No. 788,086. PATENTED APR. 25, 1905.

A. BENEDETTO.

MULTIPLE EXPANSION VIBRATORY STEAM ENGINE.

APPLICATION FILED JUNE 28, 1904.

6 SHEETS—SHEET 1.

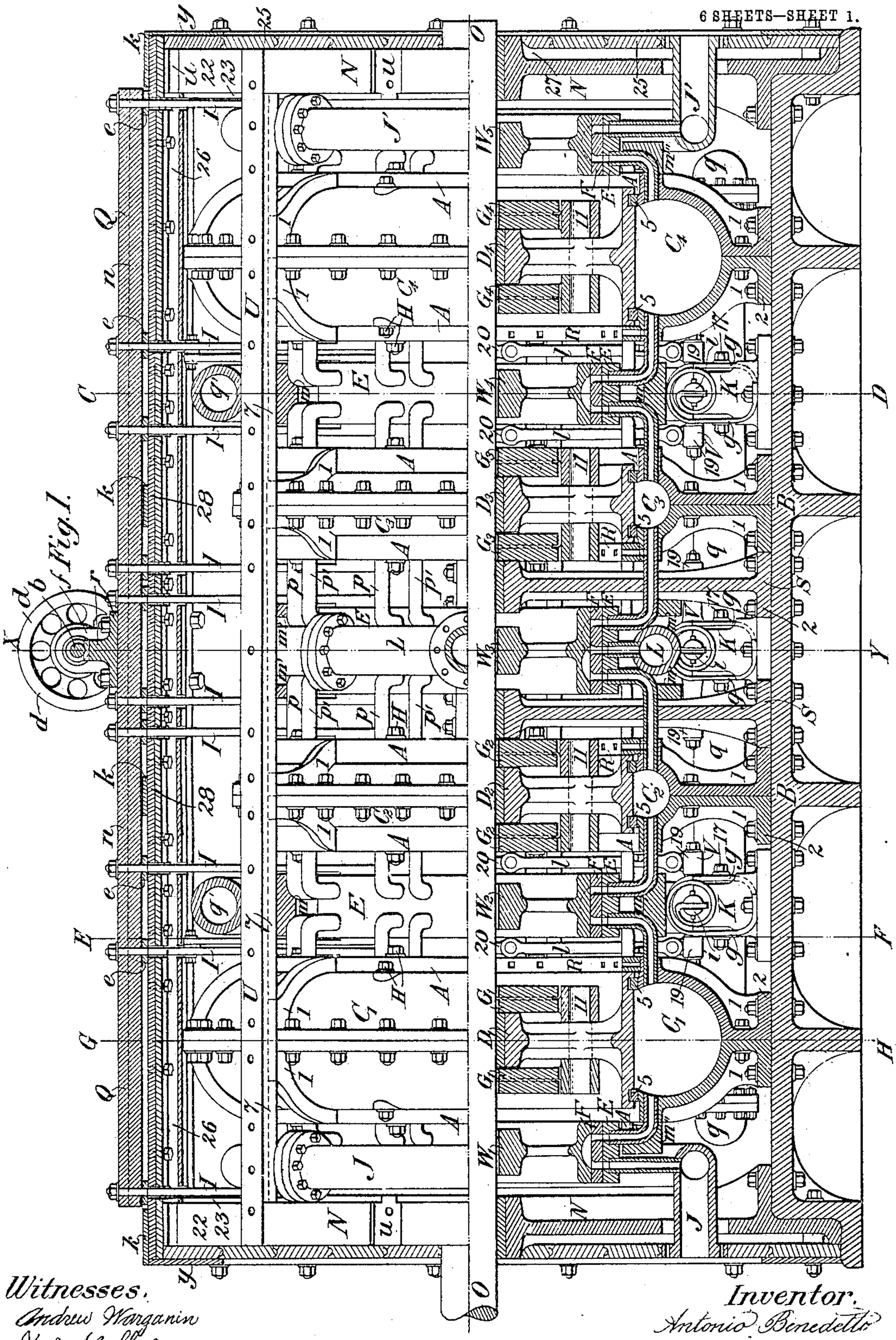

Fig. 1.

Witnesses.
Andrew Warganin
John Callahan

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Antonio Benedetto

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6 SHEETS—SHEET 2.

Fig. 3.

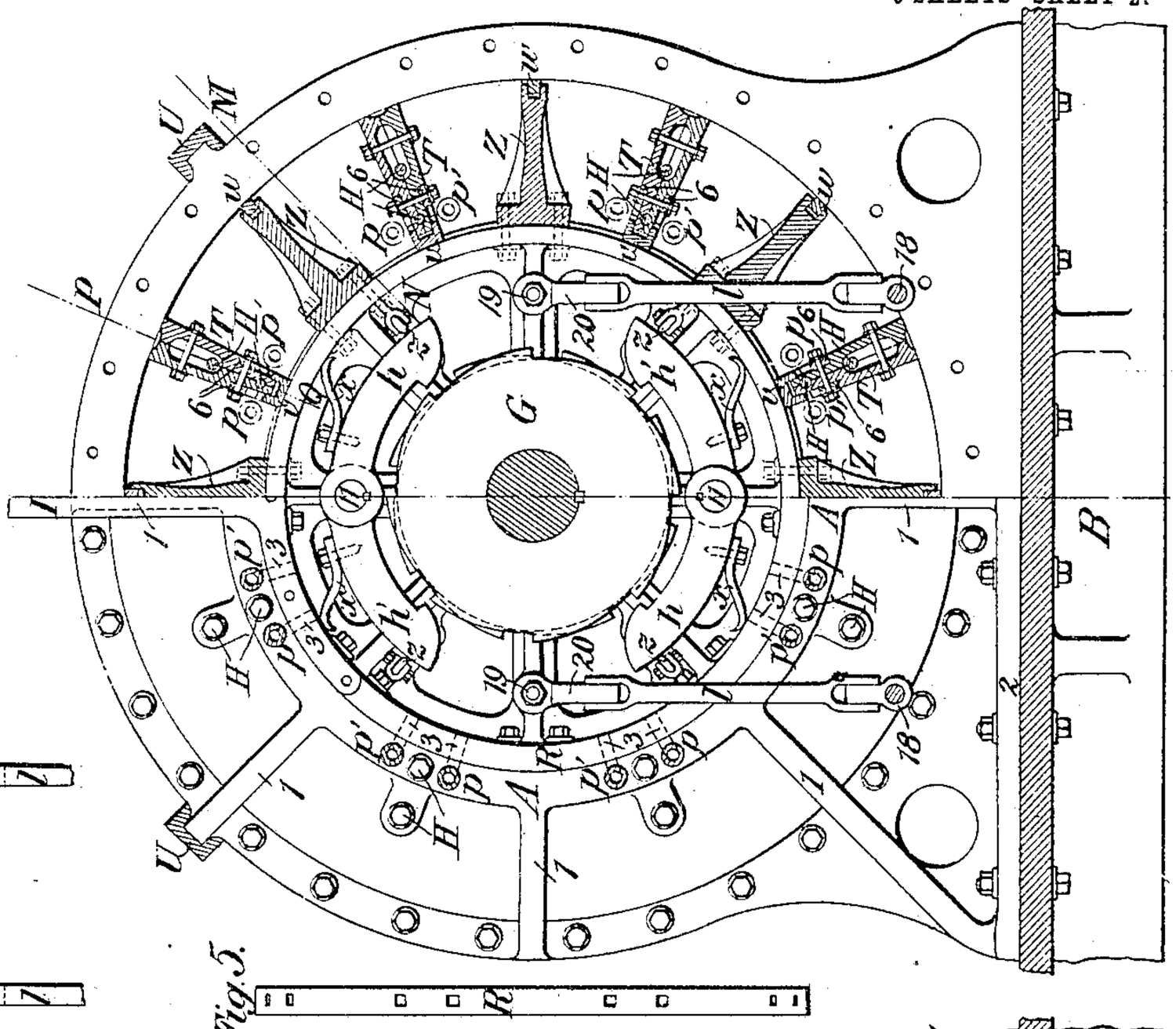


Fig. 4.

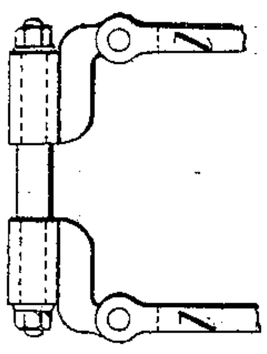
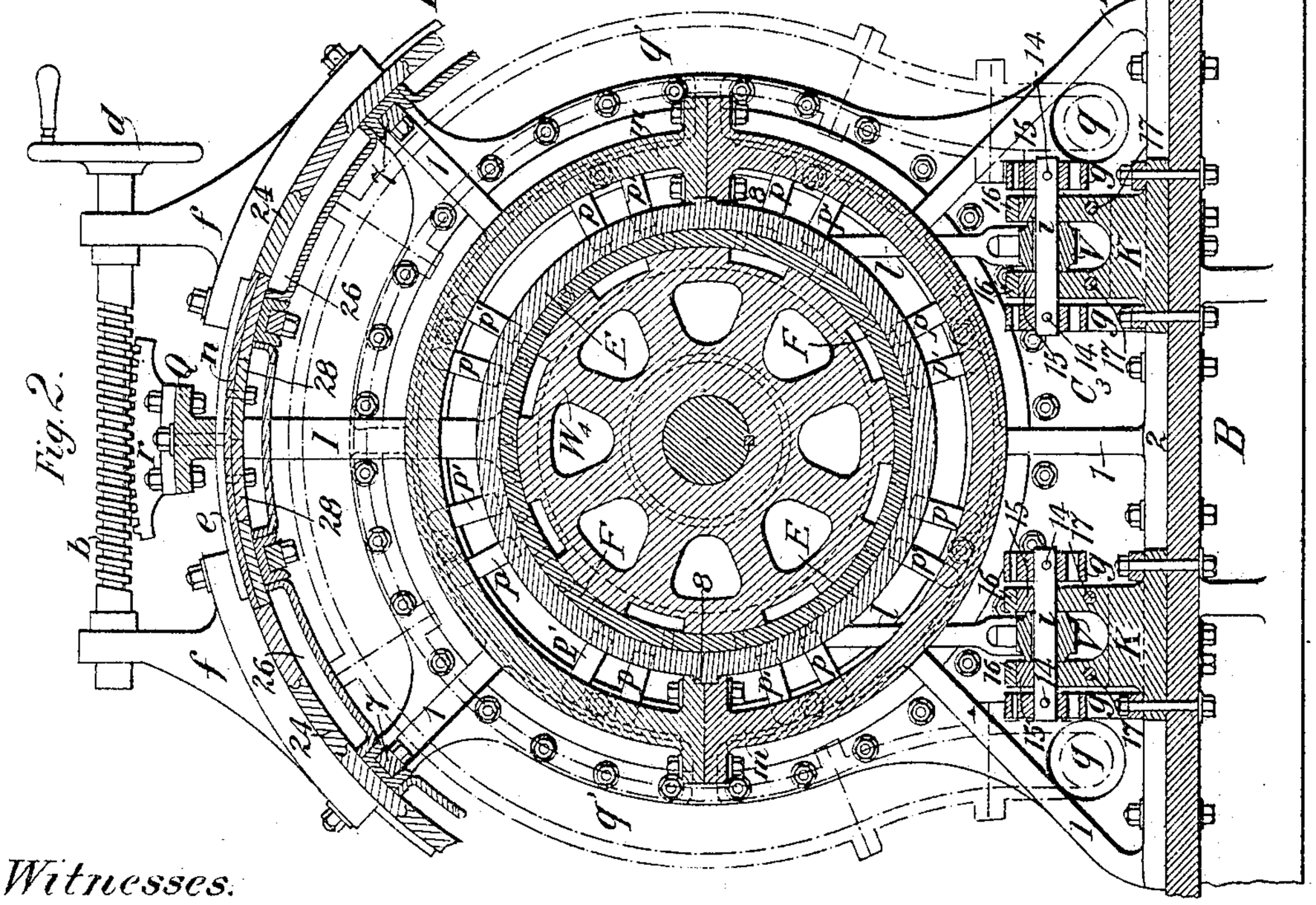


Fig. 5.

