3 Sheets—Sheet 1.

E. N. DICKERSON.

VALVE GEAR FOR STEAM ENGINES.

No. 75,387. Patented Mar. 10, 1868.

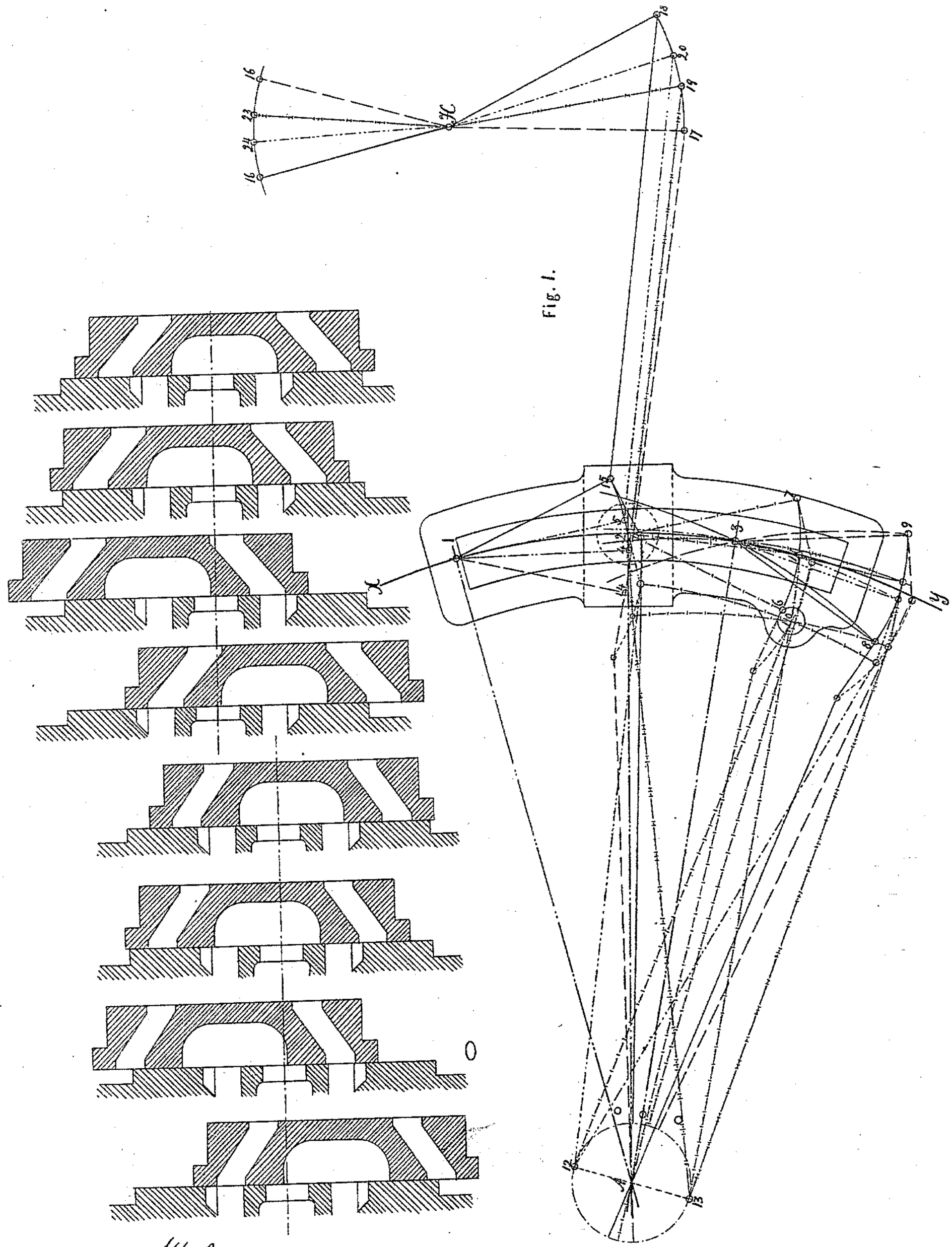

Fig. 1.

Witnesses.

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3 Sheets—Sheet 2.

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VALVE GEAR FOR STEAM ENGINES.

