No. 721,476. PATENTED FEB. 24, 1903.

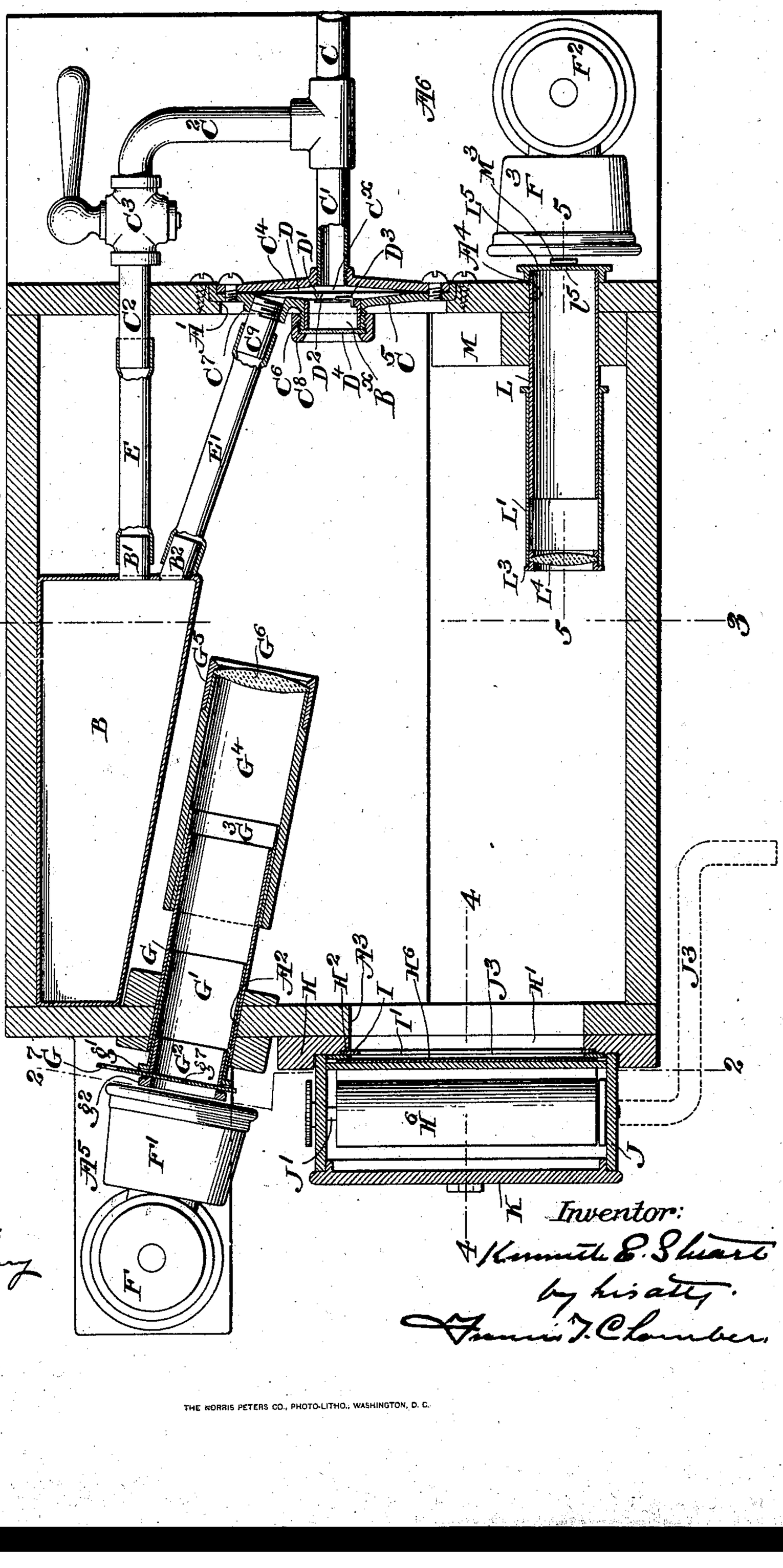
K. E. STUART.

APPARATUS FOR ASCERTAINING THE CONDITION OF PIPE CONDUITS.

APPLICATION FILED JUNE 16, 1900.

NO MODEL. 5 SHEETS—SHEET 1.

FIG. 1.

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NO MODEL. 5 SHEETS—SHEET 2.

FIG. 3.