Fig. 2.



Witnesses.

Andrew Wargavin

John Callahan

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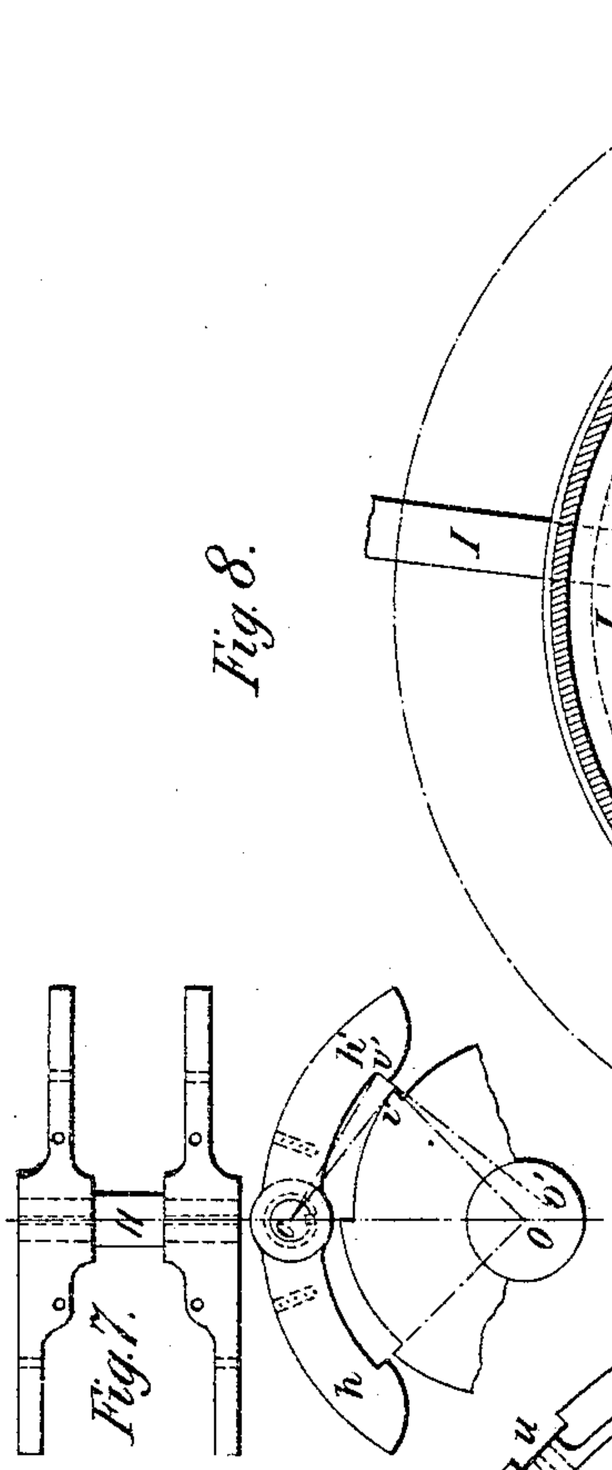

Fig. 7.

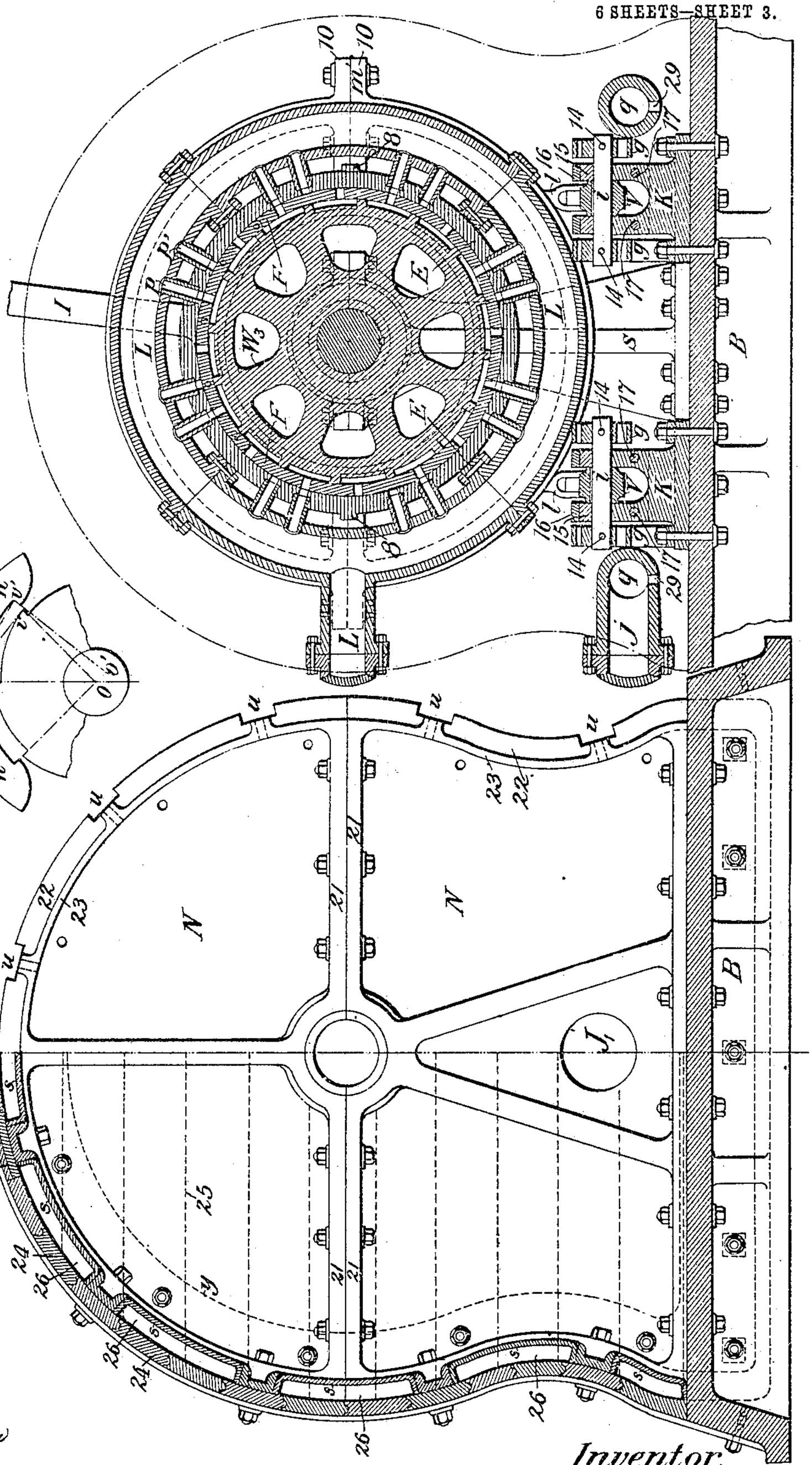

Fig. 8.

Fig. 6.

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6 SHEETS—SHEET 4.

Fig. 15.

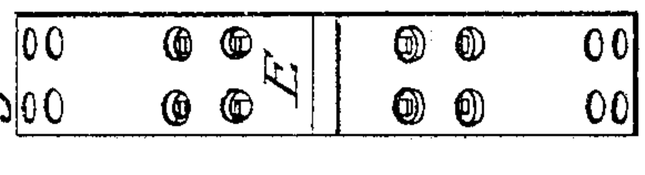


Fig. 14.

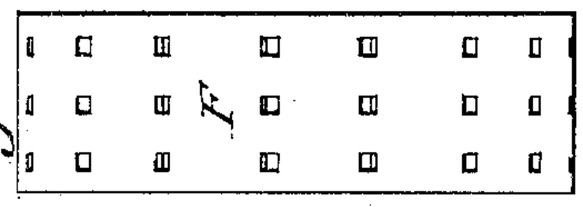


Fig. 13.

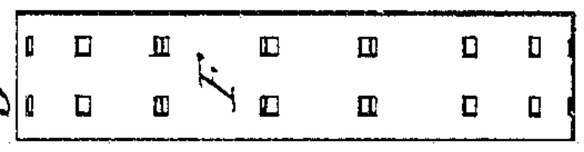


Fig. 12.

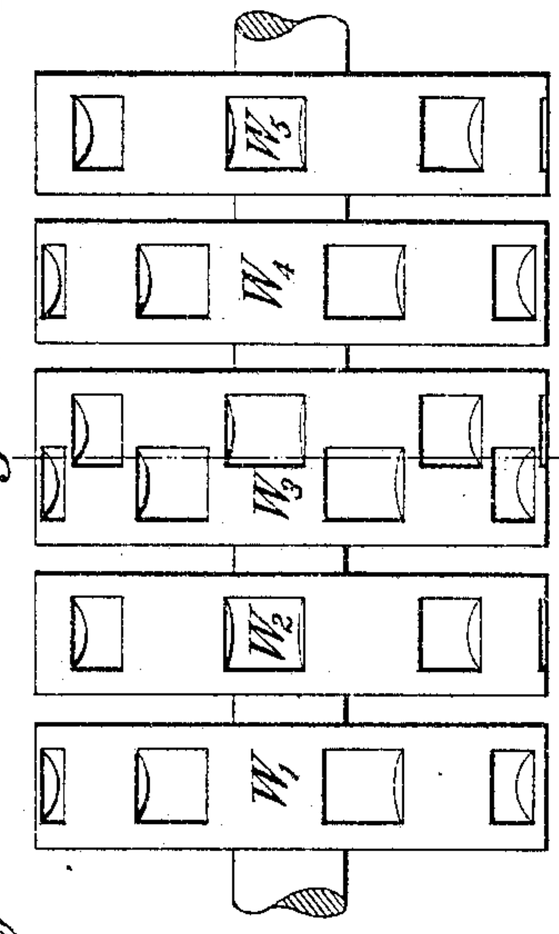


Fig. 11.