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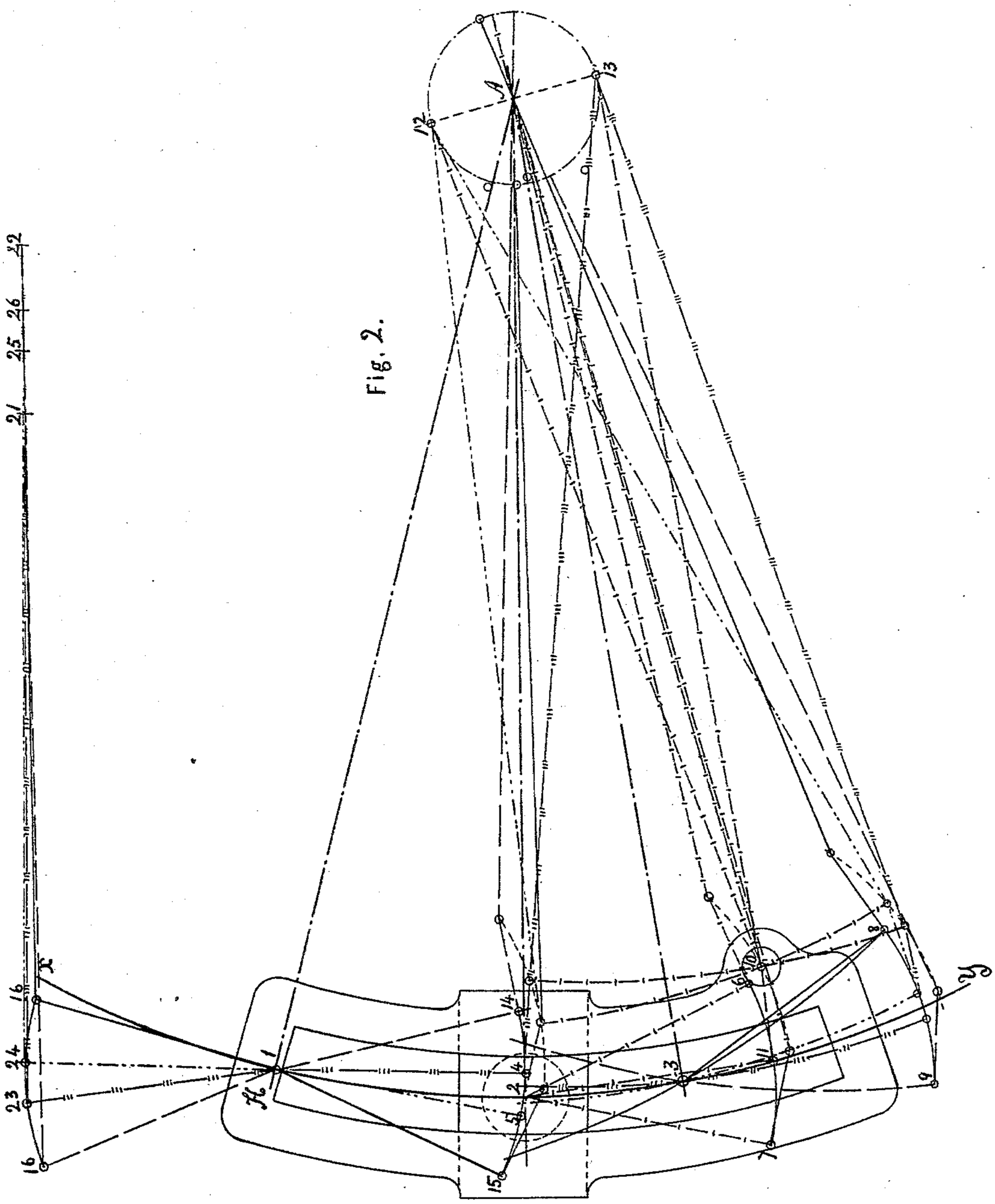
Fig. 2.



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3 Sheets—Sheet 3.

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VALVE GEAR FOR STEAM ENGINES.

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Fig. 6.