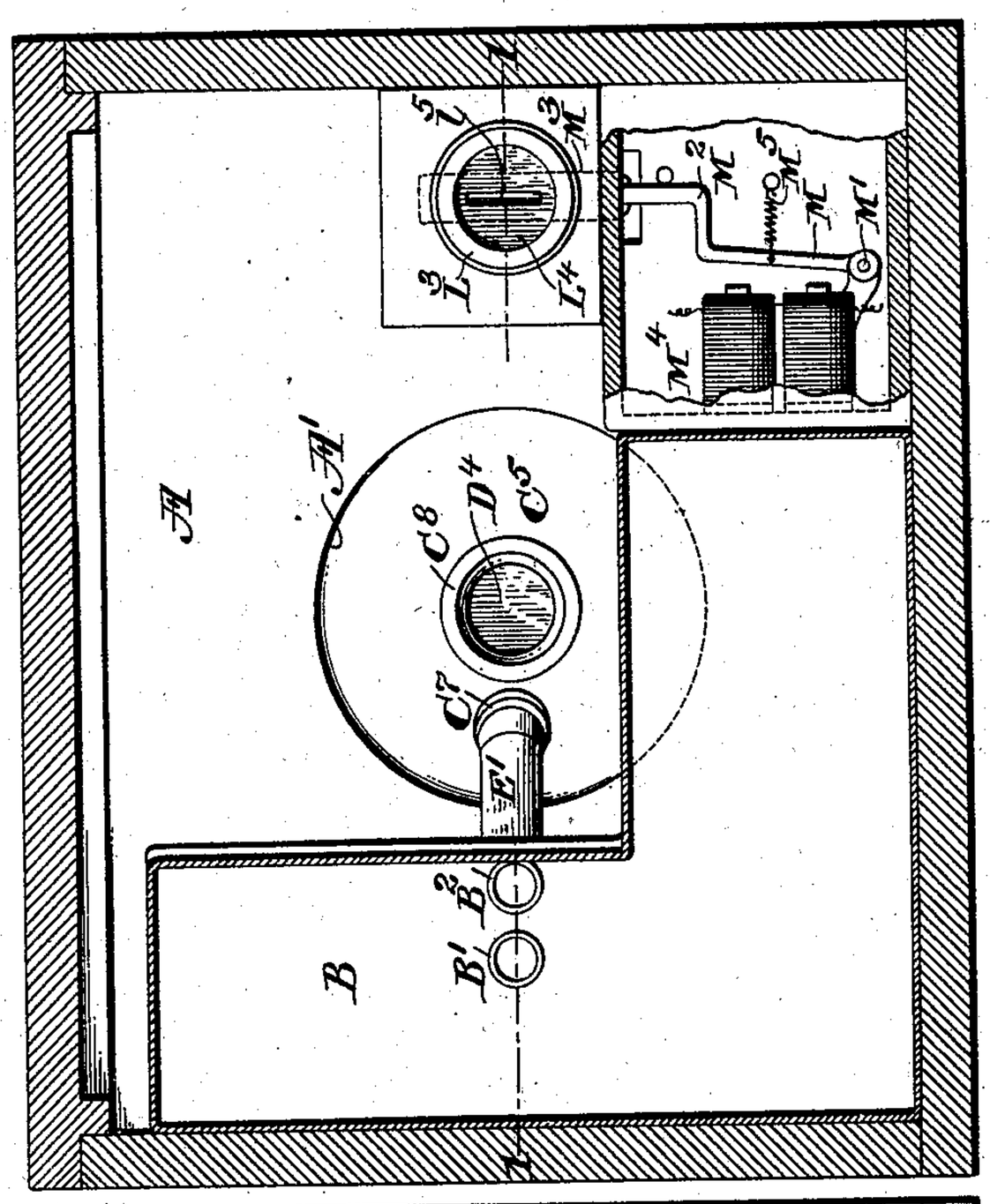
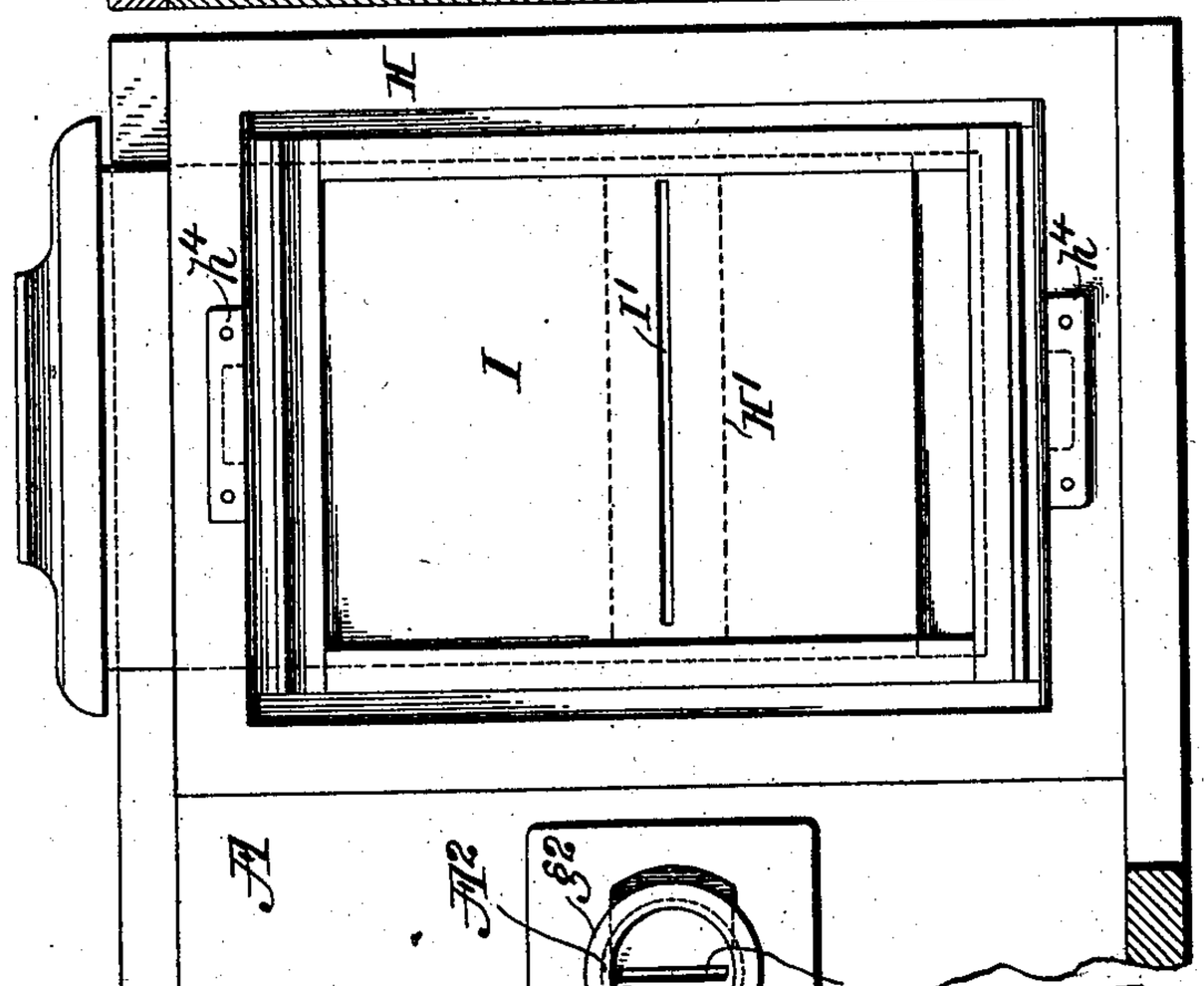



FIG. 2.

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NO MODEL. 5 SHEETS—SHEET 3.

FIG. 4.

