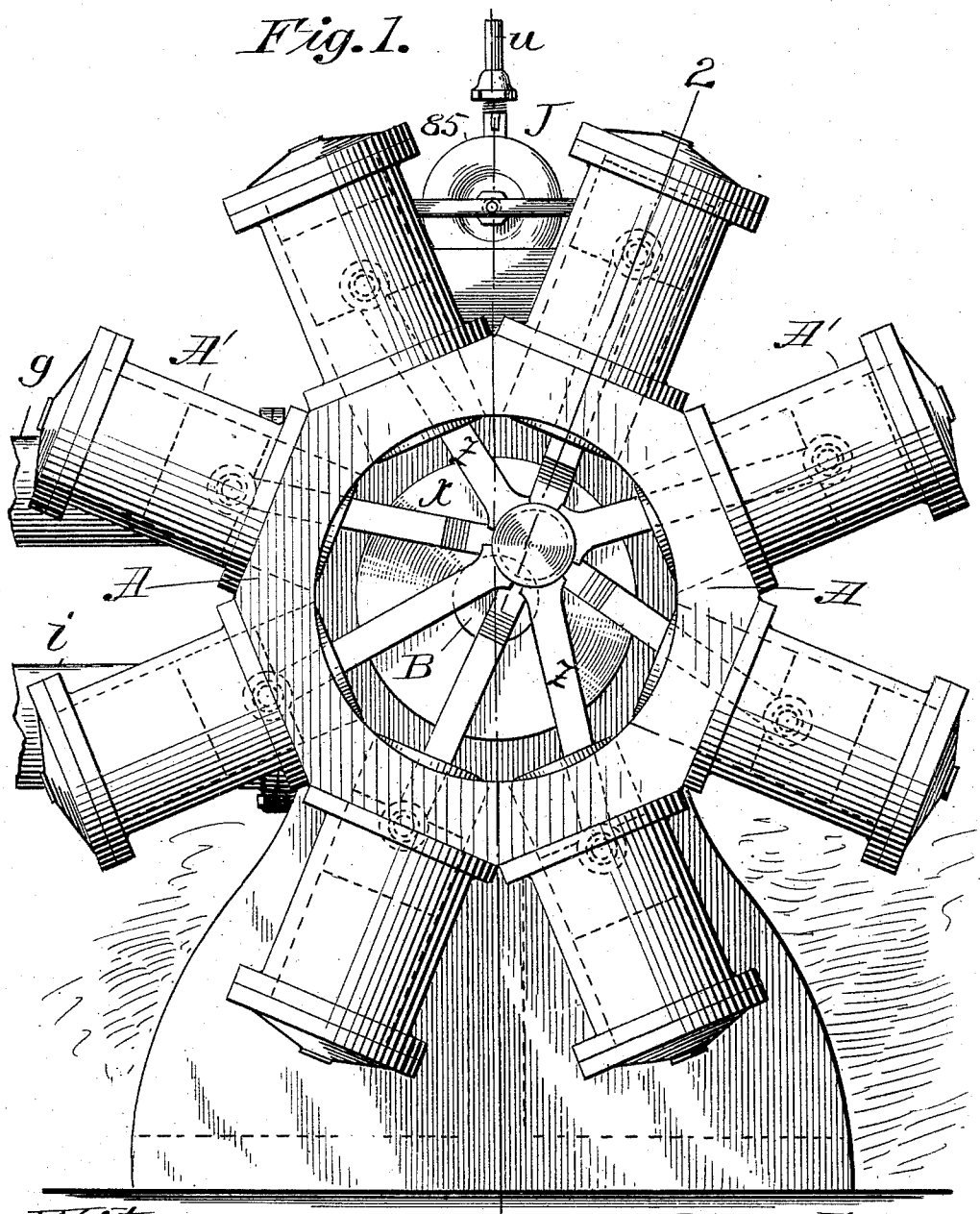
(No Model.) 11 Sheets—Sheet 1.

E. B. BENHAM.

MULTIPLE CYLINDER ENGINE.

No. 487,084. Patented Nov. 29, 1892.

Fig. 1.



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(No Model.) 11 Sheets—Sheet 2.

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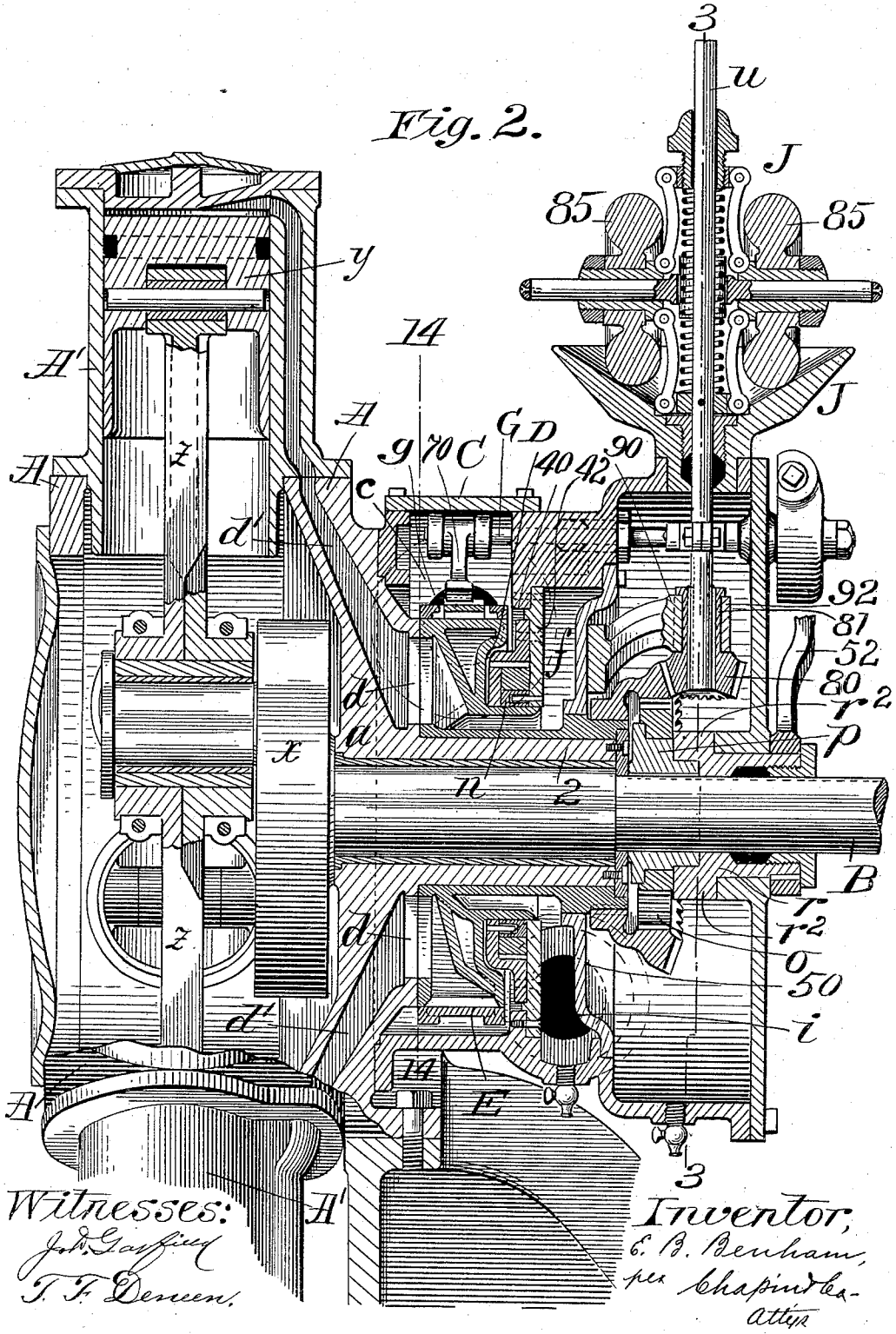
Fig. 2.



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(No Model.) 11 Sheets—Sheet 3.

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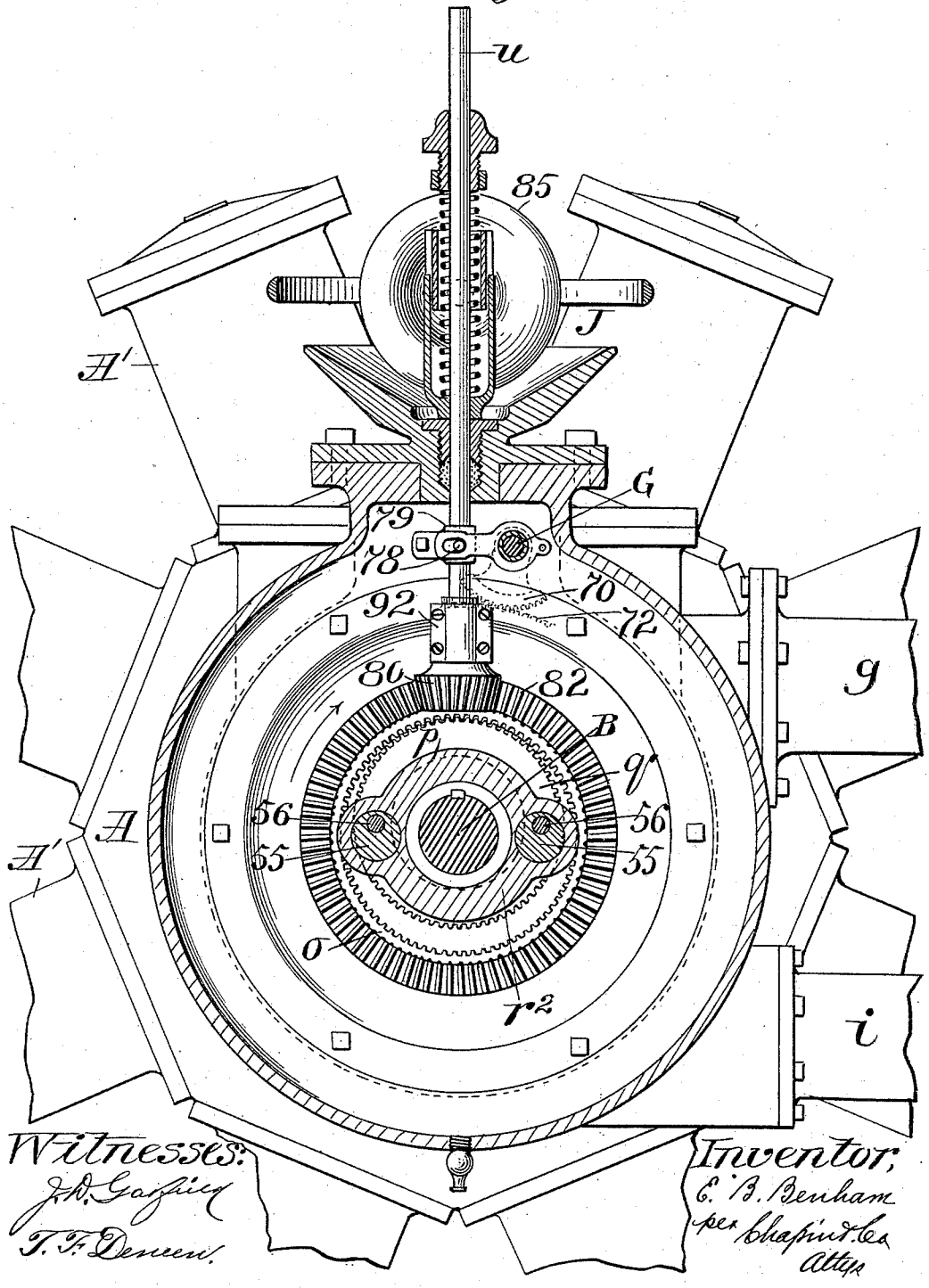
MULTIPLE CYLINDER ENGINE.