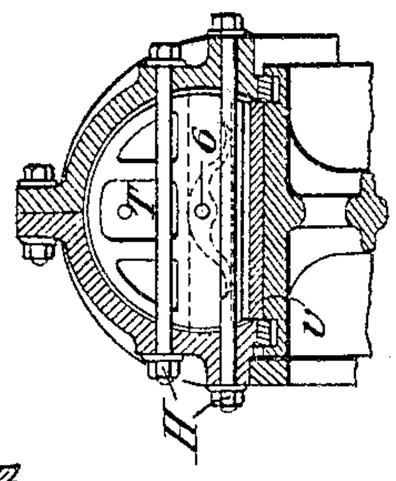


Fig. 10.

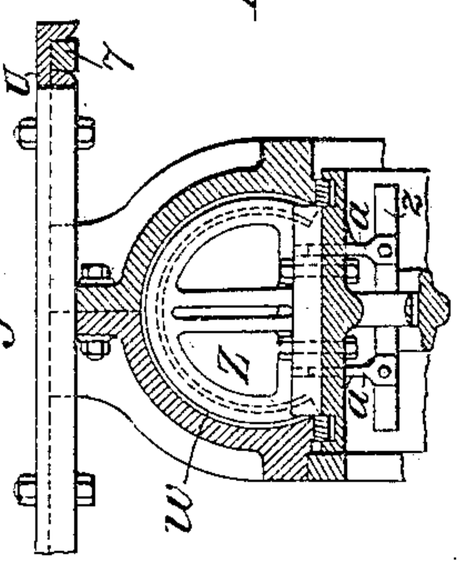


Fig. 17.

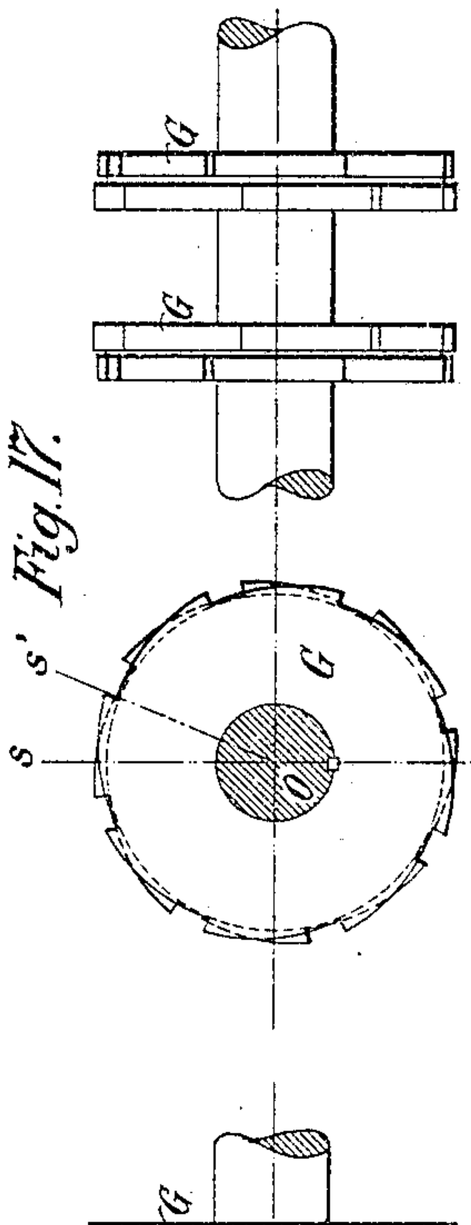


Fig. 9.

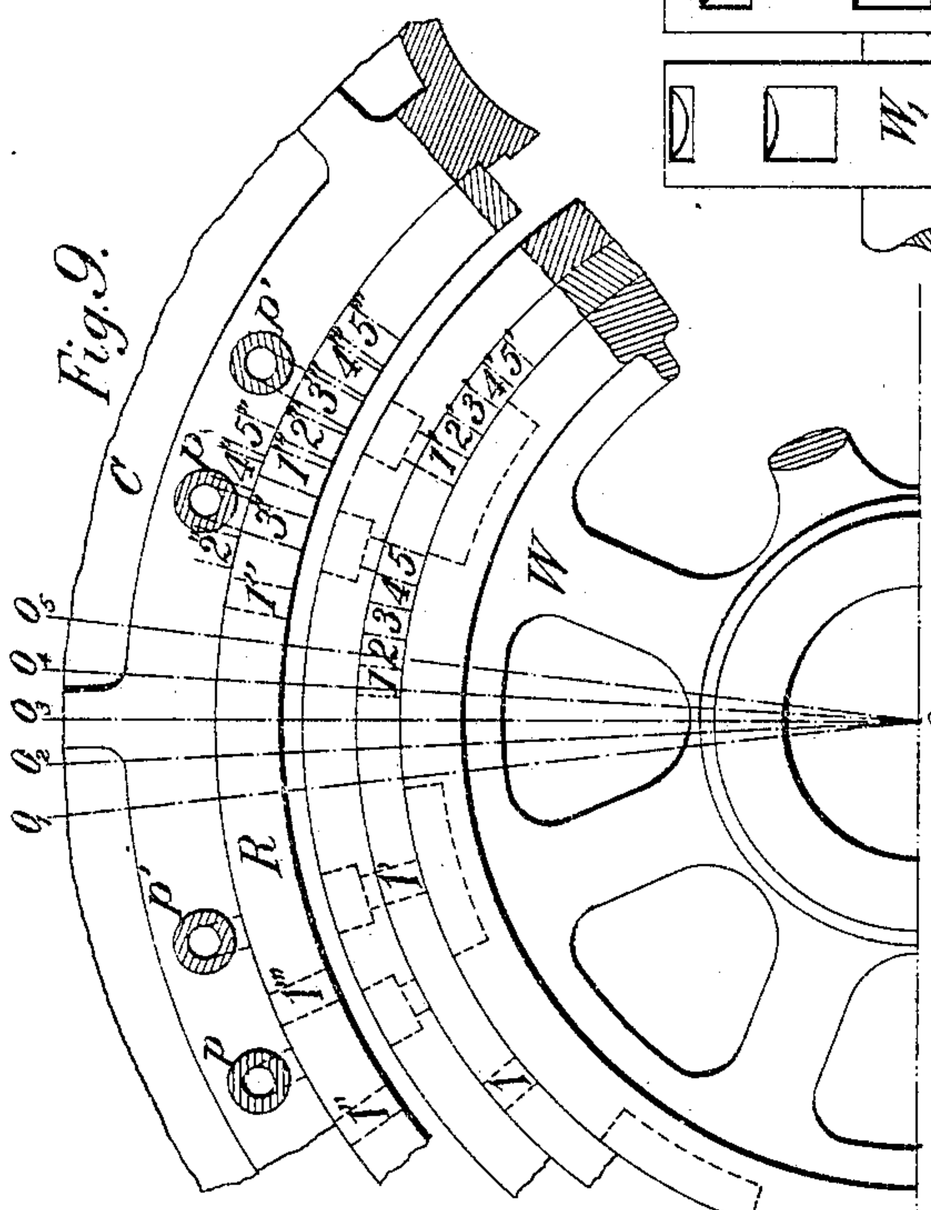
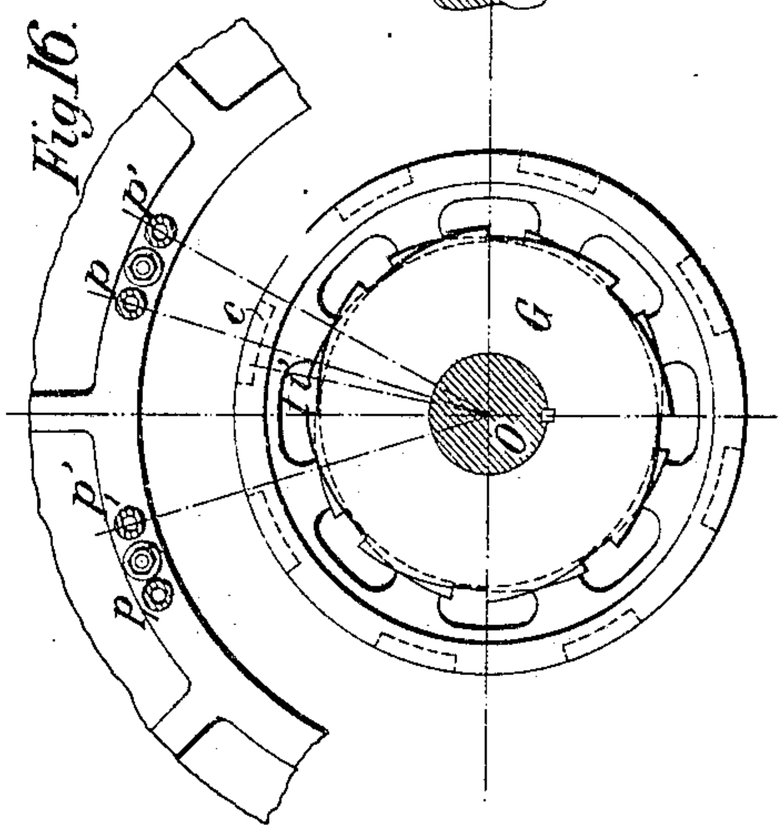


Fig. 16.



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6 SHEETS—SHEET 6.

Fig. 20.