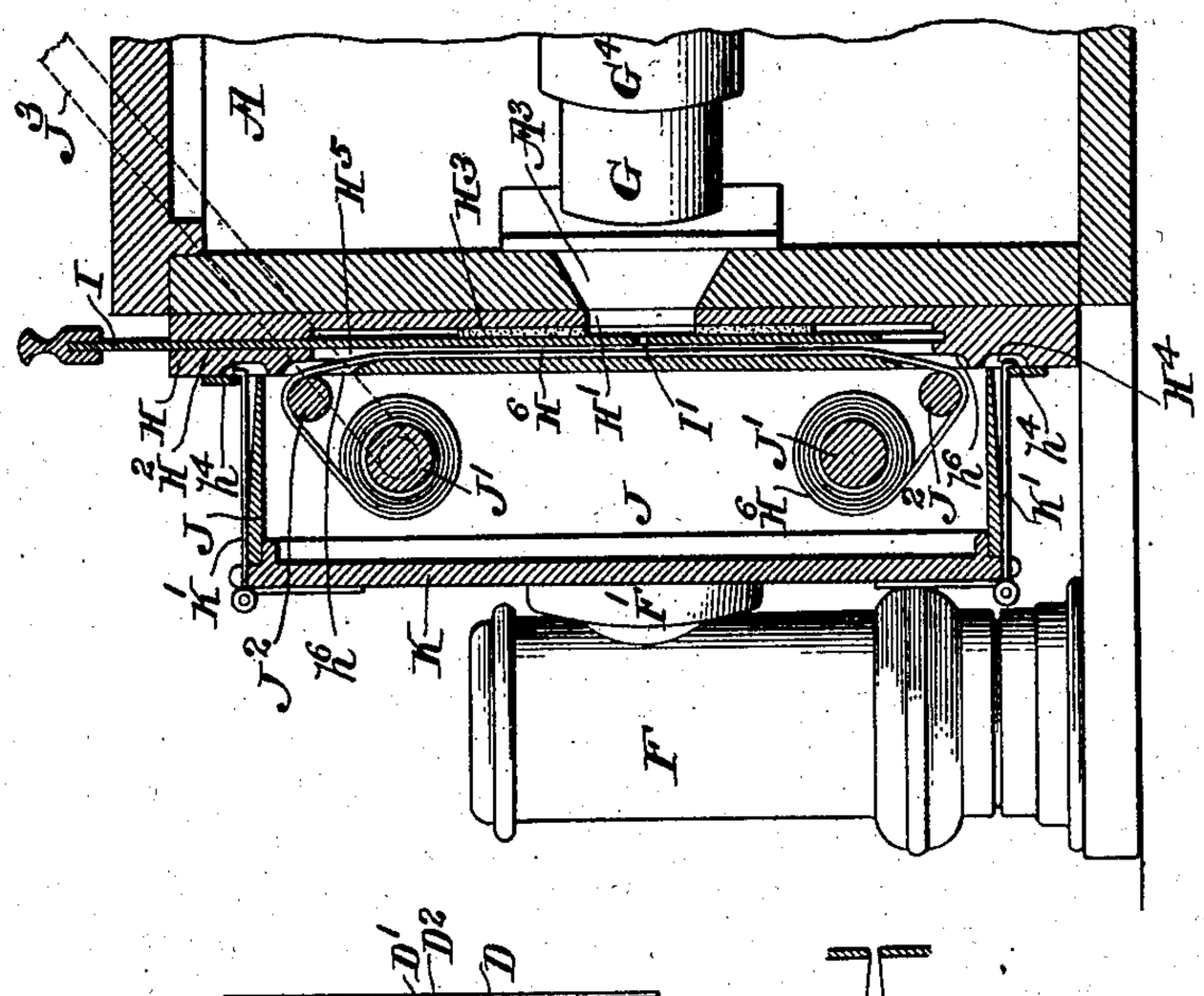
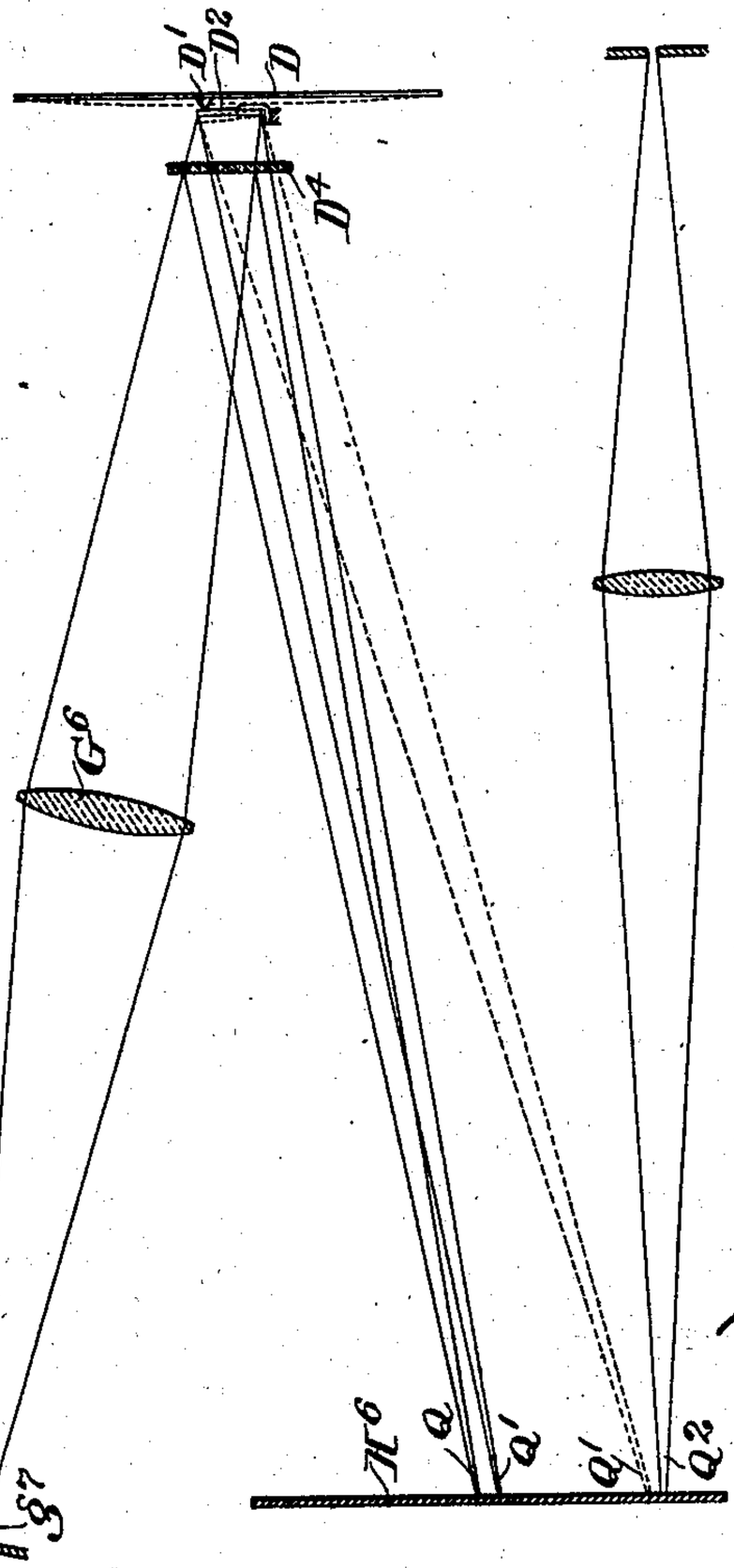



FIG. 6.