No. 487,084. Patented Nov. 29, 1892.

Fig. 3.



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MULTIPLE CYLINDER ENGINE.

No. 487,084. Patented Nov. 29, 1892.

Fig. 4.

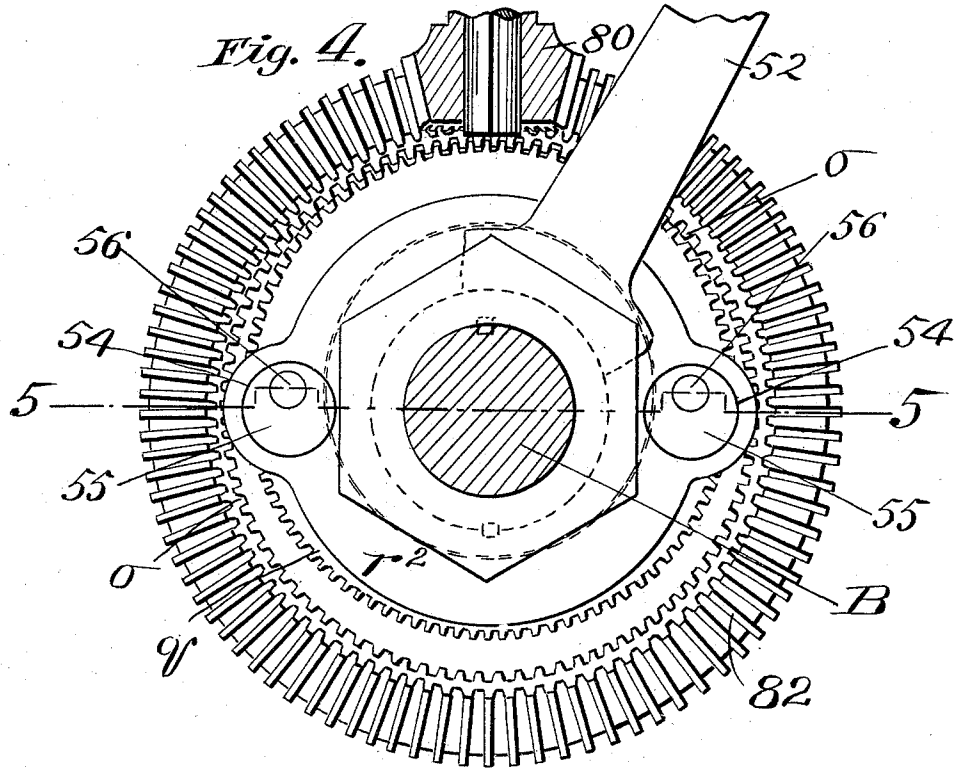
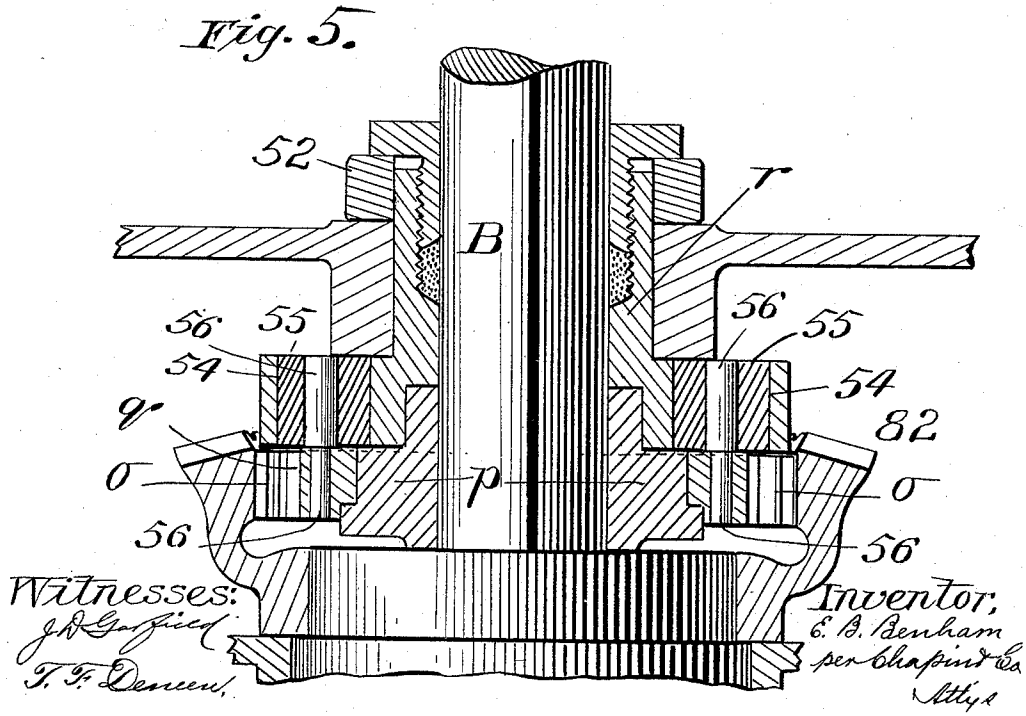


Fig. 5.



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MULTIPLE CYLINDER ENGINE.

No. 487,084. Patented Nov. 29, 1892.

Fig. 6.

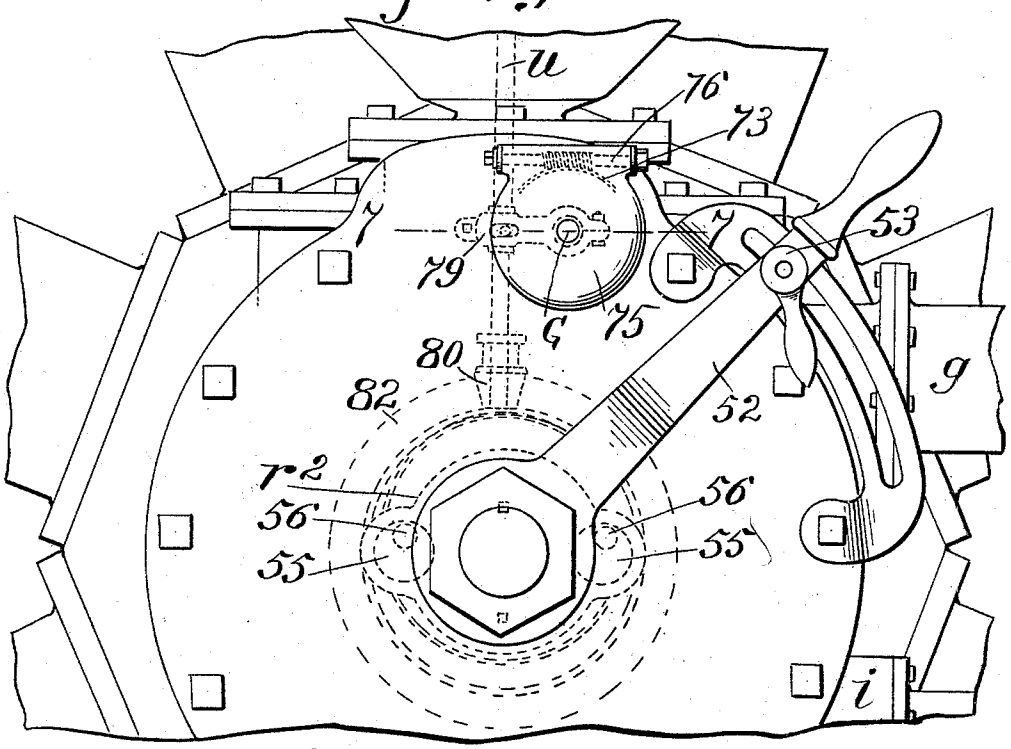


Fig. 7.