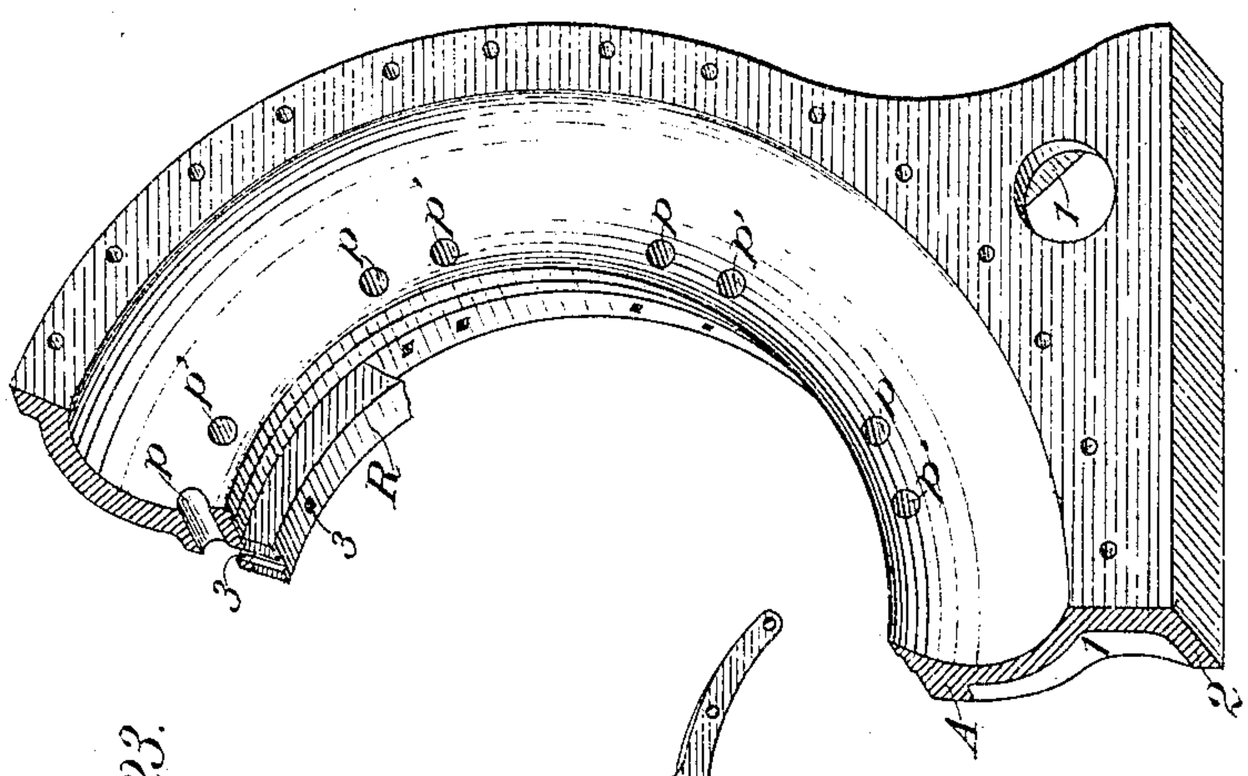


Fig. 24.

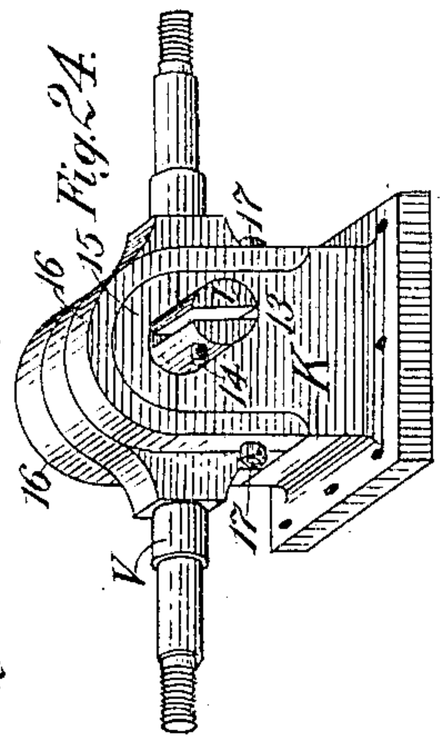


Fig. 23.

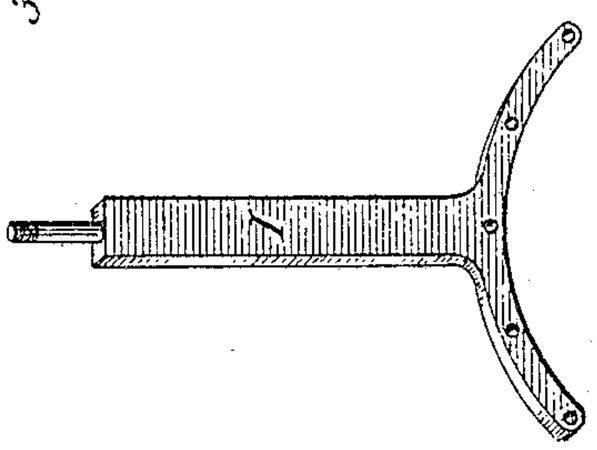


Fig. 19.

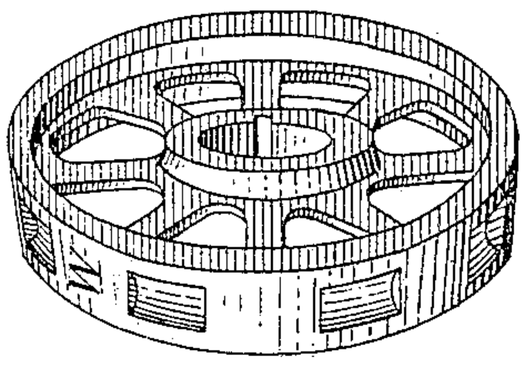


Fig. 25.

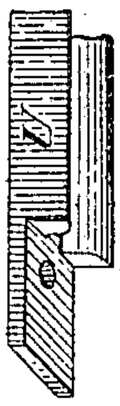


Fig. 21.

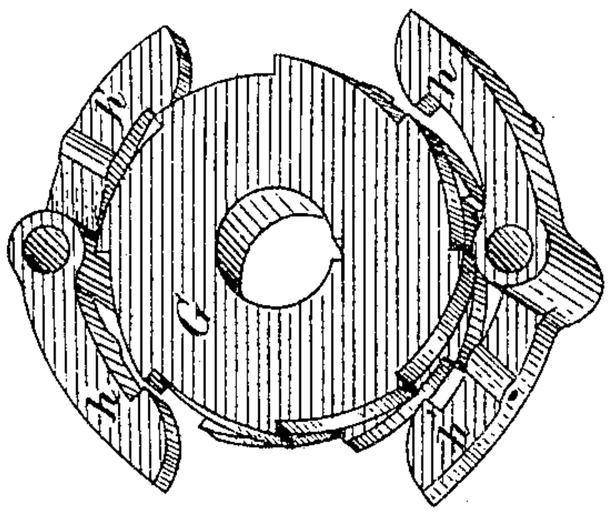


Fig. 18.

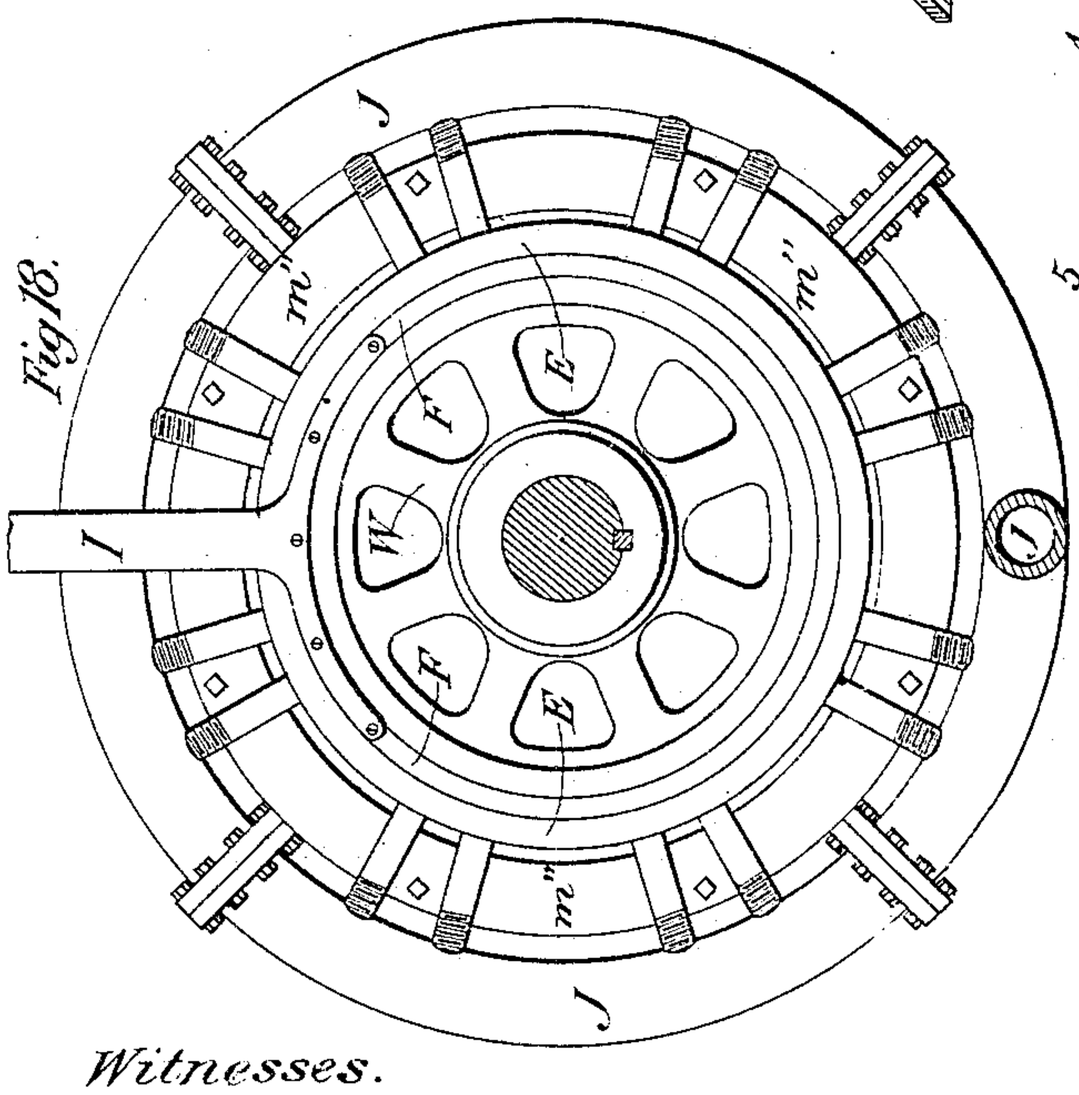
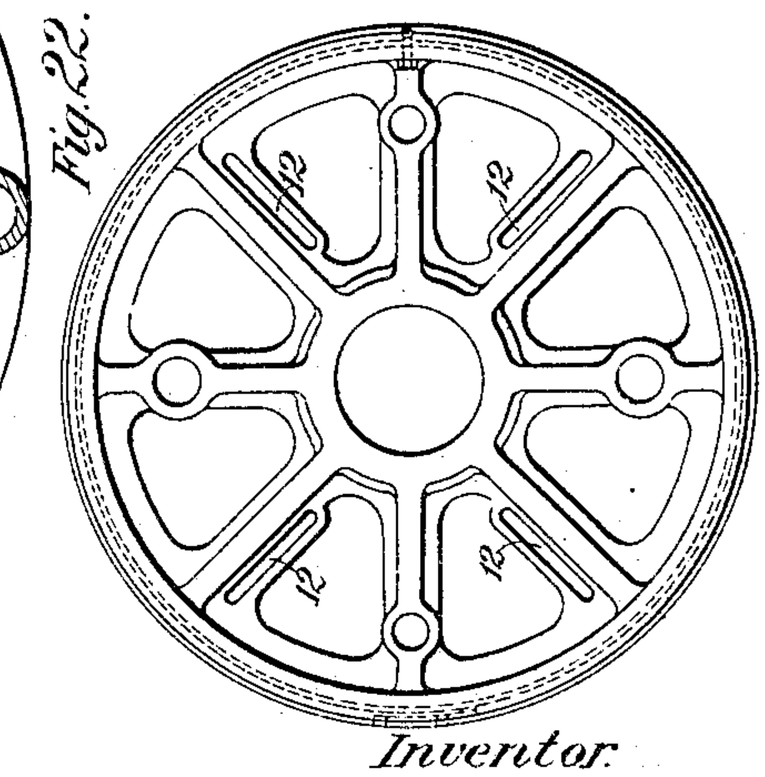
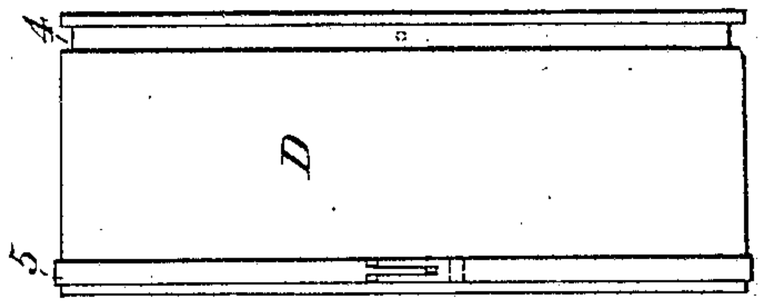