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# APPARATUS FOR ASCERTAINING THE CONDITION OF PIPE CONDUITS.

APPLICATION FILED JUNE 16, 1900.

NO MODEL. 5 SHEETS—SHEET 4.

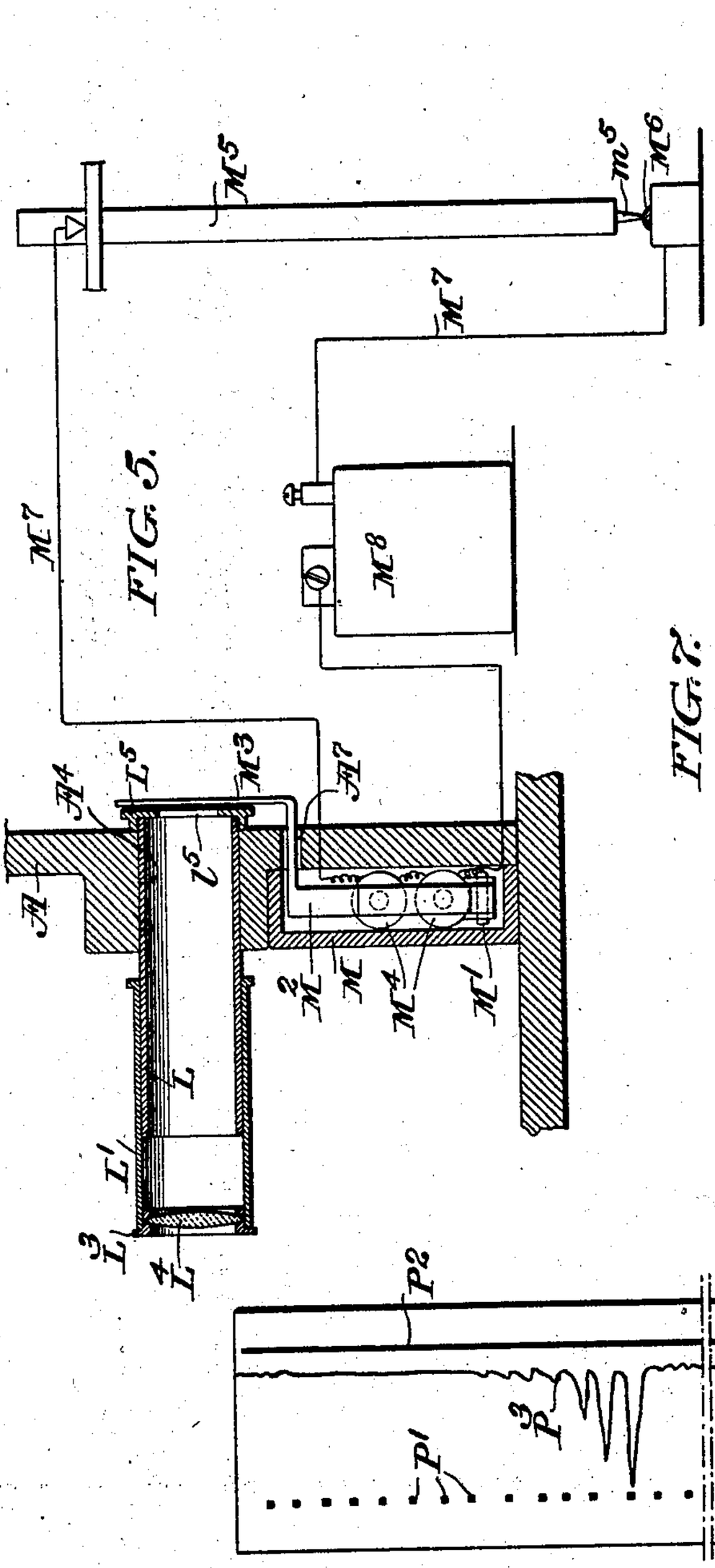


FIG. 5.

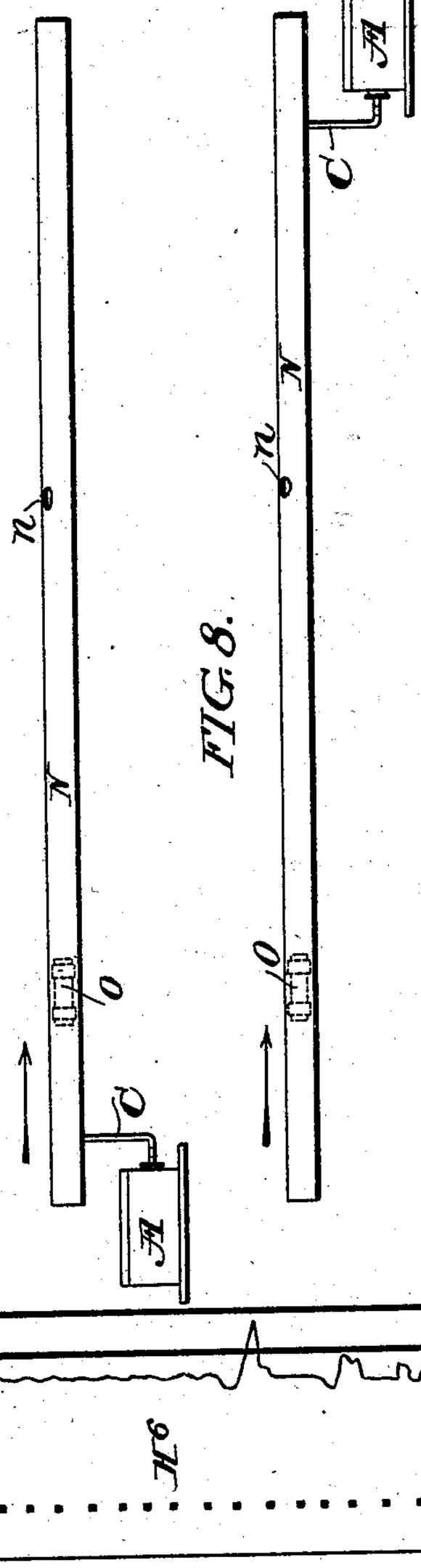


FIG. 7.