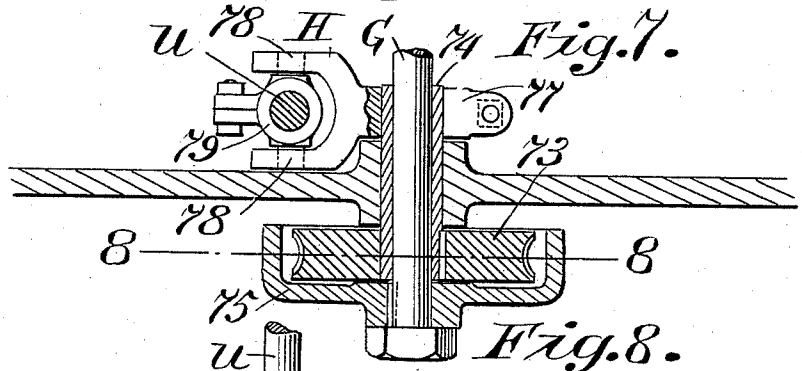
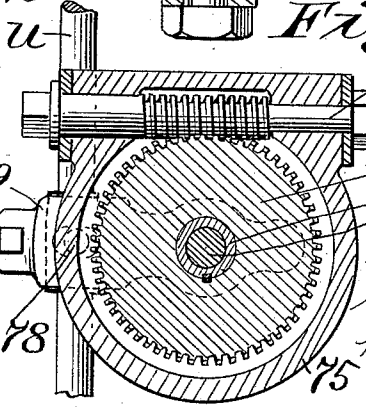


Fig. 8.



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MULTIPLE CYLINDER ENGINE.

No. 487,084. Patented Nov. 29, 1892.

Fig. 9.

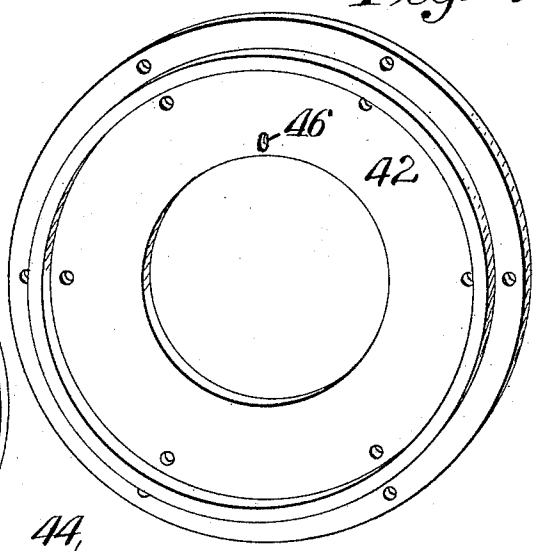
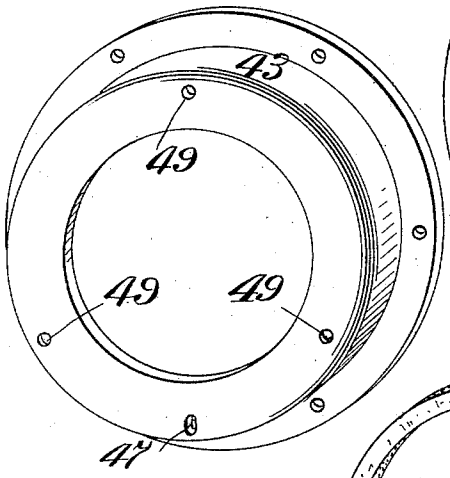


Fig. 10.



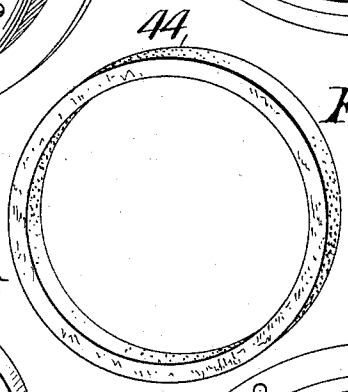


Fig. 11

Fig. 12.

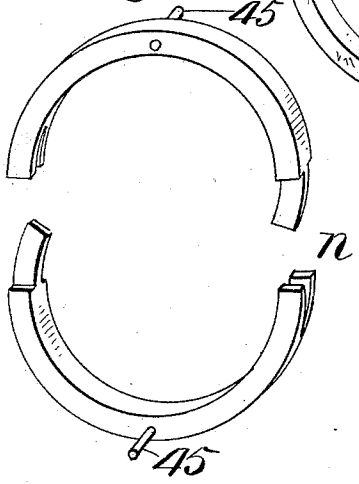
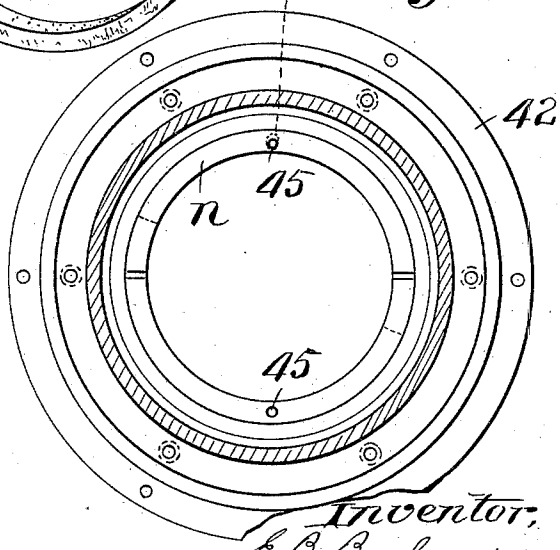


Fig. 13.



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MULTIPLE CYLINDER ENGINE.

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Fig. 14.

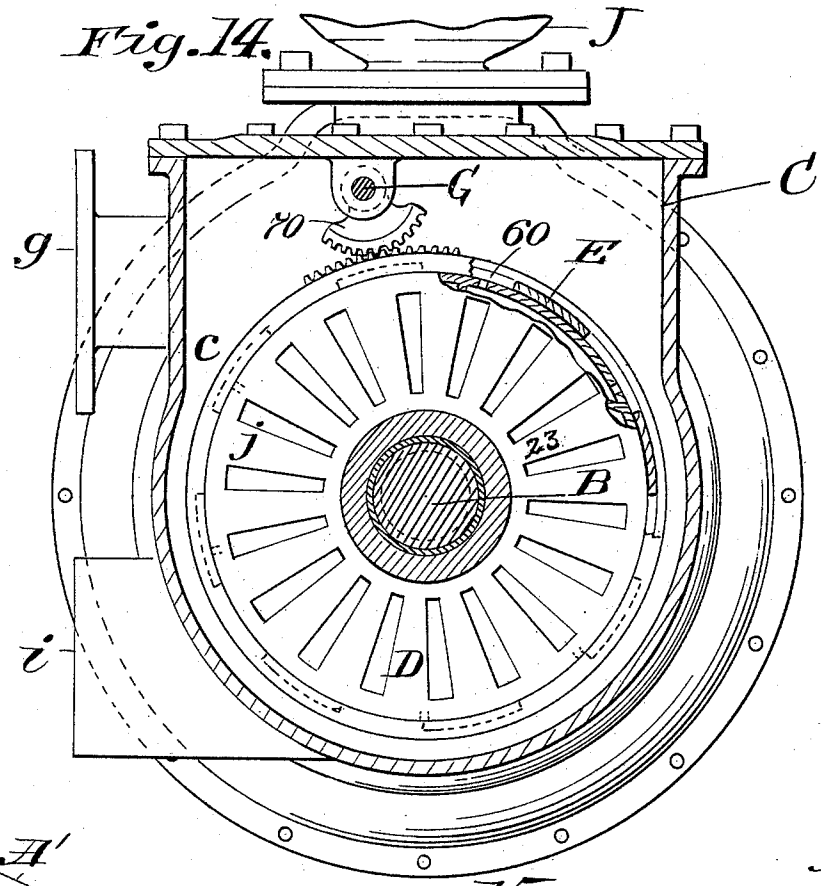
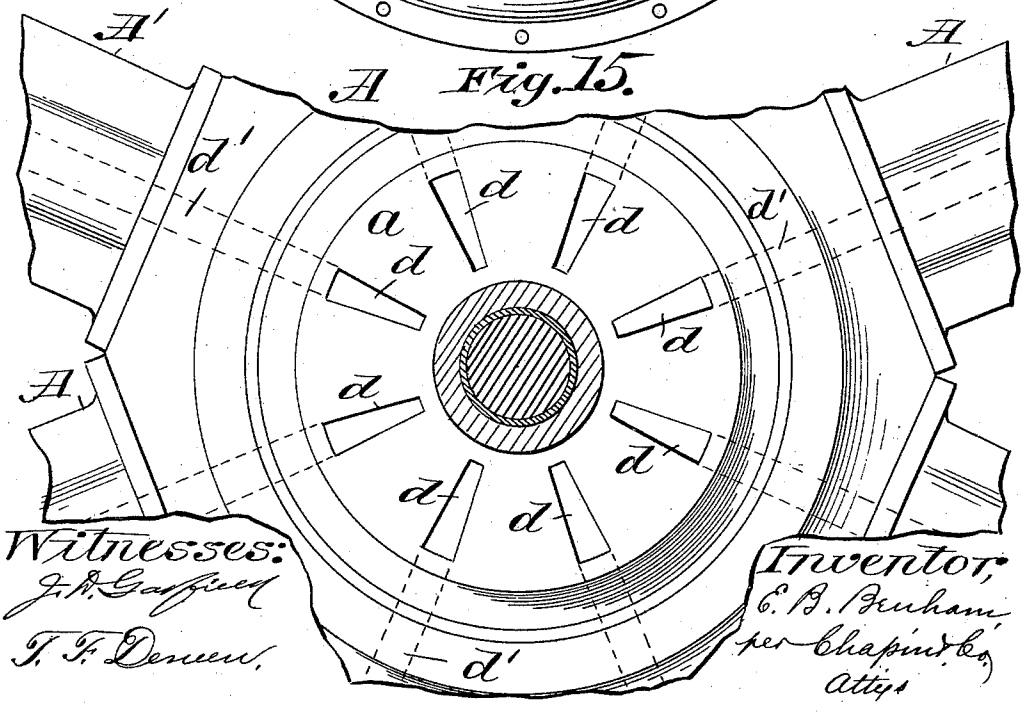


Fig. 15.



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MULTIPLE CYLINDER ENGINE.

No. 487,084. Patented Nov. 29, 1892.

Fig. 17.