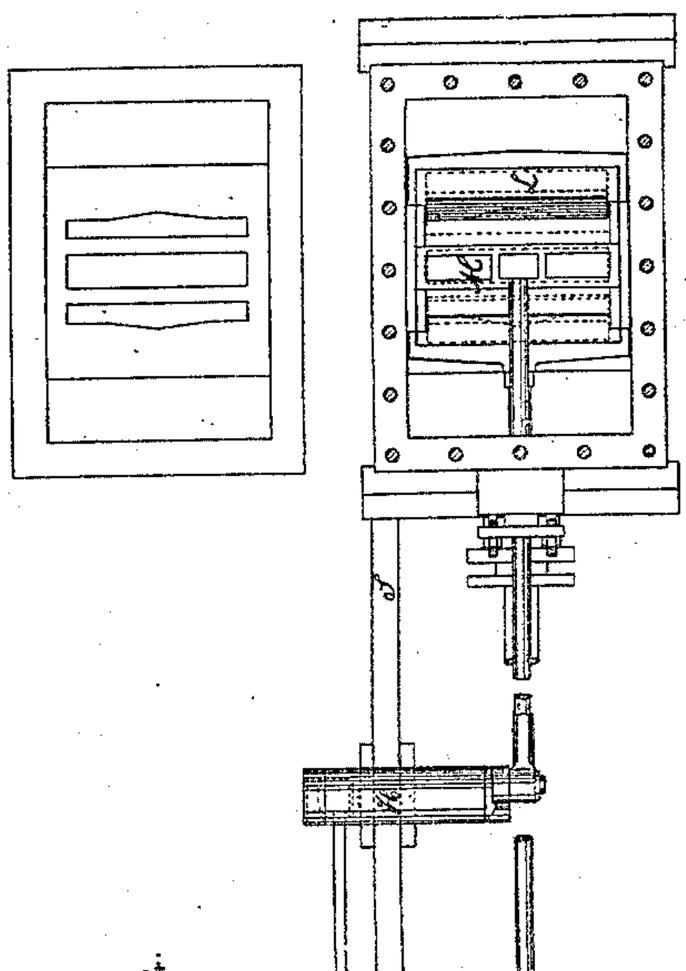

Fig. 4.

Fig. 1.

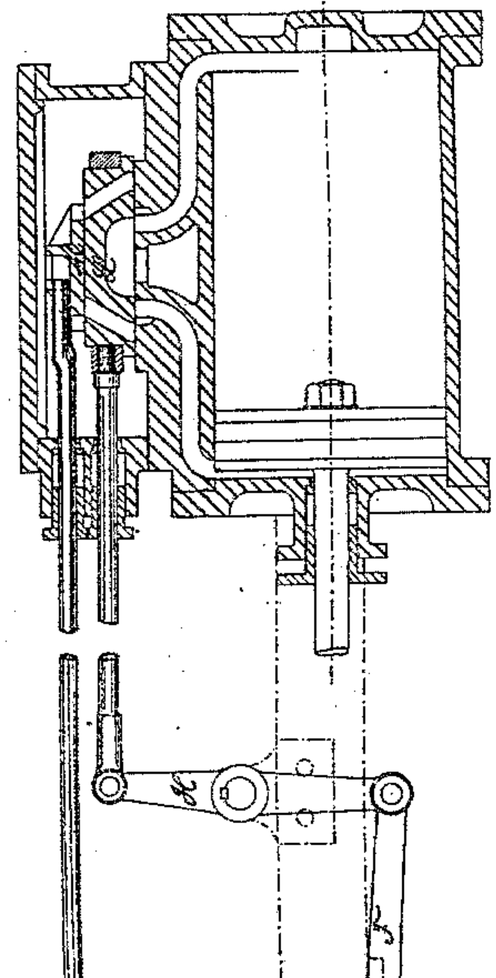

Fig. 5.

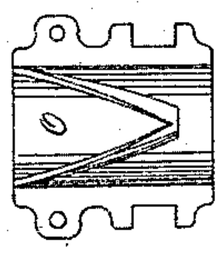

Fig. 2.

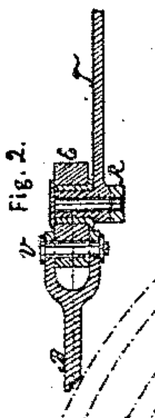

Fig. 3.

Witnesses.

J. H. Roberts

Wm. Wynn

Inventor.

Edw. N. Dickerson

United States Patent Office.

EDWARD N. DICKERSON, OF NEW YORK, N. Y.

Letters Patent No. 75,387, *dated March* 10, 1868.

IMPROVEMENT IN VALVE-GEAR FOR STEAM-ENGINES.

The Schedule referred to in these Letters Patent and making part of the same

Be it known that I, EDWARD N. DICKERSON, of the city of New York, have invented a new and useful Improvement in the Valve-Gear of Steam-Engines which, when in use, require to be reversed, the object of which improvement is to remedy the defects and retain and improve the advantages of the "link-motion," as now commonly used.

At the time of the introduction of the "link-motion" by Mr. Stephenson, all steam-engines which worked steam expansively did so by the use of some form of independent cut-off, the most simple and effective of which was a slide working upon the back of the main valve, and alternately closing the ports which passed through it. In locomotives this form of cut-off was sometimes made adjustable, through a portion of the stroke, either by altering the travel of the cut-off slide, by increasing or diminishing the length of the rocker-arms, which transmitted the motion from the eccentric to the slide, or by dividing the slide into two parts, and, by means of a screw, separating those two parts to a greater or less distance from a centre-bar moved by the eccentric. In these two forms the independent cut-off retained a value in the estimation of some locomotive-builders above the "link-motion" for several years, but finally the superiority of the "link-motion" over all forms of the independent cut-off has been universally acknowledged, and all locomotives are now constructed with that apparatus, or an equivalent of it, and without an independent cut-off.