FIG. 8.

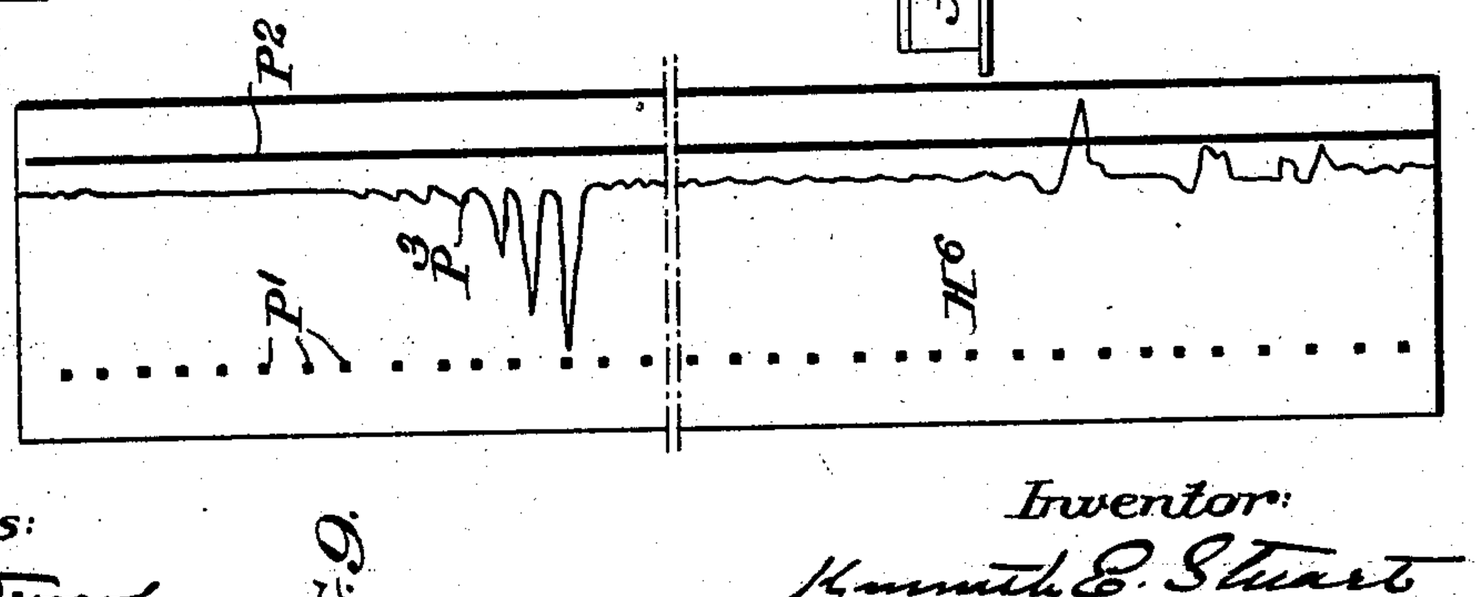


FIG. 9.

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# APPARATUS FOR ASCERTAINING THE CONDITION OF PIPE CONDUITS.

APPLICATION FILED JUNE 16, 1900.

NO MODEL. 5 SHEETS—SHEET 5.