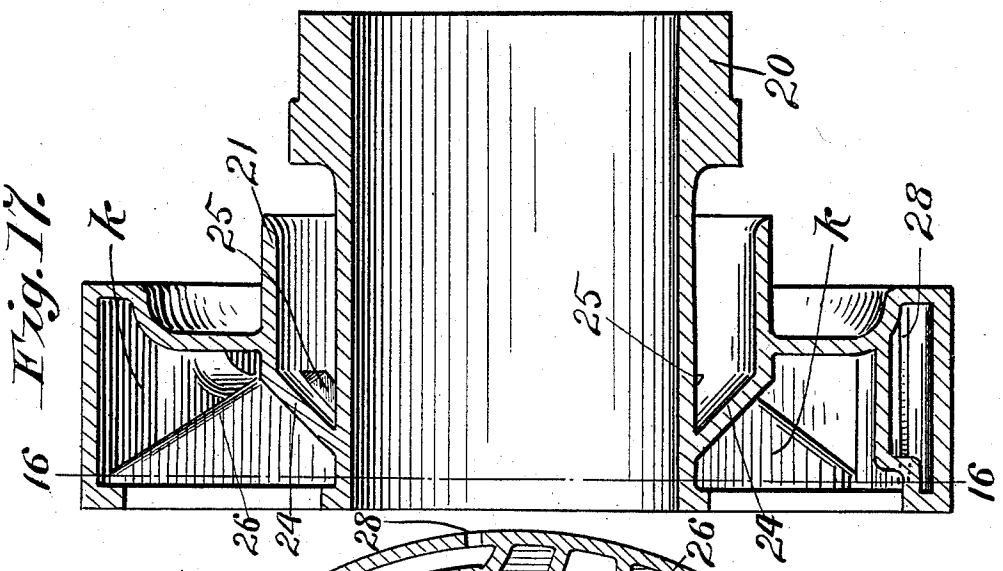
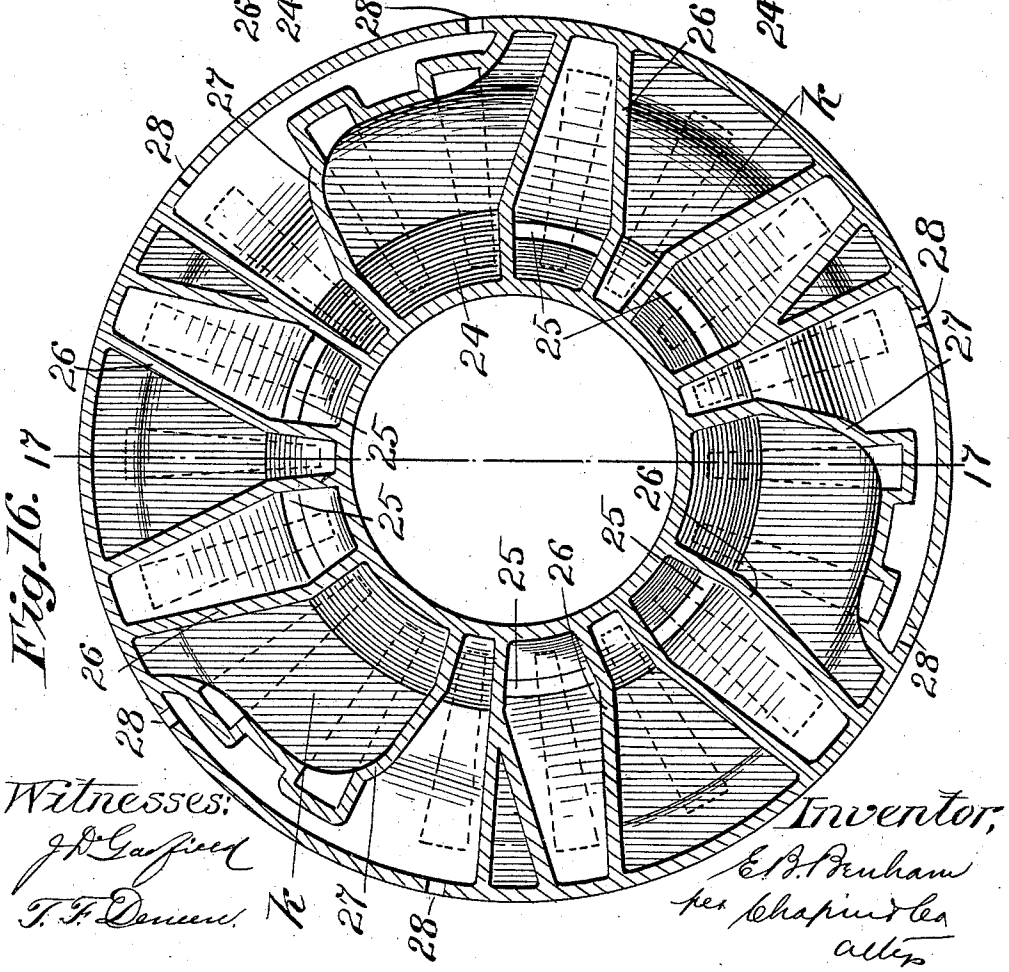


Fig. 16.



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MULTIPLE CYLINDER ENGINE.

No. 487,084. Patented Nov. 29, 1892.

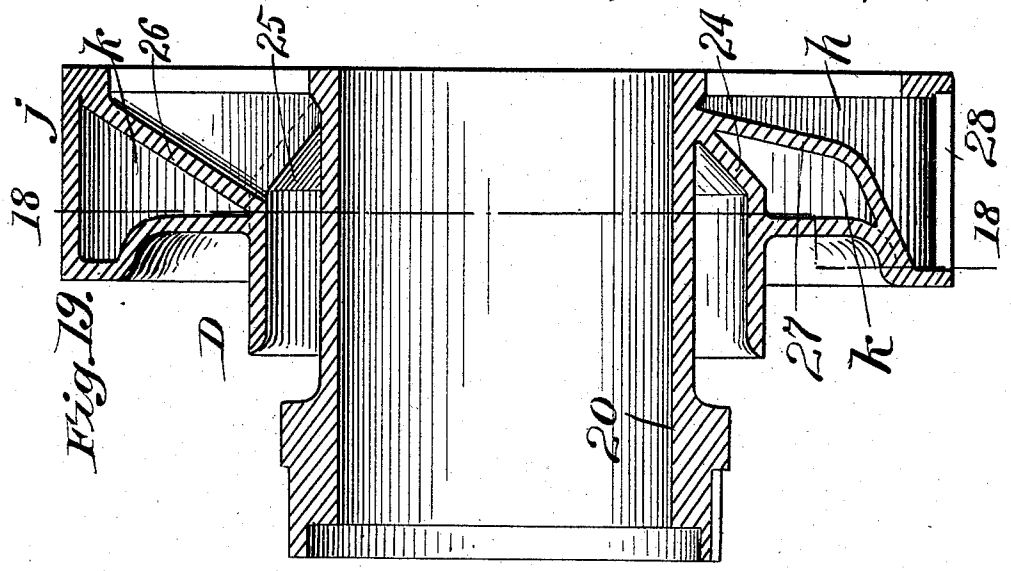

Fig. 19.

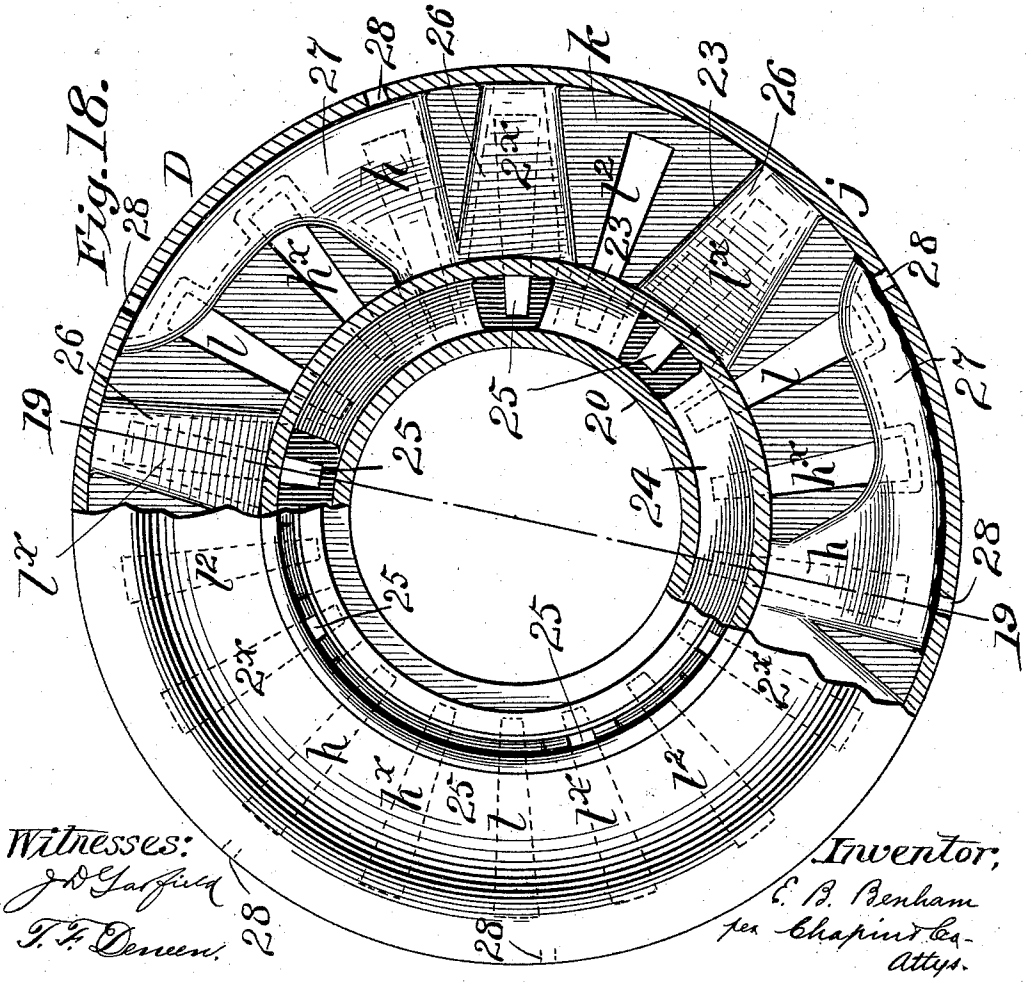

Fig. 18.