Fig. 22.





Witnesses.

John Callahan

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APPLICATION FILED JUNE 28, 1904.

6 SHEETS—SHEET 6.

Fig. 25.

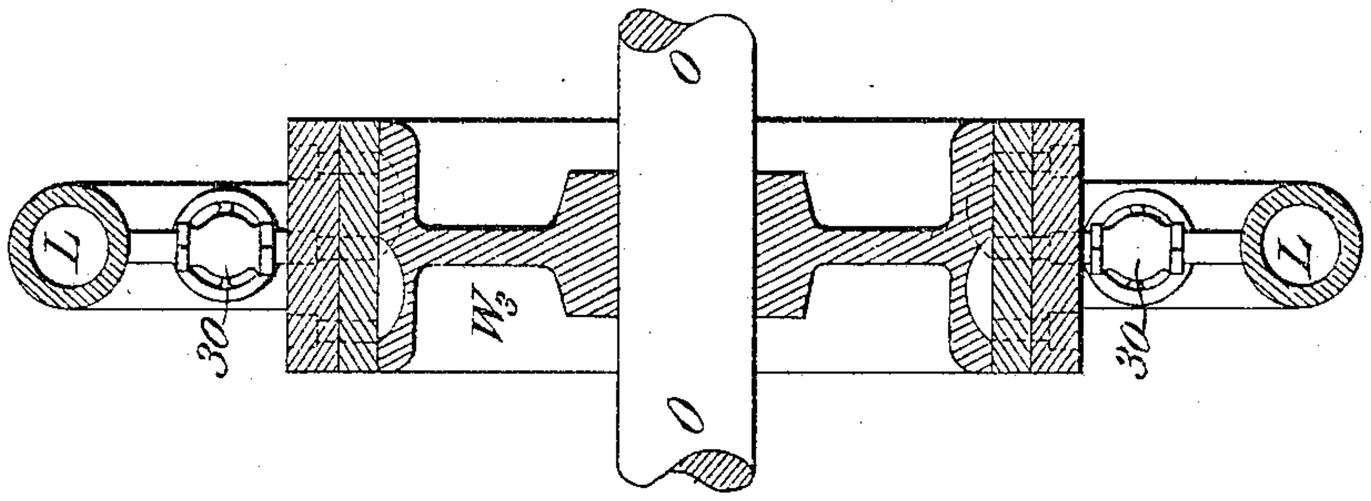
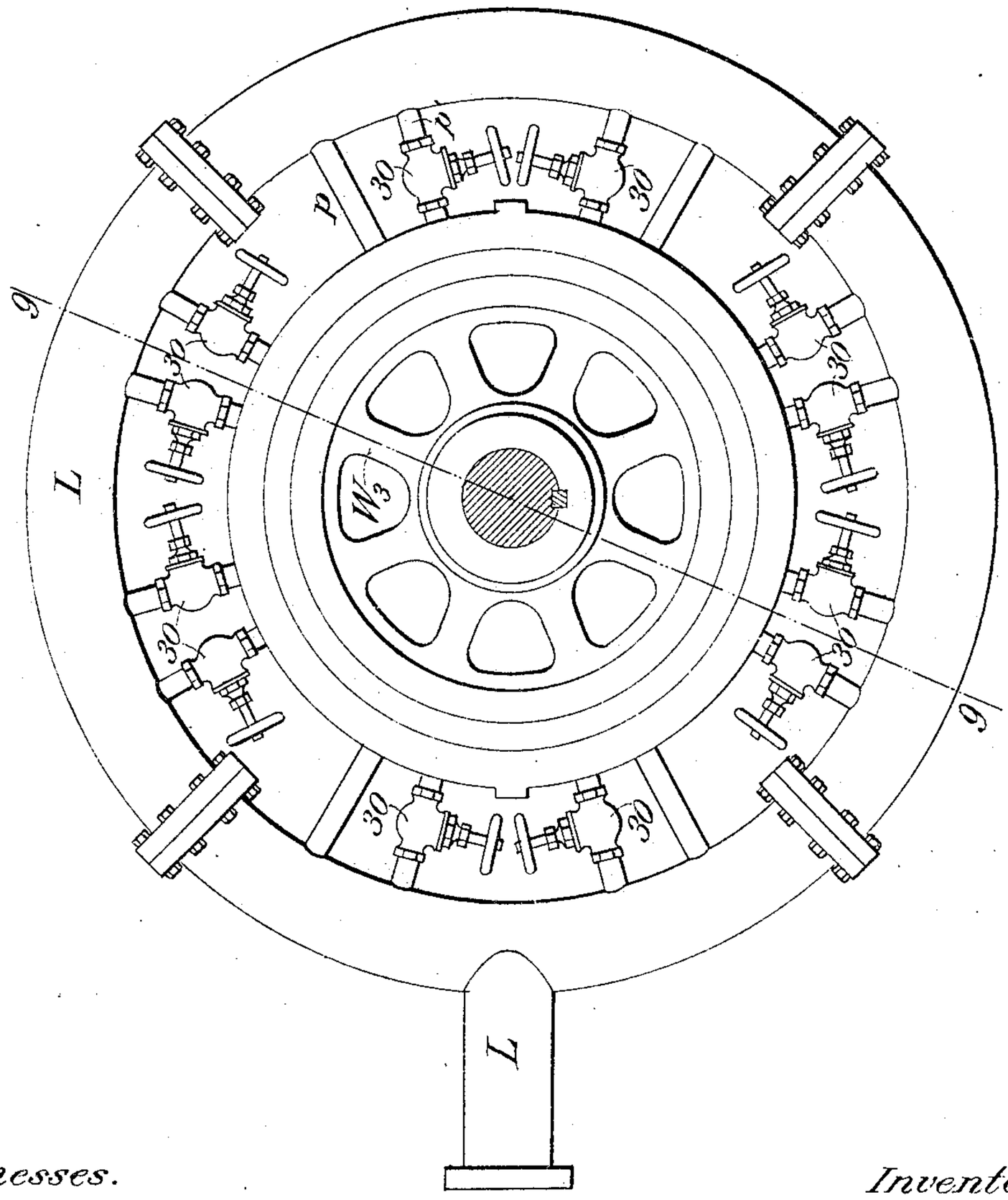


Fig. 26.



Witnesses.
John Callahan
Andrew Morganin

Inventor.
Antonio Benedetto.

No. 788,086. Patented April 25, 1905.

UNITED STATES PATENT OFFICE.

ANTONIO BENEDETTO, OF WASHINGTON, DISTRICT OF COLUMBIA.

MULTIPLE-EXPANSION VIBRATORY STEAM-ENGINE.

SPECIFICATION forming part of Letters Patent No. 788,086, dated April 25, 1905.

Application filed June 28, 1904. Serial No. 214,564.

To all whom it may concern:

Be it known that I, ANTONIO BENEDETTO, a citizen of the United States, residing at Washington, District of Columbia, have invented a new and useful Multiple-Expansion Vibratory Steam-Engine, of which the following is a specification.

My invention relates to a new system of using steam as a motive power; and the objects of my invention are, first, economy of space and weight in multiple-expansion engines; second, to reduce the steam consumption comparatively to the amount of power developed; third, to reduce the consumption of fuel for high-power steam-engines. I attain these objects by the mechanism illustrated in the accompanying drawings, in which—

Figure 1 shows on the upper part from the center the elevation of the engine as completed internally, with the covering sectioned according to a vertical plane passing through the center of the engine, and on the lower part shows a longitudinal section through one set of steam-passages, but represented conventionally in the same plane as before. Fig. 2 is a cross-section through C D, Fig. 1, and it shows only a portion of the covering at the top with the mechanism for reversing the engine. The dot-and-dash lines represent the section of a heating-pipe. Fig. 3 on the left-hand side shows a cross-section through E F, Fig. 1; but it does not show the covering, and on the right-hand side shows the section of a steam-chest according to G H, Fig. 1. The driving and the ratchet wheels in the center, with the double pawls, are shown in full. Fig. 4 shows a pin with two cross-joints for connecting the several driving-wheels. Fig. 5 is the side view of one of the rings used for opening the steam-chests to the atmosphere, therefore called "opening-rings." Fig. 6 shows one of the heads of the engine seen from the inside and fastened to the bed-plate. On the left-hand side is shown the covering as completed, and on the right are shown the castings only. Fig. 7 shows the elevation and plan of a couple of double pawls which are to be attached to the driving-wheels one on each side. Fig. 8 is a cross-section through the center of the engine according to the line X Y, Fig. 1, but not showing the covering and reversing mechanism. The dot-and-dash line represents the periphery of a steam-chest. Fig. 9 explains the theory of the reversion of the engine. Fig. 10 is a section on a steam-chest according to M N, Fig. 3. Fig. 11 is a section on the same steam-chest according to P Q. Fig. 12 shows the different positions of the wheels which carry the valves, that will be called "multivalve-wheels." They are fixed on the shaft, and the valves must correspond with each other alternatively. Fig. 13 is the side view of one of the rims which cover externally the rim of the multivalve-wheels and are used for the purpose of reversing the engine, therefore will be called "reversing-rings." Fig. 14 is the side view of the reversing-ring to be placed in the center of the engine, and it will surround the multivalve-wheel shown in the center of Fig. 12. Fig. 15 is the side view of one of the rims which surround the reversing-rings. They are used for connecting the steam-passages and therefore called "connecting-rings." Fig. 16 shows the relative position between the multivalve-wheels and the ratchet-wheels. Fig. 17 shows another position of the ratchet-wheels. They are fixed on the shaft like the multivalve-wheels. Fig. 18 is a section made between an engine-head and the exhaust-pipe, and it shows an exhaust-pipe with the exhaust-ports, a multivalve-wheel in the center, &c. Fig. 19 is a perspective drawing of a multivalve-wheel. Fig. 20 is a portion of one of the parts of the steam-chests. Fig. 21 is a perspective drawing of a double ratchet wheel with two diametrically opposite double pawls. Fig. 22 is the front and side view of a driving-wheel. Fig. 23 shows a reversing-bar. Fig. 24 is a perspective drawing of one of the posts with the beam connecting on one side two consecutive driving-wheels. Fig. 25 shows an extremity of one of the U-bars which are to be fastened to the engine-head. Fig. 26 shows the feed-pipe with the feed-ports provided with valves. Fig. 27 is a section according to the line 9 9 in Fig. 26.