The advantages of the "link-motion," which have thus brought it into universal use, are two: first, that it forms a cut-off variable from almost full stroke to about one-fifth of the stroke, readily adjustable by the same lever which reverses the engine; and second, that, as a reverser, the link holds the main valves at all times in positive connection with the hand-gear, so that, in the attempt to reverse the engine, there is no possibility of a failure of the motion of the valves, if the reversing-lever is thrown into the proper position. The "link-motion" also has the merit of simplicity.

The main disadvantages of the "link-motion" are four: first, when used as a cut-off, it is usually set to open the steam-valve before the piston has reached the end of the stroke, by reason of which the steam is admitted to resist the travel of the piston before the stroke is completed; second, it contracts the opening into the cylinder very gradually while cutting off, in consequence of which the steam is "wire-drawn," and thereby loses a considerable part of the boiler-pressure before it acts upon the piston; third, it opens the exhaust-valve too soon, and releases the steam from the cylinder before it has expended its force in driving the piston to the end of the stroke; and fourth, it closes the exhaust-valve, through which the steam that has already performed its work is escaping, before the piston which is driving it out of the cylinder has reached the end of its stroke, in consequence of which the steam, which has done all the work it is capable of doing, is confined, and compressed by the piston, in the end of the cylinder, resisting its motion and forming what is called a "cushion."

The first of these disadvantages causes a total loss of the entire power necessary to force back the steam at boiler-pressure during the period of premature admission, as well as of the friction upon the journals for the same time. If that admission is for one-half an inch (it generally is more) of the stroke of the piston, (or one forty-eighth part of the stroke,) and the steam is of the pressure of one hundred and thirty pounds to the square inch, the loss of power from this disadvantage will be equal to two and three-fourths pounds to the square inch, average pressure, for the entire stroke, which is about seven per cent. of the ordinary working power of a locomotive.

The second of these disadvantages causes a loss of all the elastic force, of which the steam is deprived by being squeezed through an aperture too small to permit the passage, at boiler-pressure, of the quantity needed to fill the cylinder as the piston moves. The amount of this loss varies with the varying sizes of the ports and the varying speed of the piston, but it is not less than ten per cent. of the whole steam power of the locomotive. The whole amount of the loss from this cause is not exhibited by an "indicator diagram," because the water, which is mechanically suspended in the steam, and carried with it from the boiler into the cylinder during the "wire-drawing" process, (but less of which would be carried if the port were sufficiently opened for a shorter time,) produces no sensible effect upon the indicator.

The third of these disadvantages causes a total loss of all the elastic force remaining in the steam, which might be employed in driving the piston to the end of the stroke, if the exhaust-valve were kept closed until

near that point. The amount of this loss varies. In extreme cases, when the average cylinder-pressure is high, the loss amounts to full six per cent. Its average is not less than three per cent. of the working power of the ordinary locomotive.

The fourth of these disadvantages, the "cushion," causes a loss which varies with the speed of the engine, the amount of "clearance," (or vacant space between the piston at the end of the stroke and the valve,) and the size of the exhaust-nozzles. This loss increases rapidly as the rapidity of the strokes increases, and the accumulated resistance from this cause, at high velocity, practically fixes a limit to the speed of a locomotive. In locomotive-cylinders, with the usual "clearance," the absolute loss from the "cushion" averages seven per cent. The clearance is an evil unavoidable in connection with the "link-motion," but in engines provided with my valve-gear, and with a clearance diminished to the practical minimum, a saving of full twenty per cent. will be effected, in consequence of avoiding the "cushion." In stating that the absolute loss from the "cushion" averages seven per cent., proper deduction has been made for the reduced rate of expansion of the steam which is driving the piston, incident to the higher mean pressure required to overcome the resistance of the "cushion," and proper allowance for the re-expansion of the cushion steam, and for the saving by filling the "clearance."

By the use of my improvement, the steam-valve is not opened until the piston reaches the end of the stroke, or a little later, and is then opened very gradually for a short time. While the steam-valve remains open, it supplies the cylinder with steam, without any material reduction of pressure in consequence of a contracted opening. When the cut-off slide closes the port, its motion is so rapid as to be practically instantaneous. The exhaust-valve does not release the steam until its force is effectually expended, and then it opens so rapidly as to release the steam instantly, and the opposite exhaust-valve does not close until the piston has reached the extreme end of the stroke, so that no "cushion" is formed. Thus all the disadvantages of the ordinary "link-motion" are remedied, and all the advantages of the ordinary "link-motion" are retained by means of a link, which reverses the engine, but which is so constructed as to reduce the wear upon itself and its connections to an amount practically no greater than is incurred in the valve-gear of an ordinary stationary engine incapable of being reversed.