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(No Model.) 11 Sheets—Sheet 10.

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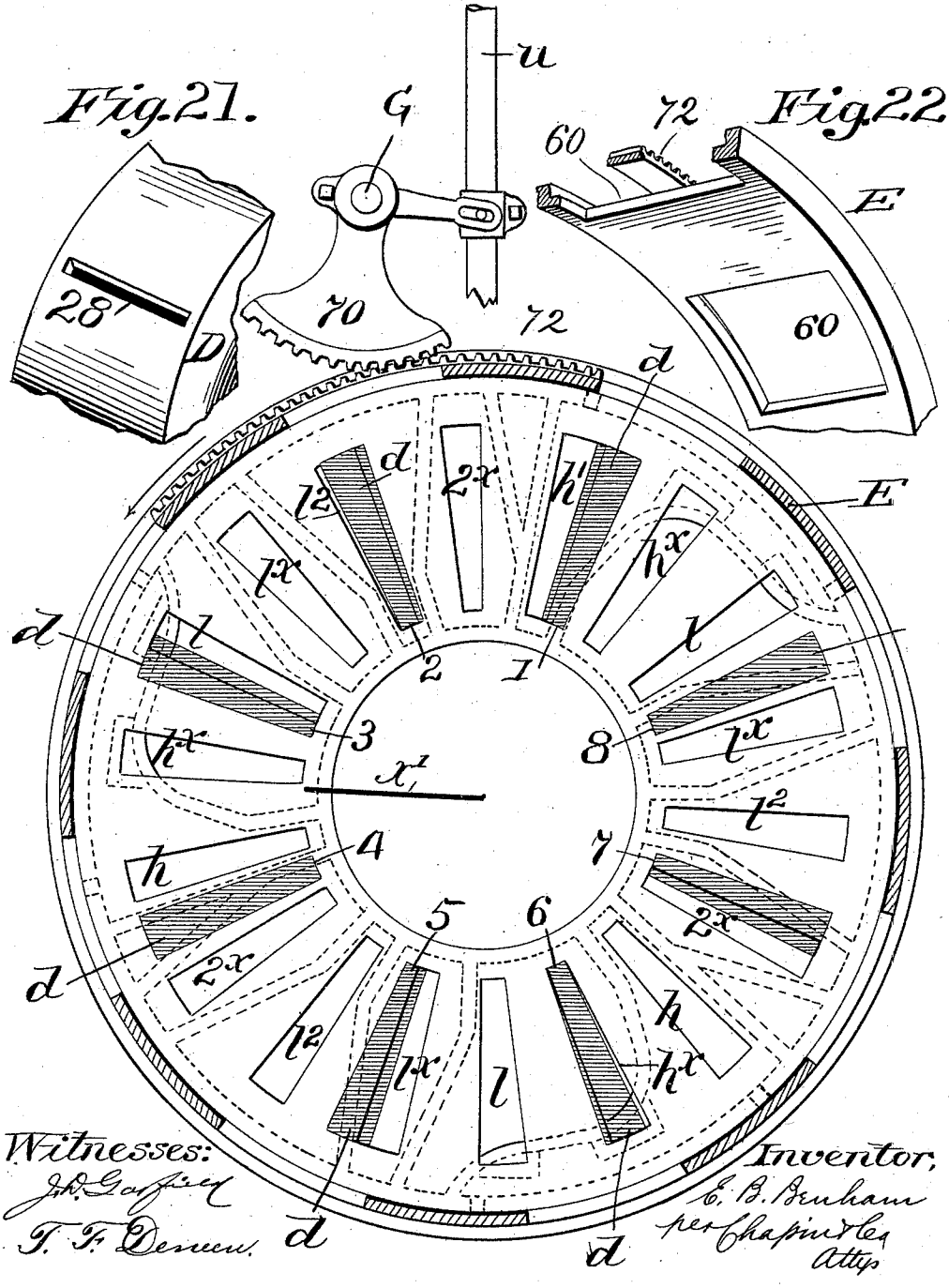
MULTIPLE CYLINDER ENGINE.

No. 487,084. Patented Nov. 29, 1892.

Fig. 20.



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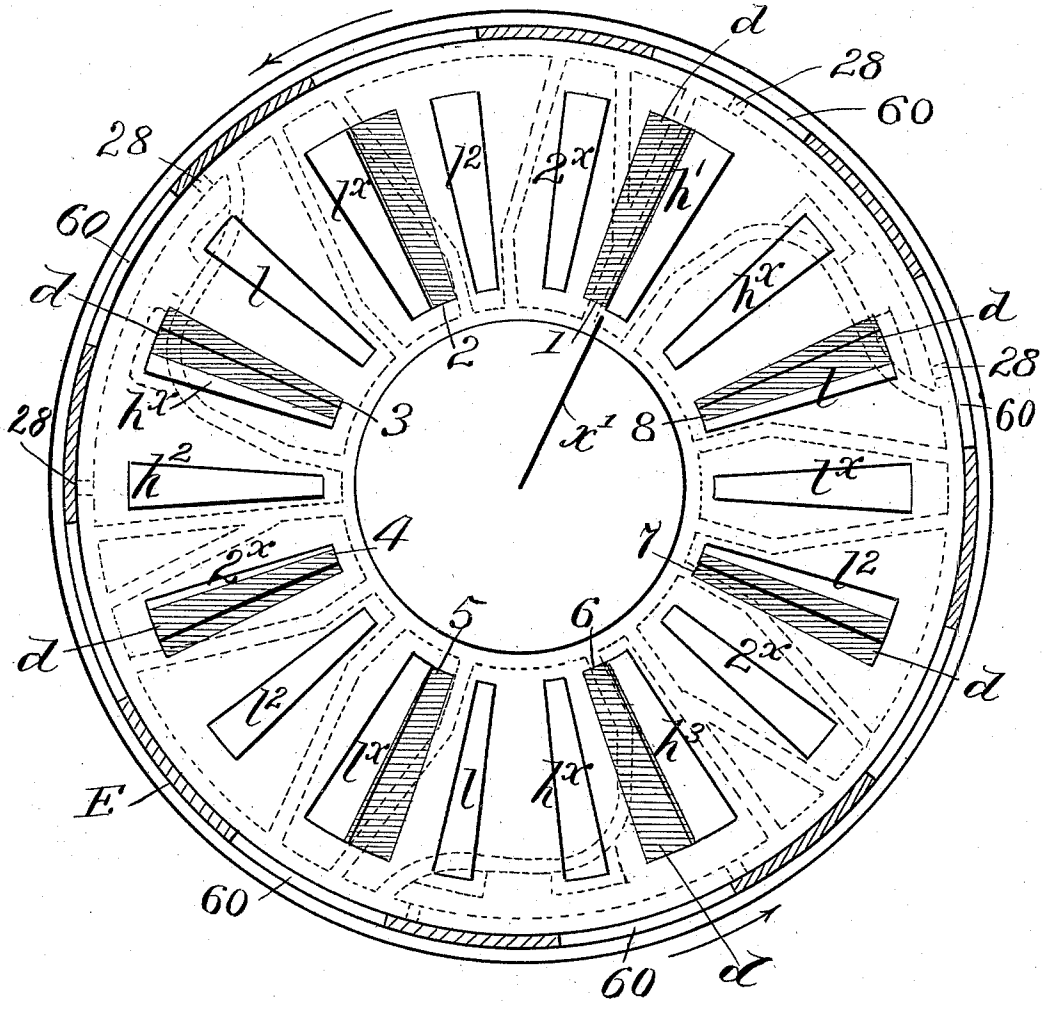
MULTIPLE CYLINDER ENGINE.

No. 487,084. Patented Nov. 29, 1892.

Fig. 23.



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UNITED STATES PATENT OFFICE.

ELIJAH B. BENHAM, OF PROVIDENCE, RHODE ISLAND.

MULTIPLE-CYLINDER ENGINE.

SPECIFICATION forming part of Letters Patent No. 487,084, dated November 29, 1892.

Application filed January 25, 1892. Serial No. 419,227. (No model.)

To all whom it may concern:

Be it known that I, ELIJAH B. BENHAM, a citizen of the United States, residing at Providence, in the county of Providence and State of Rhode Island, have invented new and useful Improvements in Multiple-Cylinder Engines, of which the following is a specification.

This invention relates to improvements in motors or engines of the multiple-cylinder class, which are especially designed to be actuated by steam.

The object of the invention is to produce an engine of the class indicated which as to its construction is comparatively simple and inexpensive and which is operative with the greatest economy of the motor fluid.

The invention is largely dependent upon the novel valve employed, and otherwise consists in constructions and combinations of parts, all substantially as will hereinafter more fully appear, and be set forth in the claims.