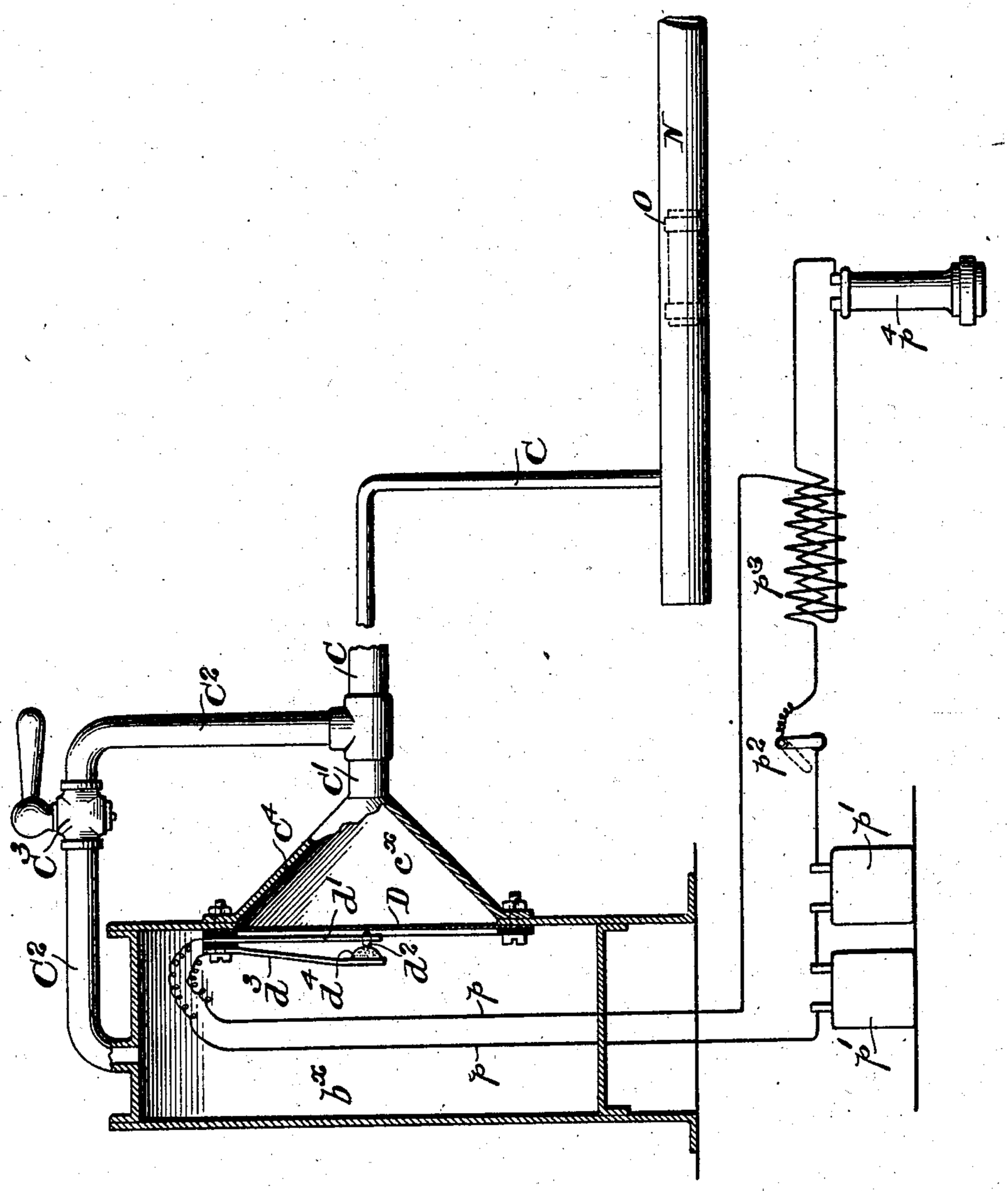


FIG. 10.

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## APPARATUS FOR ASCERTAINING THE CONDITION OF PIPE-CONDUITS.

SPECIFICATION forming part of Letters Patent No. 721,476, dated February 24, 1903.

Application filed June 16, 1900. Serial No. 20,514. (No model.)

*To all whom it may concern:*

Be it known that I, KENNETH E. STUART, a citizen of the United States of America, residing in the city and county of Philadelphia, in the State of Pennsylvania, have invented a certain new and useful Improvement in Apparatus for Ascertaining the Condition of Pipe-Conduits, of which the following is a true and exact description, reference being had to the accompanying drawings, which form a part thereof.

My invention relates to apparatus having for its purpose to enable an operator to ascertain the condition of pipe-conduits, particularly pneumatic-tube lines, my apparatus being particularly designed for the detection of leaks in such conduits, but adapted also to show with considerable accuracy the presence of inequalities and rough places in the line.

The object of my invention is to provide simple and efficient apparatus of this character; and the leading feature of my invention consists in the use of a diaphragm situated between two chambers, both of which are in communication with the pipe-conduit, in combination with means by which the vibrations of the diaphragm are made apparent to the senses.

My apparatus is adapted to be connected to a conduit containing air or other gas under high pressure, the diaphragm being secure against injury from undue pressure or impulsive fluctuations in pressure, owing to the fact that the pressure acts on both sides. In apparatus of this kind the vibrations occurring in the pipe-conduit are communicated to both of the chambers between which the diaphragm is situated, and the motions of the diaphragm will be only such as are due to the difference in the force of the vibrations acting simultaneously, or nearly so, on its opposite faces, such differences being provided for in the construction of the apparatus and preferably also by regulable mechanism by which the force of the vibrations passing to one chamber can be regulated.

My invention also consists in various mechanical devices adapted for developing the principle above stated and for producing the best effects, the nature of which will be best understood as described in connection with the drawings in which my apparatus is illustrated, and in which—

Figure 1 is a plan view of the apparatus, taken as on the section-line 1 1 of Fig. 3. Fig. 2 is an end view of the apparatus, taken on the irregular section-line 2 2 of Fig. 1. Fig. 3 is a cross-section of the apparatus, taken on the section-line 3 3 of Fig. 1. Fig. 4 is a cross-sectional view through the film-casing and end of the apparatus, taken as on the section-line 4 4 of Fig. 1. Fig. 5 is a sectional view taken as on the section-line 5 5 of Fig. 1. Fig. 6 is a diagrammatic view illustrating the light-rays and the manner in which they are thrown upon the photographic film. Figs. 7 and 8 are diagrammatic views illustrating the mode of detection of leaks in pneumatic-transit pipes. Fig. 9 is a plan view of the record made upon the photographic film, and Fig. 10 is a sectional elevation of a modification of my apparatus.

A, Figs. 1, 2, 3, 4, 5, 7, and 8, indicates a box or casing employed in the preferred form of my apparatus and having, as shown, a circular aperture $A'$ through its front wall, another circular aperture $A^2$ in its rear wall, in which is also formed a longitudinal slot, (indicated at $A^3$,) $A^4$ indicating a circular aperture in the front wall, and $A^5$ and $A^6$ projections from the bottom of the box or casing. B, (see Figs. 1 and 3) is an air-chamber inclosed, as shown, in the casing A and having short pipe-sections or thimbles, as indicated at $B'$ $B^2$, leading into it.

C is a pipe which is intended to be connected with the pipe-conduit, as shown in Figs. 7 and 8. This pipe is formed with two branches $C'$ and $C^2$, the branch $C^2$ being controlled as to its opening by a regulating-cock, (indicated at $C^3$.)

$C^4$ and $C^5$ are annular castings which are secured together at their rims, as indicated in Fig. 1, and secured in the circular aperture $A'$ of the box A. The castings are shaped, as shown, so as to form a lens-shaped chamber between them, and the casting $C^5$ is formed with an outwardly-projecting externally-threaded flange, (indicated at $C^6$,) also

with a shorter internally-threaded flange, (indicated at $C^7$,) $C^8$ indicating the clamping-ring screwing on the externally-threaded flange $C^6$, and $C^9$ indicating a short pipe-section screwing into the internally-threaded flange $C^7$.

D is a flexible diaphragm secured between the annular castings $C^2$ and $C^5$ and dividing the lens-shaped chamber formed by these castings into two chambers, (indicated at $C^\times$ and $B^\times$.)

D′ indicates a finger projecting from the inner face of the diaphragm D and resting in contact with a mirror (indicated at $D^2$) supported on a spring, (shown at $D^3$.)

$D^4$ is a transparent glass plate clamped on the end of the projection $C^6$ by means of the clamping-ring $C^8$.

E and E′, Fig. 1, indicate pipe-sections, as shown rubber hose, coupling the pipe branch $C^2$ to the thimble B′ and the short pipe $C^9$ to the thimble $B^2$.

F F′ and $F^2$ $F^3$ indicate lamps adapted to throw rays of light into the casing A through the apparatus to be described, the lamp F F′ throwing its ray of light into a tube G, secured in the aperture $A^2$ and which, as shown, has fitted in its outer end a tube-section G′, having an external flange $g'$, into the outer end of which fits another tube-section $G^2$, having an annular flange $g^2$, the tube-section $G^2$ being transversely slotted to give passage to a slide $G^7$, having a narrow vertical slot formed in it, as indicated at $g^7$, and the tube-section $G^2$ is made longitudinally adjustable in the tube-section G′, so that the slide can be held in place between the flanges $g'$ and $g^2$.