When the piston is at the end of the stroke, and the crank on the centre, it is apparent that no power can result from the application of steam-pressure upon the piston, but the friction upon the journals and crank-pins of an ordinary locomotive, during the first five degrees of the revolution of the engine from the centre, absorbs more power than is generated by the motion of the piston during that time; also, the sudden admission of steam into the cylinder produces a shock upon the crank-pins and journals like the blow of a hammer, making it necessary to reduce the slack of the connections by driving the keys hard, in consequence of which, great friction, heated journals, and rapid destruction of the brasses, are produced. With the link-motion, when working at or near full stroke, this sudden admission is not neutralized by a cushion, therefore the engine must be keyed up very close for that position, and when the cut off is short, and the cushion does prevent the shock of sudden opening, the keys are still tight, and the friction is augmented by the resistance of one piston against the other, near the centres. The remedy of these evils is effected in my improvement by admitting the steam through a graduated aperture, and "wire-drawing" it during the time occupied by the crank in moving through the first few degrees of the stroke, when full pressure on the piston would be injurious. This gradual admission of steam cannot be used advantageously in combination with the ordinary "link-motion," because, when the link is cutting off short, which is its usual operation, the gradually-accumulated "cushion" imposes a pressure upon the piston before the steam-valve opens, and thereby prevents a shock, and renders a graduated opening for the admission of steam useless for that purpose, while, at the same time, the slow closing of the graduated valve "wire-draws" the steam at a time when its pressure is needed in the cylinder, and thereby causes an absolute loss of power, but in my combination, where the cut-off is effected by an independent slide, a graduated opening may be used without loss, and, there being no tendency to a blow or shock, no "cushion" is needed to anticipate and prevent it. Thus the disadvantages of the premature admission of steam and of the "cushion" may be remedied.

In the ordinary "link-motion," when used as a cut-off, the valve opens the port to a very limited extent, and very rapidly, but closes it very slowly, in consequence of which the piston travels five times as far while the valve is closing as it travelled while it was opening. The effect of this relation between the motions of the piston and the valve is to "wire-draw" the steam and diminish its power. In my valve-gear, the main valve continues to open during the first seventy-five degrees, more or less, of the revolution of the crank, as in the old-fashioned lap-valve arrangement, so that steam is always supplied in proportion to the demand of the cylinder, if not otherwise cut off or suppressed, but my cut-off valve is so arranged as to close with almost instantaneous velocity, which is not reduced or affected by its adjustment to different points of the stroke. By this means, the disadvantage of "wire-drawing" is remedied.

In the ordinary "link-motion," the point of exhaust varies with the point of cut-off, thereby releasing the steam earlier, as its quantity diminishes; whereas, if a variation in the time of exhaust were desirable, the greater quantity should be released earlier. In my valve-gear the point of exhaust is fixed in the construction of the machine, and may be set to the best advantage. In all cases, the ordinary "link-motion," when used as a cut-off, exhausts too early for economy, but, by separating the cut-off valve from the exhaust-valve motion, this evil is remedied.

In the ordinary "link-motion," the "cushion" is unavoidable. In my valve-gear, the blow or shock being prevented by the gradual opening, as before stated, the exhaust-cavity of the main valve is elongated, so that both exhaust-valves will be open at the same time near the end of the stroke, and I make the bar of the valve, which covers the port, only as wide as the port itself, (line and line with it,) so that the exhaust-valve does not until the steam-valve opens, which is at or after the end of the stroke. Thus there can be no accumulation

the crank-pins. This sleeve N surrounds the shaft, but is a loose fit, so that it may be turned upon it. In the middle of the sleeve there is a slot cut, about two inches wide, and running around the pipe in a plane at right angles to its axes, for one hundred and thirty degrees. The object of this slot is to allow the pin W to be screwed into the shaft, and to permit the eccentrics, notwithstanding the pin, to be moved around the shaft for one hundred and twenty degrees. When the eccentrics are at right angles to the cranks, and ahead of them as the engine moves forward, the pin W should be screwed into the shaft at the back end of the slot. O is the adjusting-sleeve, which fits outside the pipe N, and is made in two semi-cylindrical halves, bolted together. On the inside of this sleeve two spiral grooves are cut, as seen at Figure 5, which are intended to receive the end of the pin W, which projects beyond the pipe N about an inch and a half, and also the block X, which is fixed upon the inside sleeve, at the end of the slot opposite to the pin, as set. When the sleeve O is moved from end to end upon the shaft, the pin W and the block X traverse the spiral grooves from end to end, and are brought nearer together, or removed farther from each other in the direction of rotation. But as the pin W is fixed in reference to the crank of the engine, it is apparent that the cut-off eccentrics must change their angular position to the cranks, as the pipe to which they are fixed is forced around the shaft by the spiral grooves acting upon the block X, and so an adjustment of the cut-off will be effected through as many degrees of the revolution of the engine as the spiral grooves diverge from each other. The travel of the cut-off slide M is eight inches, being an increase upon the throw of the eccentric, produced by a difference in the length of the rocker-arms. The point at which the cut-off will be effected varies about an inch and a quarter from the centre of the travel of the cut-off slide, so that the centre line of the eccentric must be very nearly at right angles to its rod when the cut-off is effected, and, therefore, must throw the valve, with nearly its highest velocity, at any possible point of cut-off, and by adjusting the lengths of the cut-off slide and connecting-rods, the very highest velocity will be secured at the point of usual work, with very little diminution of speed for all other points of cut-off. The longer the travel of the cut-off slide, the more perfect will be the cut-off, but eight inches are enough for all practical purposes.