The improved engine is fully illustrated in the accompanying drawings, in which—

Figure 1 is a front end view of the engine with the plate which covers the chamber that is centrally of the radially-arranged cylinders and in which the crank and pitmen move, removed. Fig. 2 is a longitudinal and general vertical section of the engine, the plane of section which intersects the cylinders being taken, however, on the line 2 2, Fig. 1. Fig. 3 is an elevation and a partial section taken on the plane indicated by line 3 3, Fig. 2, and as seen from the rear end of the engine. Fig. 4 is a view of the valve-gearing as seen in planes transversely of the main shaft; and Fig. 5 is a sectional view of said parts, taken on line 5 5, Fig. 4. Fig. 6 is an elevation taken at the rear end of the engine. Fig. 7 is a horizontal sectional view of parts of the cut-off mechanism as taken on line 7 7, Fig. 6. Fig. 8 is a vertical section the plane of which is indicated by the line 8 8, Fig. 7. Figs. 9, 10, 11, and 12 are perspective views of the separated parts of the packing-ring devices which are applied relative to the valve, and which will be hereinafter referred to. Fig. 13 is a face view of the assembled parts of the packing-ring device, with the internal annular flange of the part shown in Fig. 10 indicated as cut away. Fig. 14 is a sectional view rearward as taken through the steam-chest of the engine on the line 14 14, Fig. 2, showing the face of the valve. Fig. 15 is a view of the rear side of the motor-head, showing the cylinder-ports against which the forward end face of the valve rotates. Figs. 16 and 17 are sectional views of the valve, the former being taken transversely of the valve-axis and looking rearwardly and the latter along its axis. The plane of section Fig. 16 is indicated on Fig. 17 by the line 16 16, and the plane of section Fig. 17 is indicated on Fig. 16 by the line 17 17. Fig. 18 is in part a sectional view of a part of the valve, taken transversely of its axis and looking forwardly, and in part a rear view. Fig. 19 is an axial section through the valve, taken on the plane indicated by the line 19 19, Fig. 18, and on this section Fig. 19 is drawn the line 18 18 to more precisely indicate the plane on which the sectional part of Fig. 18 is taken. Fig. 20 is a view more in the nature of a diagram than a conventional mechanical drawing, inasmuch as it shows the forward face of the valve in its relation to the cylinder-ports, which are understood as covered by said valve, but which cylinder-ports are here indicated, for the purpose of avoiding confusion, by shaded patches instead of by dotted lines. Said view Fig. 20 also shows in section the cut-off ring and some of the mechanism which acts in conjunction therewith. Fig. 21 is a perspective view to illustrate a peripheral fragment of the valve. Fig. 22 is a perspective view to illustrate a part of the cut-off ring. Fig. 23 is a diagram in many respects similar to Fig. 20, but showing the valve in a somewhat different position relative to the cylinder-ports.

Similar letters and numbers of reference indicate corresponding parts in all of the views.

Describing the engine in detail in connection with the drawings, the motor-head consists of a substantially-annular body A, with the cylinders A′ extending radially from said body, said cylinders being open at their inner ends, but closed at their outer ends and bolted to the body A. At a rear side part of the motor-head there is a wall or body *a*, which has an axially-extended hub-bearing 2 for the support of the main driving and crank shaft B.

The said wall *a* incloses in part the circular space within the motor-head in which the crank-disk *x* is located, the casting having, however, the central opening for the passage therethrough of the shaft.

y y indicate the cylinder-pistons, and *z z* the pitmen connecting the pistons and crank, as usual in this type of multiple-cylinder motor.

There are on the rear end face of the motor-head eight ports *d*, circularly arranged at regular intervals, which are the orifices of radial passages *d'*, formed along and within the said casting, and which passages are further continued in the side walls of the cylinders and enter the cylinder-chambers at or near their outer ends.

C represents the steam-chest, which is in the form of a suitable cylindrical casing connected at the rear side of the part *a* of the motor-head, and contained within the same steam-chest casing C, but separated from and to the rearward of the steam-chamber *c*, is the exhaust-chamber *f*. (See Fig. 2.) The steam-inlet passage is indicated at *g*, and the outlet-passage for the exhaust-chamber is indicated at *i*.

The valve D is mounted concentrically about but caused to rotate independently of the rotations of the crank-shaft and has its end face upon the rear face of the motor-head to overlie the cylinder-ports. The valve in this engine is caused to make one rotation only while the crank-shaft makes nine and has a series of eighteen ports through its front end face at regular intervals in circular arrangement, certain of which as to the whole or portions of the area thereof at a given instant may register with certain of the cylinder-ports for giving steam-pressure to the cylinders or for conveying out the exhaust-steam from the cylinders. The valve consists of the tubular central portion or shank 20 (which shank closely fits for free rotation on the outer surface of the hub 2 of the casting *a*, axially through which the crank-shaft is passed) and the enlarged cylindrical head *j*, the forward end of which has the wall 23 in the form of an annulus, as seen in Fig. 14. There is an annular space *k* extending around within the enlarged head of the valve, which is entirely closed, except as to a certain nine of the valve-ports, which lead from said valve-chamber through the front end wall of the valve. Of said nine ports three thereof are designated by $h^{\times}$, three by *l*, and three by l^2. At the rear of the head of the valve and as an annular extension projected beyond the rear wall of the said valve-chamber *k* is the flange-section 21, which is of greater diameter than the tubular shank of the valve and is separated therefrom, leaving the intermediate annular space, the rear mouth of which is in communication with the exhaust-chamber of the engine, as seen in Fig. 2. This annular passage is forwardly terminated by the web-wall 24, through which, however, there are six openings 25 in particular arrangement, forward of which and within the valve-chamber they are hooded, as at 26, whereby there can be no communication between the rear exhaust-passage and the annular valve-chamber, the said hooded passages terminating in six ports at the front end face of the valve, three of which are designated by $1^{\times}$ and three thereof by $1^{\times}$. There are three ports through the front end wall of the valve, (designated by *h*, the same in the diagram Fig. 23 further having numbers 1, 2, and 3 added to the indicating-letter *h* for especial designation,) back of which and in communication with said ports are the passage-forming hoods 27, the said hoods occupying but a portion of the depth of said annular chamber, and these hoods and likewise the hoods inclosing the other said passages form no such partitions or barriers in the valve-chamber *k* as to impede the free passage and circulation of steam therein. The said hoods from the ports *h* are extended around within the valve-chamber from the positions of said ports in a direction reverse of that in which the valve rotates to extend beyond the next two adjacent ports; but the hoods, being narrower over the said next off-side ports, do not materially cover them, and 28 28 represent two apertures through the peripheral wall of the valve-body for each port *h*, whereby the steam is permitted to communicate from the steam-chamber with the said ports *h*. Of the eighteen ports of the valve here shown the three *h* thereof are arranged at intervals of one hundred and twenty degrees on the circular end face of the valve and are for giving the high-pressure steam to each cylinder as each of said ports *h* passes each of the cylinder-ports. It is now seen that there are five valve-ports between every two of said high-pressure ports *h*, the first $h^{\times}$ being for the exhaust of the steam from the cylinder which had been supplied thereto through the preceding high-pressure port into the valve-chamber. The second *l* of these intermediate ports when it comes opposite the cylinder-port gives low pressure to the cylinder from the valve-chamber or from another cylinder which had received high pressure and is at this instant exhausting into the valve-chamber. The third $1^{\times}$ of these intermediate ports is for the exhaust of the low-pressure steam from the given cylinder through the hooded passage 25 and annular passage at the shank of the valve to the exhaust-chamber. The fourth valve-port l^2 is for giving when it is brought to register with the same given cylinder-port a second low-steam pressure to its cylinder from the valve-chamber, (in which there is constantly established steam-pressure by reason of the exhaust thereinto of all of the cylinders after they have received high-pressure steam through the ports *h*,) and the fifth valve-port $2^{\times}$ permits of the exhaust of the low-pressure steam from the port, which it passes in the same manner as did the port $1^{\times}$. It will there-

fore be seen that every cylinder works first by high pressure and then by two successive low pressures. As a matter of fact the exhaust from each cylinder which had just worked on high pressure is had practically simultaneously through the valve-chamber into two other cylinders, which are at the same side of the motor-head as that at which the crank at that time happens to be.

Every pressure-port and every exhaust-port of the valve has the same action and permits the same ingress or egress of steam to or from the one cylinder-port that it does with respect to each of the cylinder-ports. A high-pressure port after having given high pressure to any cylinder does not again give high pressure to the next cylinder until both of the other high-pressure valve-ports have successively acted to permit of the communication of high-pressure steam to cylinders at other sides of the motor-head.

Under the running of the engine steam is always permitted to enter through the apertures 28 and thence to and through the ports h whenever each of said ports is over a cylinder-port, and every ninth of a rotation of the valve will insure such successive effective pressures at all of the eight cylinder-ports as to force the crank and shaft completely around, or, what is the same, the turning of the valve to the extent of an eighth of a rotation, whereby a high-pressure port is changed from one cylinder-port to the next cylinder-port, will insure the making of one and one-eighth rotations of the crank and shaft. Thus, noting the diagram view Fig. 23 and also the view Fig. 20, it will be seen that the cylinder-ports d are numbered from 1 to 8, inclusive, and the high-pressure valve-ports h are further numbered successively in the direction of the rotation of the valve 1, 2, and 3, and it will be seen on particular reference to Fig. 23 that the forward edge of high-pressure port h' (shown at the top of the view) is just at the rear edge of the first cylinder-port d, it being understood that said ports are just coming into registry, (and it will be here noted that at the instant the edge of a valve-port is in the position above specified relative to a cylinder-port the line x' of the crank is in or approximately in a line with said coinciding port edges.) Now as the said first high-pressure-port h' at the top begins to move off from the first cylinder-port, as is shown in Fig. 20, the high-pressure port h numbered 2 in advance thereof is shown as just going over the cylinder-port numbered 4, and by the time these last-mentioned ports h^2 d^4 have been brought out of registry the high-pressure port h^3 is brought over cylinder-port d^7, next in advance thereof, and while this valve-port is giving its pressure for the full stroke of the piston in the adjacent cylinder a complete rotation of the crank-shaft has been made, the valve up to this time having been turned but a ninth of a rotation, and before the last-mentioned port h^3 has been completely passed out of coincidence with the cylinder-port d^7, as last stated, the first-mentioned high-pressure port h' will be just coming onto the next cylinder-port to the left of the one it herebefore acted upon—viz., d^2—at which time the crank will then have made one and one-eighth rotations. The high pressures for the next rotation of the crank-shaft are given first by h' through d^2, then by h^2 through d^5, and then by h^3 through d^8, and so on, the pressure-port h' at each successive complete rotation of the crank next proceeding to registry with the cylinder-port in advance, as do each of the other high-pressure ports h^2 and h^3. It will also be seen that the arrangement of the low-pressure ports is such relative to the high-pressure ports that while a given high-pressure port h is in registry with a cylinder-port d two low-pressure ports toward the same side of the valve as the working high-pressure port will be more or less in registry with cylinder-ports, the said high-pressure port h and the two low-pressure ports all giving pressure at the same time into cylinders at the same side of the head. When the port h is just coming onto a cylinder-port, the two acting low-pressure valve-ports are behind such port h; but as the high-pressure port comes well over the cylinder-port a low-pressure port in advance and a low-pressure port to the rear of the high-pressure port are then the working ones; and it will be further seen by studying the diagrams that these cylinder-ports which are at the opposite side of the motor-head to those receiving pressure and which are covered at all by valve-ports are covered by exhaust-ports.

