purpose described.

18. As a means for connecting the intermediate or the outlet chamber with the space in the cylinder above the weighted piston, the port or passage connected at its upper end with such space, threaded openings between the chambers and this port, a screw-plug adapted to be screwed into either opening, as desired, larger threaded openings in the outer wall of the port or passage, a screw stop-plug, and a screw having a conical end, both adapted to be interchangeably screwed into either of such openings, as desired, substantially as and for the purpose described.

19. In combination with the valve mechanism for maintaining a constant difference between the pressures in supply and delivery pipes, the supplemental leak-preventing valve, substantially as described.

20. In a pressure-regulating apparatus, the loaded valve adapted to maintain a constant difference between the pressures in the chambers and actuated substantially as described, the supplemental valve controlling the connection between the supply-pipe and the inlet-chamber, and a weight connected with the main valve, adapted, when such valve is closed, to rest on the supplemental valve and hold it closed until the difference between the pressures in the supply-pipe and the inlet-chamber becomes greater than that at which the main valve is set to act, substantially as and for the purpose described.

21. In combination with the supplemental valve in the inlet-chamber, the weight adapted to rest thereon and hold it closed and the rod connecting such weight with the main pressure-regulating valve, substantially as and for the purpose described.

22. In combination with the piston-valve

and the weighted piston thereon, the rod passing loosely up through the valve and piston and provided with a nut or head adapted to be engaged by the piston as the latter rises, the weight on the lower end of the rod, and the supplemental valve controlling the connection between the supply-main and the space below the piston-valve, substantially as and for the purpose described.

23. In combination with the piston-valve and the weighted piston thereon, provided at its upper end with a recess, the supplemental valve below the piston-valve, having a stem projecting upward, the weight having a socket to receive this stem loosely and a rod attached to the weight and passing up through the piston-valve and piston, and a nut on the upper end of the rod in the recess in the piston, all substantially as and for the purpose described.

24. In combination with the piston-valve and the weighted piston, the grooved projection or stud on the upper end of the piston, an arm provided with a pin engaging the groove in the stud, the rock-shaft, to which the arm is attached, the arm on the rock-shaft operating a pencil or marker, and the recording-strip adapted to be driven by clockwork, substantially as and for the purpose described.

25. In combination with the piston-valve, the bushing having the valve-ports shaped so as to admit the passage of an amount of steam proportional to the height of the portion of the ports left open, and a recording or registering mechanism for indicating the movements of the valve, substantially as and for the purpose described.

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Witnesses:
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