For the purpose of placing the adjustment of the cut-off within the control of the engine-driver, a strap, Y, is passed in a groove around the sleeve O, similar to an eccentric-strap, but with one hinge-joint, for the sake of convenience, instead of two bolted joints. At opposite points in this strap two pins are fixed, Z, which pass through holes in the two ends of a reversing-clutch, P, which clutch is forced from one side to the other along the pipe, by a vertical shaft, Q, which has a projecting block on one side of its axis, that fits easily into a mortise in the arm of the clutch P. The shaft Q is vibrated from the foot-board of the locomotive, by means of a lever and bell-cranks and rods, connecting with it in a manner well known to engineers, for analogous purposes, the shifting-clutch being an apparatus well known, and used in England, on some locomotives, for altering the angular position and throw of the main eccentrics. Other means for varying the angular position of the cut-off eccentrics, when in motion, may be used for the purpose of effecting my method of cut-off, but I recommend this device, in preference to any other I know of, for similar purposes, because it completely protects the spiral apparatus from exposure.

In order to enable engineers to construct my link-motion, and apply it in all varieties of situations, sheet 2 is prepared, exhibiting five various positions of the centre-lines and centres occupied by the eccentrics, connections, links, and valves, in an entire revolution of an engine. The colors, yellow, blue, red, black, and green, indicate the connection between the valves and their connecting parts throughout. Fig. 1 represents a case similar to the drawing on sheet 1, where an intermediate hanger and rocker-shaft are employed between the link and the valve. Fig. 2 represents a case where the link-block is fixed upon one end of a rocker-arm, and the valve is worked from the other end, as is usual with the ordinary link-motion.

In constructing a valve-gear, the draughtsman should first determine the length of the link which he would desire to use, as it determines the length of the radius-bar, which, within certain limits, bears a constant proportion to it. The length of the hanger or rocker-arm, upon which the block is fixed, should be from twenty-five to thirty three per cent. of the length of the radius-bar D, which supports the centre of the link, and the chord of the lower segment of the slot in the link, from the centre-pin to the end of the slot, must be of the same length as the hanger or rocker-arm, from its centre to the centre of the block, with one-half the length of the block added. For very fast engines, the larger proportion is better than the smaller, because a greater lead is thereby effected upon the exhaust-valves; but the proportion of lead is a matter of judgment for each constructor. When that proportion has been determined, the centre of the hanger or rocker-shaft can be fixed by measuring from the centre of the shaft, a distance as much greater than the length of the hanger or rocker-arm as that proportion requires, and from the centre of the shaft A, an arc of a circle, *x y*, should be drawn, at the distance of the centre of the hanger or rocker-shaft. Upon that arc, say at 1, the centre of the hanger or rocker-shaft must be established. From that centre, with a radius equal to the distance between the centre of the hanger-pin or rocker-shaft and the centre of the block suspended at the lower end of the hanger or rocker-arm, describe an arc of a circle, 14 15, intersecting the main arc at 2, and extending either side of it, somewhat further than the eccentric throw. In this arc the centre of the block will always travel. From the point of intersection of these two arcs, 2, describe another arc, 6 7, with the same radius, and the same general dimensions. The principal arc, *x y*, will be the track of the centre of the link, as it is raised or lowered in reversing the engine; the first of the small arcs, 14 15, will be the track described by the centre of the block-pin when the engine is working; the second of the small arcs will be the track described by a point in the lower end of the link, as much below its centre as the centre of the block is below the centre of the rocker-arm, when the link is in its middle position, and the block is permanently held with its centre coincident with the centre of vibration of the link. In this position draw the line 2 11, which will be the chord of the arc of the link. when constructed, and which is of the same length as the hanger-arm. From the point 11, and at right angles to the

of steam or "cushion" in the cylinder at the end of the stroke, nor can water be caught in the cylinder, nor, when working through the engine, will it produce any jar or concussion. In the accompanying drawings—

Sheet 1 represents my valve-gear for a locomotive-engine, drawn upon the scale of one-eighth the actual size; and

Sheet 2 represents the geometry of my link-motion, in a variety of positions, upon the scale of one-fourth the actual size.