The detail construction of devices for effecting the separation of the steam-chamber from the exhaust-chamber, both of which are contained within the same cylindrical steam-chest C, will be now described in connection with Figs. 2 and 9 to 13, inclusive. The valve, while having its head rotating within the live-steam chamber c, has its rear portion extended through the partitioning devices, to be now described. The steam-chest is intermediately provided with the annular flange 40, against the rear face of which is bolted the ring-plate 42, the inner circular edge of which plate has a bearing upon the rear end of the annular flange 23 of the valve. There is screwed upon the forward face of the ring-plate 42 a thimble 43, (more plainly shown in Fig. 10,) the inner flanged edge of which also has a close bearing with relation to the said annular valve-flange 23. Inclosed within the space between the ring-plate and the thimble are two rings 44 and n, the inner one n being formed by two half-rings having at the extremities of the halves engaging tongues and sockets, as shown particularly in Fig. 12. Each half-ring or section has a pin 45 fixed thereto, which is extended laterally, one of which pins enters the radially-elongated slot 47 in the said thimble. The ring 44, which surrounds the separable section-ring n, is formed of as-

bestus or other suitable non-rigid material. The inner flange-wall of the thimble 43 is shown as provided with a series of perforations 49 49, through which steam may enter from the steam-chamber to a compressing action upon the outer edge of the asbestus packing-ring 44, and, insuring a compression thereof, also insures a constriction of the sectional ring *n* around the valve-flange 23. The rear of the exhaust-chamber *f* is constituted by the ring-plate 50, bolted upon the rear end of the steam-chest body, and the inner circular edge of such plate has a close bearing upon the rearwardly-projected shank of the valve.

The devices here employed for securing from the rotations of the crank-shaft only one-ninth as many rotations of the valve will be now described. The valve has on its rear end an internal gear *o*, and the crank-shaft has thereon an eccentric *p*, encircling which with a close but not a tight fit is a spur-gear *q*, which has eight-ninths as many teeth as the internal gear *o*. *r* represents a sleeve which loosely encircles the crank-shaft and is adapted to be held fixed in given adjusted position by means of the handle-lever 52 and the confining devices therefor. (Shown in Fig. 6.) The inner extremity of the sleeve *r* is outwardly extended or flanged, as at r^2, at different places through which at the same radial distances from the axis of the sleeve *r* and the shaft are circular openings 54, within which are set disks or cylindrical pieces 55, and each disk has a pin 56 passed through it at an eccentric point thereof which is as far off its center as is the center of the eccentric *p* off from the center of the shaft on which it is mounted, and said pins enter perforations therefor in the spur gear-wheel, which is mounted on the eccentric and which lies next to the flange of the sleeve. Now the shaft rotating also carries around the eccentric *p* and secures a motion of revolution of the spur-gear about the axis of the shaft, the spur-gear having no rotational movement on its own axis, such motion being prevented by the engagement of the pins 56 with the disks which have circular movements around the axes of the disks 55 and cause only the disks to rotate. Each roving of the spur-gear around on the internal gear fixed on the valve without rotation will therefore effect a rotational forcing of the internal gear to such an extent as the difference between the teeth of both gears is proportionate to the whole number of teeth comprised in the larger gear. Therefore if there are eighty-one teeth in the internal gear and seventy-two in the spur-gear it will require nine rotations of the shaft and nine complete rovings and forcing actions of the spur-gear upon the internal gear to effect one complete rotation of the valve.

The relative position of the valve may be modified with relation to the main shaft, whereby under a given position of the crank the valve may have a slightly-varied relation with the cylinder-ports for consequently slightly varying the distribution of effective pressures by unloosening the fastening device for the lever 52, which is shown at 53 in Fig. 6, and swinging such lever and the sleeve part in which the disks 55 are set. This change of relation of the valve may be effected whether the shaft is immovable or rotating.

Thus far the description has been given without reference to the cut-off ring, which is shown at E in Figs. 2, 14, and 20 and also in part in Fig. 22. This cut-off ring encircles the cylindrical head *j* of the valve and has eight apertures 60 through it, which are so arranged that just as a high-pressure port *h* is coming over a cylinder-port *d* and while it remains over such port the ring-apertures as to some portion of their area are over the apertures 28 28 for the working high-pressure port. The ring may, however, be so changed in its position relative to the valve that the pressure may be given only after the pressure-port has come partly to register with the cylinder-port, or the cut-off may be had before the pressure-port has entirely passed out of registry with the cylinder-port. A means for effecting both automatically and, when otherwise desired, changes of the cut-off ring as to the relations of its openings 60 with the valve-apertures 28 and cylinder-ports will be now described.

G represents a rock-shaft ranging parallel with and above the main shaft, being mounted in suitable bearings of the casing parts of the engine, the inner or forward end of this rock-shaft carrying a sector-gear 70, which is in mesh with the arc-shaped rack 72 on the cut-off ring E. Loosely surrounding the end of the rock-shaft G is a sleeve 74, on the outer end of which is fixed a worm-wheel 73, and a cup-shaped casing 75 is keyed upon the extremity of the shaft outside of the face of the worm-wheel, having its flanged portions inclosing the edge of the wheel and its one edge portion thickened to form bearings for the worm-shaft 76, which is mounted for rotation thereon and has its intermediately-formed worm-threads in mesh with the worm-wheel.

H represents a yoke comprising a split collar 77 and binding-screw (whereby it is confined upon the sleeve 74) and a bifurcated part which engages trunnion-studs 78 of a collar 79, that is immovably fixed on the vertical governor-shaft *u*. This governor-shaft at its lower end is spline-engaged, as seen in Fig. 2, with the bevel-gear 80, which is in mesh with the bevel-gear 82, that is formed as one with the internal gear *o* of the valve. This bevel-gear, as shown in Fig. 2, has the elongated sleeve-shank 81, which is flanged at its upper end and is supported for rotation and held against axial movement by the bracket 90 and strap 92, Figs. 2 and 3. The shaft *u* may therefore have a vertical movement, the bevel-gear 80 nevertheless being constantly in engagement with the gear 82, and at J are represented governor devices, to

which revolution is imparted as the valve, and consequently also the shaft *u*, rotates. The governor devices indicated at J will not be particularly described, as they constitute the subject-matter of another application for Letters Patent of the United States which it is my intention to shortly file, it being merely explained that an excessive rotation of the main shaft and valve, and therefore of the governor-shaft *u*, will generate such a centrifugal force and outward movement of the rollers 85 that they will be caused to ride upon the funnel-shaped support shown therefor and through connections which they have with the governor-shaft a raising thereof, and consequently a rocking of the shaft G and segment-gear 70 to operate the cut-off and secure a retardation of the running. The rocking motions thus automatically imparted to the shaft by the governor insure corresponding bodily movements to the sleeve 74 and the worm screw and wheel and the casing, all in unison; but it will be seen from the described construction that if it is desired to change the position of the cut-off ring, so that a greater or less lead may be given to the apertures 28 and high-pressure ports of the valve, this may be done independently of the governor by turning the worm-shaft 76 with a wrench or spanner. In doing this it will be clear that the sleeve 74 and the worm-wheel, being immovable, owing to their engagement by means of the yoke H with the governor-shaft *u*, cannot give to the worm-screw, and therefore the worm-screw must give to or crawl around on the worm-wheel, and with it the casing, which will of course by its key engagement with the rock-shaft effect a slight rocking of that shaft and the consequent slight shifting of the cut-off ring.

While, as above intimated, the parts combined with the governor-shaft *u*, which are generally indicated at J, do not constitute a part of this invention, the rack-provided cut-off-ring segment-gear and its carrying rock-shaft and the devices just above described as applied on the rock-shaft and serving as mediums of connection between it and the governor-shaft are deemed to properly constitute a part of the present invention in motors, for types of governors already well-known may be provided with relation to the shaft *u* for effecting a raising thereof when the excessive movements are imparted to the governor, and which substituted governor would be capable of efficient coaction with the said rock-shaft devices.

While in the motor here illustrated and described a motor-head having eight cylinders and cylinder-ports is set forth in connection with a valve having eighteen ports, (three of which are for giving high pressure to each of the cylinders, three for the exhaust of the high pressures into a temporary receiving-chamber or transferring-conduit, six for directing secondary pressures into the cylinders, and six for the absolute exhaust of the secondary pressures,) it is of course understood that the invention is not to be confined to such number of cylinder and valve ports, for it is entirely within the ability of mathematicians and steam or mechanical engineers after having made themselves familiar with the invention as hereinbefore set forth and without the exercise of the inventive faculty to make a design of an engine in which there are a number of cylinders and cylinder-ports different from eight and a valve for operation in conjunction therewith which will have the features and functions already set forth, but embodying a different number of ports from eighteen.

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

1. The combination, with a motor-head comprising a series of cylinders and ports therefor, all of which latter are in the same circle of arrangement, and a steam-supply chamber, of a valve mounted for rotation with a portion against the port-provided motor-head and having several passages therein which are in communication with the steam-supply and which terminate in ports that may register with the cylinder-ports, a series of exhaust-ports respectively adjacent the high-pressure ports, which may establish communication between the cylinder-ports and a chamber, (which is provided separate from the steam-supply,) other registering ports which are in communication with said chamber, and registering ports which are continued in passages through the valve for permitting the escape of the exhaust-steam, and all of the said valve-ports being in the same circle of arrangement to be brought successively into registry with each of the said cylinder-ports for the distribution of effective high and low pressures to the cylinders at one side and for the exhaust of cylinders at the opposite side of the motor-head and the number of valve-ports being unequal to the number of cylinder-ports, for the purpose set forth.