Similar letters and numerals refer to similar parts throughout the several views.

In an engine of this type I employ an annular feed-pipe L in the center of the engine connected to the main steam-pipe and forming a cylindrical ring having the internal periphery provided with feed-ports directed toward the center, which steam-ports will deliver the steam to the steam-chests on the right and on the left of said feed-pipe, Figs. 1 and 8. Therefore I employ two steam-chests for every stage of expansion, one on each side of said feed-pipe symmetrically arranged, so that the high-pressure steam-chests are the nearest to the feed-pipe and that the pressure of the steam decreases proceeding toward the two extremities of the engine, where I employ two annular exhaust-pipes, J on one side and J′ on the other, Figs. 1 and 18. These two exhaust-pipes, one on each extremity of the engine, are provided with exhaust-ports in the same manner as for the feed-pipe in the center; but in this case the exhaust-steam will be directed from the center toward the annular chamber, which is provided with an outlet in the lowest part of it leading the exhaust-steam outside of the engine passing through the engine-heads. The steam-chests are shown in the drawings in side elevation on the upper part of Fig. 1, in front elevation on the left-hand side of Fig. 3, in cross-section in the lower part of Fig. 1, and they are indicated by the letters C' C^2 C^3 C^4, where C^2 C^3 are high-pressure and C' C^4 low-pressure steam-chests. They are bolted to the bed-plate B and are made in two parts joined together and fastened at the periphery by bolts. A portion of one part of a steam-chest is shown in Fig. 20. Each part of a steam-chest has an annular rib A, a number of ribs 1, which run normally to the annular rib A, Fig. 3 on left, and one rib 2 at the base by which the steam-chest is fastened to the bed-plate. The annular rib A contains a number of openings p and p' for the steam-passages, and these openings are met internally at right angles by other openings, 3, Fig. 20, which are directed toward the center of said annular rib. To cover the internal periphery of this rib on one or on both sides of the steam-chest, I employ a ring R, that I call an "opening-ring," and it is provided with openings directed toward the center of the ring corresponding to the openings 3 of the rib A, as shown in Fig. 3 and on Figs. 5 and 20. A reversing-bar I is attached to each ring on one side.

The two parts of the steam-chest joined together will leave an internal empty space similar to a cylindrical ring having the internal periphery open. This open side is limited by the two annular ribs A A, one on each side, and the space is closed by the rim of a driving-wheel, one of which I provide to every steam-chest. Fig. 22 shows the elevation and the side view of a driving-wheel, and they are shown in section in the lower part of Fig. 1, (designated by D' D^2 D^3 D^4.) The rim of said driving-wheels is provided on each side with a groove 4 for the packing-ring 5, which will press against the internal surface of the rib A and make steam-tight the internal space of the steam-chest. I divide this internal space of the steam-chests into a number of compartments by means of the partitions T, Fig. 3. These partitions consist of two identical pieces of cast-iron, joined together as shown in section on the right-hand side of Fig. 3. They are stationary and free from the driving-wheel, fastened to the steam-chest by means of the bolts H, which pass through them. These bolts, as shown in Fig. 11, are employed also for the purpose of fastening together the two parts of the steam-chest, and to secure them against the pressure of the steam I employ a packing-piece v to each partition, which presses against the external surface of the rim of the driving-wheel on account of the two springs 6, fastened one on each side of the partition, Figs. 3 and 11.

In each compartment I employ a piston-head Z, which I fasten to the driving-wheel by means of bolts passing through a flange at the base of the piston-head and through the rim of the driving-wheel, Figs. 3 and 10, and a portion of a packing-ring w, which presses against the walls of the steam-chest, so that every compartment will be divided into two steam-tight chambers. I provide every chamber with a steam-passage in each side of the steam-chest for a reversible engine. For a non-reversible engine I provide with a steam-passage in each side of the steam-chests only the chambers on one side of the piston-heads.

The openings for the steam-passages are located one on each side of the partitions T and designated by the letters p and p'.

I employ a longitudinal shaft O O, passing through the hub of each driving-wheel and by the center of the annular feed-pipe and exhaust-pipes. It is supported at the extremities by two engine-heads N N and by one or more supports S between the extremities. The engine-heads N N are placed next to the exhaust-pipes. They are conforming to the periphery of the steam-chests and bolted to the bed-plate B in two ways, horizontally and vertically, in order to secure steadiness of the parts. Several longitudinal U-bars U are connecting these two engine-heads, as it will be hereinafter explained, and two or more of them are for preventing the steam-chests from vibration on account of a projection of some of the ribs 1 of the steam-chests that is entering into the longitudinal cavity of the U-bars, and there it is confined by the blocks 7, Fig. 10, which are fastened to the bars. These blocks are shown by dotted lines on the upper part of Fig. 1.

Between two consecutive steam-chests and between the low-pressure steam-chest and the

exhaust-pipe on each side of the engine I employ a multivalve-wheel, which is fixed on the shaft. These wheels are shown in section in Fig. 1 and in side view in Fig. 12 and Fig. 19 in perspective drawings they are designated by the letters W' W^2 W^3 W^4 W^5. The one in the center, W^3, between the two high-pressure steam-chests and corresponding to the center of the feed-pipe L has an even number of cavities cut in its rim, one to the left side and one to the right, alternatively, so that one half of these cavities will be toward the right side and the other half toward the left side of the wheel. The distance between two consecutive cavities, measured on the external surface of the rim, will be equal to the inside diameter of the feed-ports connected to the feed-pipe L. The cavities on the left will project to the right of the center line by one-half that distance, and the cavities on the right will project to the left of the center line by the same amount. The other multivalve-wheels have only half that number of cavities, and said wheels are keyed to the shaft, so that the cavities of the wheels W' W^4, Fig. 12, will correspond to the ones on the left in W^3, and the cavities of the wheels W^2 W^5 will correspond to the cavities on the right in W^3.

In a reversible engine I employ externally to the rim of each multivalve-wheel an annular rim F, that I call a "reversing-ring," the side view of which is given in Figs. 13 and 14. They are provided around the periphery with two lines of square openings, and the side of the square of these openings is to be equal to the inside diameter of a feed-port. The ring surrounding the multivalve-wheel W^3 is shown in Fig. 14, and it is provided with three lines of openings, the middle one corresponding to the center. The location and the number of these openings will be specified hereinafter. Each of these reversing-rings has a reversing-bar I attached to each side of it or to one side only. I cover each one of these reversing-rings with another rim E, that I call a "connecting-ring," which in a non-reversible engine would surround the rim of the multivalve-wheel, in which case the reversing-rings would not be employed. They are provided with two lines of openings corresponding to the openings for the steam-passages in the annular rib A of the steam-chests, Fig. 15. Each opening is round for a certain portion of the thickness of the ring, so as to fit exactly the pipe of the steam-passage. For the remaining portion of the thickness the opening is square and of the same size as the openings of the reversing-rings. They are kept steady by the rings m, m', and m'' by means of a little projection 8 on each side of them engaged in a cavity on each side in the internal periphery of the rings m, m', and m'', Figs. 2, 8, and 18. The connecting-ring in the center is provided with three lines of openings, the middle one corresponding to the center, the same as in the reversing-rings. The steam-passages consist of elbows of steam-pipe and are kept in place by the rings m and m', which are made in two sections fastened together on each side by the flanges 10 and by the rings m'' between the low-pressure steam-chests and the exhausts, which consist of one piece only. These rings, which I call "fastening-rings," are shown in Fig. 1 sectioned according to a longitudinal vertical plane passing through the center of the engine, and in Figs. 2 and 8 the rings m'' are fastened to the annular rib of the steam-chest, as shown in Fig. 18.

As the steam when it is admitted in the steam-chests will act upon the piston-heads, it will put in motion the driving-wheels, which are free from the shaft. Therefore for communicating the motion of the driving-wheels to the shaft I employ on each side of each driving-wheel a ratchet-wheel fixed on the shaft and two opposite pawls attached to the driving-wheel, this for the case of a non-reversible engine. In a reversible engine I employ on each side of each driving-wheel a double ratchet-wheel G, fixed on the shaft, and two diametrically opposite double pawls forming two couples of them, attached to the driving-wheel, one on the upper part and one on the lower part of it. Each couple consists of a double pawl h h' on each side of the wheel, fastened at the extremities of a pin 11, which is passing through the vertical arm of the wheel. Fig. 21 shows a double ratchet-wheel with two opposite double pawls. The pawls are kept in a normal position by the springs x x, Fig. 3—that is, in the same position as shown in the figure, in which they do not engage with the ratchet-wheels on either side. Fig. 7 shows the relative disposition between the ratchet-wheels and the pawls, where the angle c c o must be equal to the angle c v' o'. In a reversible engine I employ between the rim of the driving-wheel and each end of the pawls a crossing-bar z, Figs. 3 and 10, which extends from the pawl on one side of the driving-wheel to the one on the other side, passing through an opening 12 left in the arm of the same wheels, Fig. 22. Attached to it and in correspondence with the pawls I employ two pins a a, Fig. 10, which enter two openings made in the rim of the wheel, and said pins will fit them perfectly so as to make them steam-tight. When the steam is flowing into the steam-chest by the passages p', it will exert a certain pressure on the heads of the pins a a, which will bear, through the piece z, upon the pawls h' on each side of the wheel and on two opposite sides of it. When the engine is reversed, the steam will flow into the opposite chambers by the passages p, and therefore the pressure is exerted on the opposite side, or on the pawls h h, and being no pressure on the pawls h' they will be lifted up. The disposition of

the teeth in a double ratchet-wheel is shown by Fig. 16, where the line passing by one tooth t on one side and the line passing by the nearest tooth t' on the other side if projected in the same plane will make an angle equal to the lines passing by p and p' from the center o—viz., the angle $t\ o\ t'$ will be equal to the angle $p\ o\ p'$. Another position of the ratchet-wheels is shown by Fig. 17, where the wheel is rotated to the right or to the left by one-half the distance between two consecutive teeth from the position in Fig. 16 and where the vertical line $o\ s$ assumed the position $o\ s'$, the shaft having always the previous position. The ratchet-wheels G G and G^3 G^3 can have either one of these positions; but if they have the first position the other wheels, G^2 G^2 G^4 G^4, must have the second one. The relative position between the ratchet-wheels and the multivalve-wheels must also be specified, and it is shown by Fig. 16, where the angle made by the line $t\ o$ and by the line $o\ p$ passing by the middle of a cavity c in the multivalve-wheel will be equal to one-half the angle $p\ o\ p_1'$. For instance, supposing that the steam enter by the passage p it will drive the piston-head to the left, and therefore the pawl will engage with the tooth t; but when the engine is reversed the steam will enter by the passage p' on the opposite side of the partition, and it will drive the piston-head to the right and the pawl will engage with the tooth t'. Therefore the angle $t'\ o\ p'$ must be equal to $t\ o\ p$—that is, one-half $p\ o\ p_1'$. The position shown in the figure is when the piston-head has completed one-half of the stroke and when the steam enters by the passage p.