$G^3$ is a tube-section fitting on the slide on the inner end of the tube G and having secured to it, as shown, another pipe-section $G^4$, against the outer end of which is clamped a lens $G^6$ by means of a clamping-ring $G^5$.

H (see Figs. 1 to 4) is a wooden block secured against the rear face of the casing A and having formed in it a chamber or recess H′, corresponding to and registering with the slotted opening $A^3$ in the rear of the casing. The block H is also longitudinally slotted, as indicated at $H^2$, to receive a slide I, having a horizontal narrow slit I′ formed in it, $H^3$ indicating a backing, which may conveniently be of black velvet, which is secured to the inner portion of the slit $H^2$ and in contact with which moves the slide I.

$H^4$ $H^4$ indicate recesses formed in the outer face of the block H, over which project metallic lugs, (indicated at $h^4$.) It should be mentioned that the slot $H^2$ is enlarged in the interior of the block, as indicated at $H^5$, so as to afford room for the passage of a photographic film, (indicated at $H^6$,) which enters and leaves the slots through openings (indicated at $h^6$ $h^6$) in the rear face of the block.

J indicates a rectangular box supporting rolls, (indicated at J′ J′,) also guide-rolls, (indicated at $J^2$ $J^2$,) the film $H^6$ being wound on the rolls J′ and passing over the guide-rolls $J^2$ on its way to and from the slot $H^5$, as shown in Fig. 4.

$J^3$ indicates a crank-arm by which one of the rolls J′ can be revolved and the film caused to move through the slot.

K indicates the outer lid or cover of the box, which is provided with metallic fingers (indicated at K′) having an outward spring and adapted to fit under the metal lugs $h^4$, as shown. When these fingers are engaged with the lugs, the film-box J is securely held in position and tightly closed against the admission of light.

L is a tube fitting into the annular opening $A^4$ and having a telescopic extension fitting over its inner end, in which is held a lens $L^4$, secured in place by a clamping-ring $L^3$.

$L^5$ is a head screwing on the outer end of the tube L and having a narrow slot formed in it, as indicated at $l^5$, which should be vertical, as indicated.

M (see Figs. 1, 3, and 5) is a box in which is supported a pivot M′, upon which is pivoted an arm $M^2$, supporting a screen $M^3$, which is adapted to rock from a position covering the slot $l^5$ to a position to one side of said slot.

$M^4$ is an electromagnet by which the arm $M^2$ is drawn to a position which will move the screen away from the slot, a spring, as indicated at $M^5$, serving to draw it back to normal position covering the slot, stop $m^5$ holding the screen or shutter in proper position. The electromagnet $M^4$ is connected with an electrical circuit, (indicated at $M^7$,) $M^8$ indicating the battery, and $M^5$ a pendulum, which, as indicated, is intended to be a second pendulum and which forms a part of the circuit supporting a point $m^5$, which at each swing of the pendulum comes in contact with a button $M^6$, completing the circuit.

N, Figs. 7, 8, and 10, indicates a pneumatic-transit line connected with my apparatus through pipe C, as shown, $n$ in Figs. 7 and 8 indicating leaks or openings in the conduits, and O O indicating carriers moving in the conduits in the direction of the arrows; P, in Fig. 9, a portion of the photographic film with the record made by my apparatus upon it, P′ indicating a series of dots indicating time, $P^2$ an unbroken line formed by the effect of a ray reflected from the glass plate $D^4$, and $P^3$ a line formed on the film by the action of the ray reflected from the mirror $D^2$.

In Fig. 10 I have illustrated a modification of my apparatus in which the record is received by ear. In this construction the annular cone-shaped casting $C^4$ is secured directly to the air-box, (here indicated at $b^\times$,) which in this construction takes the place of both the air-box B and the chamber $B^\times$. D indicates the diaphragm situated between the chamber $c^\times$ and the chamber $b^\times$. $d'$ is a metallic finger secured at one edge of the diaphragm, but out of electrical contact with it. $d^2$ indicates a platinum button supported on the finger $d'$, and resting against the diaphragm $d^3$ is a metallic finger supporting a

carbon button $d^4$, which rests against the platinum button $d^2$. $p$ indicates an electric circuit connecting with the finger $d'$ and $d^3$, $p'$ indicating a battery, $p^2$ a switch, $p^3$ an induction-coil, and $p^4$ a telephonic receiver.

In operation of my preferred visual recording apparatus the lights (indicated at F F′ and $F^2$ $F^3$) are lighted, the first light throwing through the slit $g^7$ of the slide $G^7$ a vertical ray of light against and through the glass plate $D^4$ and against the mirror $D^2$. This ray is reflected from both the glass plate and the mirror, as indicated in Fig. 6, the light reflected from the plate being indicated at Q and the light reflected from the mirror being indicated at Q′, the dotted line (also marked Q′) indicating the effect of vibrations in the mirror. The ray from the lamp $F^2$ $F^3$, thrown through the vertical slit $l^5$, is indicated at $Q^2$ in Fig. 6, and the time-escapement operating the shutter or screen $M^3$ being in operation the light-ray $Q^2$ will only be thrown intermittently on the film $H^6$, making when the film is moving a series of dots, (indicated at P′, Fig. 9,) each of which marks the lapse of a second.

It will be obvious that all vibrations occurring in the conduit-line N will be communicated to the tube C and through the branch C′ of said tube to the chamber $C^\times$ and the inner face of the diaphragm D. These vibrations, however, if not modified in scope and to some extent in character will not be of such a character as to be easily recorded; but obviously the same vibrations are indicated through the branch tube $C^2$ and the air-chamber B and the pipe E′ to the chamber $B^\times$ and with an amplitude which can be nicely regulated by the cock $C^3$. The motion of the diaphragm D, however, will be that resulting from the difference in the impulses communicated to the two chambers between which it is situated, and these "differential vibrations," so to speak, will still be of a character to nicely indicate the actual changes and the character of vibrations in the tube.