The same letters refer to the same parts throughout.

In Figure 1, sheet 1, S represents a part of the engine-frame of an eight-wheel locomotive, with the cylinder attached, and with one driving-wheel, shown in red ink. The engine is represented on the after centre. A is the shaft, B is the main eccentric and rod, C is the cut-off eccentric, and G its rod. E is the link, which is connected, as usual, with the eccentric, B, at one end, but the other end is free. D is a radius-bar, which is suspended by a strap on the main shaft, around which it vibrates in reversing the engine. The link E is suspended by the pin T to the end of the radius-bar farthest from the shaft, in the same manner as the ordinary link is suspended to the reversing hand-gear. R is a hanger, the upper end of which is suspended upon the frame by a pin, upon which it swings. To the lower end of this hanger the ordinary link-block is suspended by a pin, which passes through it. F is a connecting-rod, which connects the hanger and block-pin with the main rocker-arm H, to work the main valve L, in the usual manner.

Figure 2 is a section through the block, connecting-rod, and hanger-end, showing how, for greater rigidity, the end of the connecting-rod has a hollow pin forged upon it, which passes through the block. From the centre of the main shaft to the centre of the link-pin T, through the radius-bar, the distance is thirty inches, and from the centre of the eccentric to the centre of the pin U is twenty-seven inches and four hundredths. From the centre of the pin U to the centre line of the link is three and one-eighth inches. The hanger is eight inches long from centre to centre, and the link is cut in a circle, the radius of which is twenty-eight and one-half inches to the centre line. The throw of the eccentric is five and one-half inches, and the travel of the main valve four and a half inches. The tumbling-shaft K is connected with the centre of the link in the usual position, but around the hub of the radius-bar, and by its vibration it elevates or depresses the link to the required positions, in the usual manner.

Figure 6 represents a plan of the ports and valve-seat. The steam-ports, instead of being rectangular, have their outside edges formed in the shape of an obtuse V, the point of the V projecting half an inch outside of the usual edge, and the widest part of the V being seven inches across. The triangular opening thus formed ought to be one-ninth of the travel of the valve in length, and one-half of the width of the port, but this V-shape may be made in the inside edges of the passages through the main valve, and the ports in the seat left rectangular. The proportion here given is suitable for engines making one hundred revolutions a minute, but for slow-moving engines this V-shaped port may be more obtuse without producing a shock. For fast engines, the port may be graduated for a longer distance of travel, and with a wider base to the triangle, so as to prevent shocks. One-fifth of the travel of the valve, and a base to the triangle as wide as the port, may be used.

The valve-gear is represented in the forward position, in which the axis of the centre-pin of the link is in the same line and centre with the axis of the centre-pin of the hanger R; and as the radius-bar D holds the centre-pin of the link firmly in that position, there can be no slip of the block in the link as it vibrates; hence, all wearing of the link and block is avoided, except that which results from the slip of the block in backing, when the link is lowered, and the block works in its upper segment. When the link-centre is lowered so that it coincides with the centre of the block, the block is firmly held in the link, exactly thirty inches from the centre of the shaft, and although the engine may be running, no motion is imparted to the main valve, and all the wear of valves, when the engine is shut off, is prevented; whereas, in the ordinary "link-motion," the valves are never entirely at rest when the engine is moving. Another advantage results in my valve-gear from holding the valves still on the centre, which is, that both exhaust-ports are kept open at the same time, and in running down hill the piston is not resisted by atmospheric pressure, as it is by the ordinary "link-motion," and the engine will run without steam, in many cases, where steam would otherwise be required to keep the train in motion. This peculiarity will be found of very great advantage on railroads having heavy grades, because, in running down a grade of one to one hundred and thirty, with the ordinary "link-motion," the engine requires steam enough in the cylinder to balance the atmospheric pressure which resists the piston, and thus is wasted a quantity of steam, half as much as would be needed to drive the engine thirty miles an hour on a level. My link-motion is not capable of producing a cut-off by itself, and is only valuable in combination with an independent cut-off, but it may be used advantageously with any of the forms of independent cut-off, besides that herein described.