For obtaining a vibratory motion of the driving-wheels the piston-heads must at the end of the stroke be carried back to the starting-point, and for that purpose I connect the several driving-wheels between each other and on each side of the center in the following manner: I employ one post K on each side of the longitudinal center line and between two consecutive driving-wheels. Said posts are fastened to the bed-plate B and each of them will carry a beam V. A pin i is fixed to the beam transversally in the center of it, having the extremities supported by bearings in the post and extended on each side beyond the bearings, Fig. 24, each extremity having a slot 13 in which engages a spiral spring on each side of the post, and said springs are fastened to the pin i by another small transversal pin 14. Each bearing has a cap 15, which is kept by the strap 16 fastened to the post by the bolt 17. To each extremity of the beam V is attached a link l by means of a cross-joint 18, which permits the links to have a free movement independently of the beam. The other extremity of the link is attached to the adjacent driving-wheel by means of a pin 19 passing through the horizontal arm of the driving-wheel and of the cross-joint 20, Fig. 4, at the extremity of said pin, permitting thus the link to have a free movement independently of the driving-wheel. In this manner the several driving-wheels will have a reciprocating motion alternatively, so that the wheels D' D^3, Fig. 1, will move together and in the same direction, and the wheels D^2 D^4 will move together and in the direction opposite to the previous one for a small portion of the circumference.

As the engine must always start from the normal position for a certain reason that will be specified hereinafter, I employ for this purpose two spiral springs g to every post, one on each side of the beam V, fastened to the bed-plate with the post and engaged in the slots 13 at the extremities of the pin i and fastened to it by the pin 14, thus tending to keep the beam V in a horizontal position. These spiral springs will also balance the oscillating motion of the beams V and the reciprocating motion of the links l.

When the steam is flowing into the feed-pipe L, it will pass through the several feed-ports in connection with said pipe, and it will be delivered to the steam-chests on the right and on the left alternatively, according to the cavities or valves carried by the multivalve-wheel in the center; but in a reversible engine the steam can only be admitted to the steam-chests either by the passages p or p'. Supposing that the steam is admitted by the passages p, the steam will flow into one of the high-pressure steam-chests—for instance, into the one on the left, or C^2, Fig. 1—and act on the same side of the piston-heads contained in it. The driving-wheel D^2 will then be put in motion, and so the shaft on account of the ratchet wheels and pawls and also all the other driving-wheels on account of the connections. As the multivalve-wheels rotate with the shaft, they will at the end of the stroke change position from the previous one, and after the first stroke of the piston-heads (which will be one-half of the full stroke) all the valves will have their position inverted. The steam in the feed-pipe will be cut off from the steam-chest C^2, and it will be admitted in the high-pressure steam-chest on the right, or C^3. The steam inclosed in C^2 will be admitted in the following steam-chest C, where it will expand. After the second stroke the position of the valves will be inverted again, and so on successively, so that the steam will pass from one steam-chest to another until it is discharged into the exhaust-pipes on both sides of the engine alternatively. The length of the stroke will depend on the number of cavities carried by the multivalve-wheel in the center of the engine. For instance, if the said wheel carries sixteen valves the stroke will be one-sixteenth of the circumference.

The number of teeth in the ratchet-wheels must also correspond to one-half of that number.

For reversing the engine the passages *p* must be closed and to open the passages *p'*, so as to admit the steam on the opposite side of the piston-heads. For this purpose a slight turn must be given to the reversing and to the opening rings, and this can be done by means of the reversing-bars I, attached to these rings, as before explained. They are fastened at the top to a longitudinal piece Q, Fig. 1, to which is fastened in the middle a portion of gear-wheel *r*. A square threaded screw *b*, supported by the posts *f f*, engages with the teeth of the gear, and it can be turned by means of a hand-wheel *d*, Fig. 2, so that the gear *r* is enabled to swing to the right or to the left, making the bars I describe a certain angle. Such an angle is shown in Fig. 9 as O' O O². In this figure I suppose to have a portion of steam-chest C, containing the passages *p p p' p'*, a portion of opening-ring R, which is provided with the openings 1'' 1''' 1'' 1''', and a portion of a reversing-ring between the connecting-ring and the multivalve-wheel W, having the openings 1 1' 1 1'. The rings having this position respectively to the passages *p* and *p'*, the center line of the reversing-bars will have the position O O'. In this position the passages *p'* will be open to the steam, so that the shaft will rotate to the right. When the line O O' takes the position O O², the openings in the two rings 1 1' 1'' 1''' will take the positions 2 2' 2'' 2''', respectively, so that the steam will be cut off from the passages *p'*, that will stop the engine. When it takes the position O O³, the openings of the rings will move in 3 3' 3'' 3''', respectively, in which position the steam will still be cut off and the passages *p p'* will be opened to the atmosphere by the ring R. At this point the steam left in the steam-chests will flow out and the atmospheric pressure will take its place, and it will also be established in every chamber, so that the driving-wheels are enabled to take their normal position through the spiral springs *g*. In that position every piston-head occupies the middle of each compartment, so as to divide it into two equal chambers. In this manner the volume of air confined in the back chambers will balance the vibratory motion of the driving-wheels. In the position O O⁴ all the openings in the steam-chest will be closed again by the said ring, and the steam will still be cut off. In the last position O O⁵ the openings 1 1' 1'' 1''' will take the positions 5 5' 5'' 5''', respectively, where the openings of the steam-chest will still be closed up and the passages *p* will be opened, so that the steam will act upon the opposite side of the piston-heads, making the shaft rotate to the left.

In order to reduce the loss of heat by radiation from the steam-chests and from the steam-passages and for protecting all the working parts of the engine, I employ a covering consisting of the two engine-heads N N, which are made in two sections joined together by a horizontal rib 21 on each side of the shaft and fastened at the base to the bed-plate in two ways, as it has been before specified. Their periphery consists of a rib 22, which extends on both sides of the wall, and have in the internal side another small rib 23, that follows the previous one, Fig. 6. An opening J' is left in the lower part of each head-piece for the exhaust-pipe. These two head-pieces are connected by several longitudinal U-bars U, which are cut at the extremities, as shown in Fig. 25, so as to fit the grooves *u* around the periphery of the head-pieces. Longitudinal metal sheets *s*, which are turned off on each side, are laid between the bars, resting on the rib 23 around the periphery of the head-pieces and on the periphery of the steam-chests. These metal sheets are covered with longitudinal boards 24, which rest at the extremities on the periphery of the head-pieces and longitudinally some of them on the U-bars, and they are fastened by the strings *k*. An empty space 26 remains between the boards and the metal sheets, which may be filled up with some non-conducting substance. The two head-pieces are also covered with boards 25 on the outside, resting at the extremities on one side of the rib 22, leaving an empty space 27 between them and the external surface of the wall of the same head-pieces, which space may also be filled up with a non-conducting substance. The boards covering the head-pieces are kept against them around the periphery and at the base by the plate-ring *y*, which is bolted to the same head-pieces.

A transversal opening in the covering is provided on top for each reversing-bar, so as to allow them to describe a given angle. A longitudinal piece of metal sheet *n*, in which are made transversally all the openings necessary and of a prescribed length and width, is fastened on top of the engine, and it is covered internally and between the openings by pieces of boards 28 fastened to it. I employ a piece *e* for each bar on the external surface of this metal sheet that will slide against it, so as to cover the opening in any position the bar may be, and it is fastened to the bar lying between the shoulder of the bar underneath and the piece Q above.

In order to maintain a high temperature inside of the covering, I employ two longitudinal pipes *g g*, one on each side, closed at the extremities, which communicate with each other by means of a series of pipes *g' g'* surrounding the steam-chests and the steam-passages, and I connect one of the longitudinal pipes to the main steam-pipe or to the heating-supply

by means of the joint *j*. I employ this system of pipes also for the purpose of reëvaporating the water that might condense in the steam-chests. An opening 29 for the steam-traps is left in the lower part of each longitudinal pipe when steam is used for heating purposes.

For regulating the admission of the steam from the feed-pipe to the steam-chests I employ a valve 30, Fig. 26, on several feed-ports, so that the steam may be cut off at any time from any number of diametrically opposite chambers of the steam-chests. The said valves may be by means of any device arranged so that they could be worked from the outside of the covering of the engine. It is obvious that in a reversible engine must be left open the feed-ports which admit the steam in the chambers where the steam-pressure acts also on the pawls of the driving-wheels.

In this type of engines it is apparent that the expansion of the steam can be carried as far as desired.

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

1. A multiple-expansion steam-engine having the steam-chest formed by two parts joined together and fastened by bolts at the periphery, having an internal space similar to a cylindrical ring, open at the internal periphery and closed by the rim of a central driving-wheel; said steam-chests provided on each side with an annular rib containing a number of openings for the steam-passages which are met internally by openings directed toward the center of the ring, the internal periphery of said annular ribs being covered by opening rings each having a reversing-bar attached to one side of it, and provided with openings corresponding to the openings in the annular ribs which are leading to the steam-passages; each part of the steam-chest provided externally with several ribs running normally to said annular rib and with a horizontal rib at the base by which the steam-chest is fastened to a bed-plate; the internal space of the steam-chest divided into several compartments by fixed abutments or partitions formed by two identical pieces joined together and traversed by one or more bolts which will also hold together the two parts of the steam-chest, substantially as specified.