The necessary difference in the character of the vibrations communicated to the opposite sides of the diaphragm D can be brought about by any means which will bring about an inequality in the force of the vibrations communicated through the two conduits to the diaphragm, and in the construction illustrated this inequality is brought about by means of four different but coacting devices, namely: in the first place, by the restriction of the passage in the conduit $C^2$ by means of the stop-cock $C^3$; in the second place, by including in the conduit $C^2$ a chamber, such as B, of greater area and capacity than any chamber directly connected with the conduit C′; in the third place, by directing the vibrations against the diaphragm in different directions—for instance, the conduit C′ being at right angles to the diaphragm and the conduit $C^9$, forming the delivery end of the conduit $C^2$, being at an acute angle to the diaphragm—and, in the fourth place, the effective force of the vibrations will vary in accordance with the portion of the diaphragm upon which they directly impinge. Thus the vibrations communicated through conduit C′ act with greater force than those from conduits $C^2$ $C^9$, because the first impinge on the center of the diaphragm and the last near its outer edge. When the carrier passes a leak, a wave of rarefaction is sent traveling through the tube in the direction of the source of the air-supply and a wave of compression in the opposite direction. This may be explained as follows: While the carrier is passing through a smooth unbroken conduit the air coming from the source is always just sufficient to occupy the space displaced by the carrier. After the leak is passed some of the air supplied at the source escapes through it. The air that does not escape is not sufficient to occupy the space displaced by the carrier traveling at undiminished velocity. Consequently its velocity must diminish. Owing to the momentum of the carrier, however, such diminution of velocity requires an appreciable lapse of time, during which the pressure immediately behind the carrier must fall somewhat. In other words, before the carrier can adjust itself to the new conditions it has opened up a region of comparative rarefied air behind itself, and this region travels back to the source in the form of a wave. Before the carrier has reached the leak some of the air ahead of it escapes through the leak. After the carrier has passed the leak this exit is closed. Before the carrier has adjusted itself to the new conditions it must, therefore, have caused a region of comparatively dense air ahead of itself, which region travels in the form of a wave through the conduit away from the source of air-supply.

It will be seen that the comparatively rarefied region at the rear of the carrier and dense region ahead of it at the instant succeeding the passing of the leak do not exist permanently, for within a brief space of time the velocity of the carrier will have diminished, so that the space displaced by it is completely filled by the air that does not escape through the leak. Equilibrium is therefore restored, and though the carrier continues on its way at diminished velocity the disturbance caused by the passing of the leak gradually dies out.

Irregularities, rough places, shoulders between joints, &c., all tend to retard the passage of the carrier, causing a momentary rarefaction ahead of it and compression behind it. These disturbances travel in the form of waves in their respective directions, and the one reaching the terminal at which the instrument is located impresses a record upon the photographic film.

It will be seen that the disturbance caused by an obstruction is opposite in character to

that caused by a leak, so that there is no difficulty in distinguishing between the records produced in the two.

The rate of the speed of the carrier being known, it is obvious that the position of the carrier in the tube at the time when an irregularity in the vibrations recorded occurs will be nicely indicated on the diagram by reference to the line of dots P'. There is also a still more refined method of determining the location of the carrier at the instant when it passes a leak, as indicated by the photographic record, as follows: When the carrier passes the leak, a disturbance is sent traveling down the tube in both directions with the velocity of sound. The disturbance reaches the instrument, leaves a record, and is reflected back through the tube again after the manner of echoes. Upon striking the carrier the disturbance undergoes a second reflection and is again sent traveling forward toward the instrument. In this way every disturbance produces from two to seven distinct records at time intervals, being a function of the distance between the instrument and the carrier and the speed of sound. The velocity of sound under the given condition being known, the distance from the instrument to the leak may be computed with a high degree of accuracy, the motion of the carrier being eliminated mathematically.

Having now described my invention, what I claim as new, and desire to secure by Letters Patent, is—

1. In a device for ascertaining the condition of the interior of pipe-conduits, a diaphragm separating two chambers, as $C^{\times}$ $B^{\times}$, connections from each of said chambers to the pipe-conduit, one of said connections being provided with a means for creating an inequality between the force with which impulses from a single origin strike upon the two sides of the diaphragm and means of conveying to the senses the vibrations of the diaphragm.

2. In a device for ascertaining the condition of the interior of pipe-conduits, a diaphragm separating two chambers as $C^{\times}$ $B^{\times}$, connections from each of said chambers to the pipe-conduit, said connections being of different volumetric capacity in order that impulses from a single origin may strike upon the two sides of the diaphragm with unequal force, owing to the greater cushioning in the connection having the greater volume and means for conveying to the senses the vibrations of the diaphragm.

3. In a device for ascertaining the condition of the interior of pipe-conduits, a diaphragm separating two chambers, as $C^{\times}$ $B^{\times}$, connections from each of said chambers to the pipe-conduit, said connections leading into the chambers at different angles so that impulses from a single origin may strike upon the two sides of the diaphragm with unequal force owing to the different degrees of obliquity and means for conveying to the senses the vibrations of the diaphragm.

4. In a device for ascertaining the condition of the interior of pipe-conduits, a diaphragm separating two chambers, as $C^{\times}$ $B^{\times}$, a pipe, as C, having branches, as C' $C^2$, connecting with the two chambers respectively, said pipe being adapted to connect with the pipe-conduit and means for conveying to the senses the vibrations of the diaphragm.

5. In a device for ascertaining the condition of the interior of pipe-conduits, a diaphragm separating two chambers, as $C^{\times}$ $B^{\times}$, a pipe, as C, having branches, as C' $C^2$, connecting with the two chambers respectively, said pipe being adapted to connect with the pipe-conduit, a regulating device, as cock $C^3$, situated in one of the branches, and means for conveying to the senses the vibrations of the diaphragm.

6. In a device for ascertaining and recording the condition of the interior of pipe-conduits, a diaphragm arranged in position to be vibrated by vibrations in the air column in the conduit, in combination with a mirror connected to and vibrated by the diaphragm, a stationary reflector, a lamp arranged to throw a ray of light on the mirror and stationary. reflector, a photographic film and means for moving the same and a film-casing having a slot through which the light-rays reflected from the mirror and reflector are thrown on the film.

7. In a device for ascertaining and recording the condition of the interior of pipe-conduits, a diaphragm arranged in position to be vibrated by vibrations in the air column in the conduit, in combination with a mirror connected to and vibrated by the diaphragm, a stationary plate of glass arranged in front of the mirror, a lamp arranged to throw a ray of light through the glass plate on the mirror, a photographic film and means for moving the same and a film-casing having a slot through which the light-rays reflected from the glass plate and from the mirror are thrown on the film.

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