2. The combination, with a motor-head comprising a series of cylinders and ports therefor, all of which are in the same circle of arrangement, and a steam-supply chamber, of a valve mounted for rotation with a portion against the port-provided motor-head and having several passages therein which are in communication with the steam-supply and which terminate in ports that may register with the cylinder-ports, a chamber contained within the valve, having port-openings which may also register with the cylinder-ports, and several other registering ports which are continued in exhaust-passages through the valve, and all of said valve-ports being in the same circle of arrangement to be brought successively into registry with each of the said cylinder-ports for the distribution of high and low pressures to cylinders at one side and for the exhaust of cylinders at the other side of the

motor-head, the number of valve-ports being unequal to the number of cylinder-ports, for the purpose set forth.

3. The combination, with a motor-head having a series of cylinders and ports therefor, all of which are in the same circle of arrangement, and a steam-supply chamber back of the motor-head, and an exhaust-chamber separated from the steam-supply chamber, of a valve mounted to rotate with a portion against the port-provided head and having passages therein which are in communication with the steam-supply and terminate in ports for registry with the cylinder-ports, an annular chamber having ports which may register with the cylinder-ports, and several registering ports which are continued in exhaust-passages through the valve and lead to the said exhaust-chamber, the total number of valve-ports being unequal to the number of cylinder-ports and all in a coincident circle of arrangement, substantially as and for the purposes set forth.

4. The combination, with a motor-head comprising a series of cylinders and ports therefor, all of which are in the same circle of arrangement, a steam-supply chamber, and the crank-shaft and cylinder-pistons in connection therewith, of a valve having several registering high-pressure ports which are in communication with the steam-supply chamber and registering ports for the exhaust of the high-pressure steam, which lead to a chamber which is provided for receiving such exhaust-steam, registering ports which communicate with said receiving-chamber, and other registering ports continued in passages through the valve for insuring an absolute exhaust of the secondary-pressure steam, the total number of valve-ports being unequal to the number of cylinder-ports and all in a coincident circle of arrangement, and mechanism for securing a rotation of the valve at a different rate of speed from that of the crank-shaft.

5. In a multiple-cylinder motor, the combination, with a motor-head having the series of cylinders and ports therefor and a steam-supply chamber, of a rotatable valve having several passages through it which lead from its portion next to the steam-supply chamber and terminate in ports for registry with cylinder-ports and arranged to give during the rotation of the valve successive high pressures at different cylinder-ports, a movable apertured cut-off device overlying the surface of the valve in proximity to the steam-chamber and adapted to permit the passage of steam through the valves at times of the port registry, and means for shifting the cut-off ring, whereby the periodicity of steam-inlet to the valve-passages may be modified with relation to that of the port registries, for the purpose set forth.

6. The combination, with the motor-head having cylinder-ports therefor and the rearwardly-extended hub and the crank-shaft therethrough, of a steam-chest at the rear of the head and surrounding the hub, the valve having a tubular shank and cylindrical head which incloses an annular chamber and having high-pressure passages in communication with steam-chamber and terminating in ports *h*, other ports which communicate with the said annular chamber, and further ports leading through the valve for the discharge of exhaust-steam, the valve being mounted for rotation on the said hub, and means intervening between the valve and crank-shaft for securing a rotation of the valve differential to that of the shaft, for the purpose set forth.

7. The combination, with the multiple-cylinder port-provided motor-head and the steam-chamber, of the valve having a cylindrical head with ports in front end wall for registry with the cylinder-ports and which are extended in passages through the valve-head to the periphery, a cut-off ring located in the steam-chamber and surrounding the valve-head and provided with apertures 60 and the rack, and a rock-shaft and sector-gear which engages said rack, substantially as described.

8. The combination, with the multiple-cylinder port-provided motor-head, the crank-shaft, the steam-chamber, and the valve having a cylindrical head with ports in its front end wall for registry with the cylinder-ports and which are extended in passages through the valve-head to the periphery for communication with the steam-chamber, of a cut-off ring located in the steam-chamber surrounding the valve-head and provided with apertures 60, a governor adapted to be driven by the running of the engine, and connections between same and said cut-off ring for securing on the excessive running of the governor a slight turning of the cut-off ring, substantially as described.

9. The combination, with the multiple-cylinder port-provided motor-head, a steam-chamber, and the valve having a cylindrical head, the ports in its front end wall for registry with the cylinder-ports and which are extended in passages through the valve-head to the periphery, of a cut-off ring located in the steam-chamber and surrounding the valve and provided with apertures, a governor adapted to be driven by the running of the engine, and connections between same and said cut-off ring for securing on the accelerated movement of the governor a slight turning of the cut-off ring, and further devices and connections with the cut-off ring operative to turn same independently of and without interference by the governor, substantially as and for the purposes set forth.

10. The combination, with the multiple-cylinder and port-provided motor-head, a steam-chamber, and the valve having the cylindrical body with high-pressure ports extended to the periphery, and the apertured cut-off ring having the rack, of the rock-shaft G, having the sector-gear and provided with a sleeve having a worm-wheel fixed thereon, a yoke connected

to the said sleeve to have a swinging movement from same as its center of motion, a governor-rod adapted to have a vibration and engaged with said yoke, and a part carried on the said shaft having mounted thereon for rotation a worm-shaft, the worm-screw of which is in engagement with said worm-wheel, substantially as and for the purposes set forth.

11. The combination, with the valve having the cylindrical body and the steam-chest and the passages leading from the steam-chest through the valve, of the apertured cut-off ring having the rack, the rock-shaft G, having the sector and having connected thereon a yoke or arm, and the governor adapted to be driven by the running of the engine and embodying a vibratory shaft which has an engagement with the said rock-shaft arm, substantially as described.

12. The combination, with a cylindrical valve and the cut-off ring surrounding same, provided with a rack, of the rock-shaft G, having the sector-gear 70 and the sleeve 74, with the worm-wheel 73 fixed thereon, the vibratory governor-shaft *u*, the yoke H, connected on said sleeve to swing therefrom as its center of motion and having the pin-and-slot engagement with said governor-shaft, and the cup-shaped casing 75, fixed on the rock-shaft adjacent the worm-wheel and having the worm-shaft 76 rotatably mounted thereon to engage the worm-wheel, all substantially as shown.

13. In a multiple-cylinder motor, the combination, with a motor-head having a series of cylinder-ports in circular arrangement, the crank-shaft, and the valve mounted for rotation to lie against the part of the motor-head comprising the cylinder-ports and provided with a series of pressure and exhaust ports unequal in number to the cylinder-ports and all so arranged that the distribution of effective pressures given through the valve will be at any given instant opposite to the exhaust-port registry, of an internal gear on the valve, an eccentric on the main shaft, and a surrounding gear-wheel having a less number of teeth than said internal gear, a normally-stationary part through which the shaft rotates, having a portion which is located alongside of the eccentric-carried gear and with one or more circular openings, cylindrical pieces set to rotate in said openings, and pins eccentrically engaging the cylindrical pieces and also engaging the said eccentric-carried gear, substantially as and for the purpose set forth.

14. In a multiple-cylinder motor, the combination, with a motor-head having a series of cylinder-ports in circular arrangement, the crank-shaft, and the valve mounted for rotation to lie against the part of the motor-head comprising the cylinder-ports and provided with a series of pressure and exhaust ports unequal in number to the cylinder ports and all so arranged that the distribution of effective pressures given through the valve will be at any given instant opposite to the exhaust-port registry, of an internal gear on the valve, an eccentric on the main shaft, and a surrounding gear-wheel having a less number of teeth than said internal gear, a normally-stationary part through which the shaft rotates, having a portion which is located alongside of the eccentric-carried gear and with one or more circular openings, cylindrical pieces set to rotate in said openings, and pins eccentrically engaging the cylindrical pieces and also engaging the said eccentric-carried gear, and a device connected to said normally-stationary part for securing at pleasure a rotational movement thereof, and means for locking said part against movement, substantially as and for the purpose set forth.

15. In combination, a multiple-cylinder motor-head and ports therefor, a valve of a general cylindrical form mounted for rotation against said motor-head, and an annular body surrounding the valve, with an intervening space, and packing and partitioning appliances for dividing said intervening space into supply and exhaust chambers, consisting of a ring-plate secured to the body, a thimble secured to the ring-plate, metallic ring-sections, and a surrounding ring of compressible material in the annular space formed between the thimble and ring-plate, the said metallic sections bearing peripherally on the valve, and passages through the thimble for the admission of steam to a contracting action upon said compressible ring, substantially as described.

16. In a motor, the combination, with the annular body and a valve of general cylindrical form mounted for rotation concentrically therein, of a partitioning appliance consisting of the ring-plate 42, thimble 43, with passage 49, the sectional ring with engaging tongues and sockets, and the restraining-pins 45, and the ring of compressible material surrounding the metallic packing-ring, and all combined and arranged for operation substantially as set forth.

17. In a multiple-cylinder motor, the combination, with a rotary valve having a gear thereon, of the stationary support 90 and the removable strap 92, the pinion 80, having the extended and flanged shank engaged by said support and strap, and the governor-rod spline-engaged with said gear, substantially as and for the purposes set forth.

18. A rotary valve for a multiple-cylinder motor, having a cylindrical head with an annular chamber therein and several ports through its front wall which are continued in passages within the valve-head to apertures at the periphery, other ports through the front wall communicating with the annular chamber, and other ports through the front wall which are rearwardly continued in exhaust-passages terminating at the rear of the valve-head, substantially as and for the purposes described.

19. A valve for a multiple-cylinder motor, having a head in the form of an annular shell

and having at intervals of thirds around its front end wall high-pressure ports which are extended in hooded passages terminating at the periphery of the valve-head and intermediate of pairs of said high-pressure ports, two ports through said end wall leading to the annular chamber within the valve, next a port continued in a hooded passage through and terminating at the rear of the valve, next another port communicating with the said valve-chamber, and next another port continued rearwardly in a hooded passage which terminates at the rear of the valve-head, for the purposes set forth.

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Witnesses:
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