2. A multiple-expansion steam-engine having a longitudinal shaft passing through the center of the engine, supported at the extremities by two engine-heads, an annular feed-pipe forming a chamber similar to a cylindrical ring, surrounding the shaft in the middle of the engine, and the internal periphery of which is provided with feed-ports directed toward the center of the ring, which may be provided with valves for controlling the admission of the steam; two steam-chests for each stage of expansion, one on each side of said annular feed-pipe, disposed symmetrically and having a disposition similar to the feed-pipe, the high-pressure steam-chests being the nearest to said feed-pipe so that the pressure decreases proceeding toward the extremities of the engine, two annular exhaust-pipes, one on each extremity of the engine, forming two exhaust-chambers similar to cylindrical rings, the internal periphery of which is provided with exhaust-ports similar to the feed-ports of the feed-pipe in the middle; the shaft carrying a multivalve-wheel in each space between two consecutive steam-chests, and between the two low-pressure steam-chests and exhaust-pipes, provided with cavities on the external surface of the rim forming a number of separate valves, said wheels fixed to the shaft with the valves located as set forth in the specification; the wheel in the center of the engine having two rows of cavities alternating each other to the right and to the left; the feed-ports in the center leading the steam through a connecting and a reversing ring against the external surface of the rim of said multivalve-wheel in the center which will distribute the steam to the high-pressure steam-chests on the right and on the left of said feed-pipe alternatively, each steam-chest provided on both sides with steam-passages or elbows of steam-pipe, held in place by fastening-rings, and that by means of the connecting-rings lead the steam from one steam-chest to another, through the several stages of expansion to the exhaust, always passing through the valves of the multivalve-wheels carried by the shaft, substantially as specified.

3. A multiple-expansion steam-engine having an annular feed-chamber in the middle, provided with feed-ports directed toward the center; steam-chests of annular form, two for each stage of expansion, disposed symmetrically, one on each side of the said feed-chamber, fastened to a bed-plate, and which have the internal space open at the internal periphery, and divided into several compartments by fixed abutments or partitions; two annular exhaust-chambers, one at each extremity of the engine; a longitudinal shaft passing through the center of the rings formed by the feed-chamber, steam-chests and exhaust-chambers, the whole inclosed in a covering; a number of valves closing and opening the steam-passages between the feed-chamber and the adjacent steam-chests, between two consecutive steam-chests and between steam-chests and exhaust-chambers, regulated by the revolving of the shaft; a driving-wheel in the center of each steam-chest through the hub of which the shaft passes; all the driving-wheels connected in series on each side of the center, which connection enables them to have an alternate reciprocating motion as set forth in the specification, and said driving-wheels having a rim which closes the internal space of the steam-chests, which rim is provided on each side

with a packing-ring, to make the said internal space steam-tight; each driving-wheel carrying a number of piston-heads or paddles at the periphery, one in each compartment of the steam-chests, each piston-head being provided around the portion of its periphery that is in contact with the walls of the steam-chest with a portion of packing-ring so as to divide each compartment into two steam-tight chambers, the fixed abutments or partitions being provided at the base with a packing-piece pressed against the external surface of the rim of the driving-wheel by two springs one on each side of the partition; said driving-wheels transmitting to the shaft the power of the steam by means of two diametrically opposite couples of double pawls attached to each wheel, which pawls engage with ratchet-wheels carried by the shaft and located in respect to the pawls in the manner set forth in the specification, said pawls being pressed against the periphery of the ratchet-wheels by the action of the steam by means of pins having their heads exposed to the steam-pressure in certain chambers of the steam-chests, and the said pawls being kept in a normal position when the engine is at rest by means of springs, substantially as specified.

4. A multiple-expansion steam-engine, having an annular feed-chamber in the middle; two series of annular steam-chests, which have a symmetrical disposition on each side of the feed-chamber, fastened at the base to a bed-plate, the internal space of each one of them divided into a number of compartments; two annular exhaust-chambers, one at each extremity of the engine; a longitudinal shaft in the center, passing through the hub of driving-wheels, one of which is provided in the center of every steam-chest; said driving-wheels all connected in series, provided at the periphery with paddles or piston-heads inclosed in the internal space of the steam-chest one to each compartment, and transmitting to the shaft the action received from the steam; a series of multivalve-wheels fixed to the shaft, which are provided with cavities or valves around their periphery; each wheel located between two consecutive steam-chests and between the low-pressure steam-chest and the exhaust-chamber at the two extremities of the engine, the middle one of said multivalve-wheels being double and corresponding to the annular feed-chamber; each multivalve-wheel surrounded by a reversing-ring provided with two lines of square openings around the periphery disposed near the outer edges of the cavities or valves of the wheel, the reversing-ring surrounding the multivalve-wheel in the center being provided with three lines of openings around the periphery, all the said openings located as set forth in the specification; each reversing-ring surrounded by a connecting-ring with openings corresponding to the steam-passages to which they are connected, said rings being provided externally with two diametrically opposite projections which enter two cavities of the fastening-rings by which they will be held in a steady position; reversing-bars attached to the reversing-rings, fastened at the top to a longitudinal piece to which is fixed in a midway a segment of gear-wheel which engages with a screw supported by two posts fastened to stationary parts of the engine, said screw provided with a hand-wheel at one extremity, so that by giving to it a few turns all the reversing-bars are enabled to swing together of a certain angle and make the reversing-rings rotate of a small arc so as to cut off the steam from one series of steam-passages from the connecting-rings and to open the other one, substantially as specified.

5. A multiple-expansion vibratory steam-engine having a longitudinal shaft passing through the hub of driving-wheels in the center of the steam-chests; said wheels connected to each other, through which connection they are allowed to oscillate around the shaft for a certain portion of the circumference, each driving-wheel having a reciprocal oscillatory motion contrary to that of its adjacent driving-wheels, said connection consisting of two pins to each driving-wheel, passing through the horizontal arm of said wheel, one on each side of the center, connected at the extremities on each side of the wheel to a link by means of a cross-joint so as to permit the link to have a free movement independently of the driving-wheel; two posts between every two consecutive steam-chests, one on each side of the longitudinal center line fixed to the bed-plate, provided with bearings on each side, with cap surrounded and held by a strap fastened to the same post by a bolt, and supporting an oscillating beam by means of a transversal pin having the extremities extending beyond the bearings, said beam connected at the two extremities to the links above mentioned by means of cross-joints similar to the previous ones so as to allow the links to have a free movement independently of the beam; two spiral springs to each post, one on each side of the beam, fastened to the bed-plate together with the post, connected to the transversal pin fixed in the center of the beam, each extremity of said pin that is extending beyond the bearings, provided with a slot into which the spring is engaged and fastened to it by means of a small cross-pin, said springs tending to hold the beam in a horizontal or normal position substantially as specified.

6. A multiple-expansion steam-engine having steam-chests provided with steam-passages on both sides, leading the steam to and from valves carried by multivalve-wheels between the steam-chests, said steam-passages entering openings around the periphery of connecting-rings, both, steam-passages and connecting-rings being held in place by fastening-rings,

which for convenience of construction are made in two sections connected together, except two of them, that are the ones near to the exhaust-pipes, which consist of a single piece bolted to the annular rib of the steam-chests; said fastening-rings having two diametrically opposite cavities in the internal periphery, into which are confined the two projections of the connecting-rings substantially as specified.

7. A multiple-expansion vibratory steam-engine, having, an annular feed-chamber in the middle, provided with a number of feed-ports directed toward the center of the ring formed by the said feed-chamber, which feed-ports are provided with valves by means of which the steam passing through the feed-ports can be regulated or cut off at any time and on any number of them; one series of annular steam-chests on each side of the said annular feed-chamber, fastened at the base to a bed-plate, each series consisting of one steam-chest for each stage of expansion, the high-pressure steam-chest of each series being next to the feed-chamber, the low-pressure steam-chests following it, toward the extremity of the engine; an annular exhaust-chamber at each extremity of the engine, next to the last low-pressure steam-chest of each series, and provided with exhaust-ports without valves, having the same direction and disposition as the feed-ports; a longitudinal shaft passing through the center of the engine supported by two engine-heads at the extremities; each steam-chest provided with a driving-wheel in the center, through the hub of which the shaft passes, the internal space of each steam-chest, which has an annular form and is opened at the internal periphery, being closed by the rim of the said driving-wheel, and divided into a number of compartments by fixed partitions, in each compartment being inclosed a piston-head which is fixed to the periphery of the driving-wheel dividing the compartment into two separate chambers; each chamber of the steam-chests provided with openings leading to the atmosphere, which openings can be closed or opened by means of opening-rings, and the said chambers provided with a steam-passage, inlet and outlet, which leads through valves or cavities around the periphery of multivalve-wheels fixed to the shaft, one of which is located between every two consecutive steam-chests, and between the last low-pressure steam-chests and exhaust-chambers, and surrounded at the periphery by a reversing-ring, moved by means of reversing-bars, and provided with openings around the periphery located as set forth in the specification, said reversing-ring surrounded by a connecting-ring; all the driving-wheels connected in series, through which connection they have an alternate reciprocating vibratory motion under the action of the steam, and transmitting to the shaft the motive force they receive from the steam, by means of pawls attached to them and of ratchet-wheels fixed to the shaft; a covering inclosing the whole body of the engine, substantially as specified.

8. A multiple-expansion vibratory steam-engine having a heating apparatus, and inclosed in a covering consisting of two engine-heads fastened to the bed-plate in two ways, horizontally and vertically, the periphery of which is formed by a rib provided with grooves, said rib having a shoulder in the internal side; said engine-heads having an opening in the center for the shaft and one below for the exhaust-pipe, for convenience of construction each of them being made in two sections joined together on a horizontal rib, and having the exterior side covered with boards held against them by a plate-ring, leaving an empty space between the boards and the surface of the wall of the same engine-heads, which space may be filled with a non-conducting substance; said engine-heads connected to each other by several longitudinal ⌊⌋-bars fastened at their extremities in the grooves at the periphery of the same pieces or engine-heads, some of said ⌊⌋-bars preventing also the steam-chests from vibration by means of the arrangement set forth in the specification; longitudinal metal sheets lying between the ⌊⌋-bars and resting at the extremities on a shoulder in the internal side of the engine-heads; longitudinal boards resting at the extremities on the periphery of the engine-heads and fastened by several metal strings surrounding the whole body of the engine, an empty space being left between the metal sheets and the boards, which space may be filled with some non-conducting substance; the top of the covering consisting of a longitudinal sheet provided with transversal openings corresponding to reversing-bars and covered internally with boards, a piece of metal sheet attached to each reversing-bar covering said transversal opening and being in contact with the longitudinal top sheet, substantially as specified.

In testimony whereof I have signed my name to this specification in the presence of two subscribing witnesses.

ANTONIÒ BENEDETTO.

Witnesses:
ANDREW WARGANIN,
JOHN CALLAHAN.