My apparatus for effecting an independent adjustable cut-off differs from all others, in the fact that its adjustment is effected by varying the angular position of the cut-off eccentrics on the main shaft, in consequence of which any desired range of adjustment can be obtained, and the cut-off valve will always be closed at its highest velocity nearly. It may be used with any reversing-apparatus.

Fig. 1, of sheet 1, represents an elevation of one cut-off in action, adjusted to cut off near the commencement of the stroke. The cut-off slide M is just about to close the port through the main valve L, which is just opening the point of the V-shaped port, for the admission of steam at the commencement of a stroke.

Figure 4 represents a plan of the cut-off apparatus, with one cut-off valve connected, and with the eccentric for the other valve.

Figure 3 is a section through the main shaft, sleeves, and adjusting-clutch of the cut-off apparatus.

The eccentrics, C, are fixed upon a pipe or sleeve, N, which, in this case, is cast in two halves with the eccentrics, and bolted together. The eccentrics are at right angles with each other, in the same direction as

line 2 11, draw the line 10 11, as long as the desired distance between the centre-line of the link and the centre of the eccentric link-pin, which will be at 10. Take the distance from the centre, 2, to 10, as a radius, and describe a dotted curve through 10, with that radius, and that will be the track of the eccentric link-pin. Describe a similar arc from the centre 1. From the point 10 draw a straight line to the centre of the shaft A, and at right angles to that line, through the centre of the shaft, draw another line, 12 13. From the centre of the shaft describe a circle, the diameter of which is equal to the throw of the eccentric. At the points 12 13, at which that circle intersects the right-angled line last drawn, will be the two centres of the eccentric, at the two opposite centres of the engine. Connect these points with the eccentric link-pin 10, and the distance from the centre of that pin to either of the eccentric-centres will be the length of the eccentric-rod. In this position the main eccentric should be keyed to the shaft, and never changed, and when the engine is on either centre, the radius arc *x y* will pass through the centre-line of the link at the points 2 and 11. When the link is elevated from this position to that in which its centre is at 1, its lower extremity will be drawn away from the arc *x y*, into one of the positions colored red or blue, as the engine may be on the back or forward centre, and that departure will constitute the lead for forward motion. The track of the eccentric link-pin is traced in yellow, and the yellow lines indicate the positions of the link at both centres of the engine, (which are the same,) and at full throw when the valves are out of action, and when only the link is moved, if the engine should be running. The full throw of the link may also then be ascertained, by laying down the black and green lines, which is done by using the eccentric-rod length 10 12, set in a pair of dividers, one end of which is to be applied to the circle of the eccentric throw, at its points furthest from and nearest to the arc 14 15, and the other end to the dotted arc in which the eccentric link-pin travels, by means of which the extreme throw of that pin will be known, and from those points, at a distance equal to 10 11, on the arc 14 15, will be the points of extreme throw of the centre of the block-pin 14 and 15. In that state of the drawing the curve of the link may be ascertained, which depends upon the travel that is desired for the main valves in backing, and which need not generally be more than two-thirds of their travel in going ahead. From the centre 2 measure off on the radius arc the distance 2 3, the same proportion to the distance 1 2 that the travel of the valve in backing is to its travel in going ahead. From the centre 3 sweep the arc 8 9, of the same radius as the arc 14 15, and also the corresponding dotted arc, and upon those arcs lay off the full-throw positions of the centre of the eccentric link-pin and the centre-chord of the link, as shown in the black and green lines 3 8 and 3 9. The point 8 or 9 will be a point of the curve of the link, the centre 3 will be another point, and the third point will be on the arc 14 15, and between its ends, the exact position of which may be determined, experimentally, as follows: Sweep an arc through the two first-established points, 3 8, with a radius somewhat less than the radius A 1, and mark where it intersects the arc 14 15. With the same radius sweep another arc through the points 3 9, when the link is at full throw in the opposite direction, and mark where it intersects the arc 14 15. If the radius selected for sweeping this arc should chance to be the true one, the two points of intersection on the arc 14 15 will divide the distances 2 14 and 2 15, on that arc, in similar proportions. If they do not so divide those distances, the radius selected for the experiment is too long or too short, and another experiment, with a different radius, must be tried, until the arcs 2 14 and 2 15 are similarly divided. The radius thus found will be the radius of the link, and the travel of the valve in backing will be equal each way from the points of lead. With that radius thus found, through the points 2 11 draw the centre-line of the link, and construct the entire link around that centre-line, in the usual manner. The curve of this link will coincide with the curve *x y* only at the points 2 and 11, but it will transmit a true valve-motion from the eccentric to the valve, in all positions. If it is desired to make the backing-travel as long as the forward-travel, the centre 3 must be dropped nearly as far below the centre 2 as the centre 2 is below the centre 1, and in that case the experimental curves for determining the radius of the link would intersect the arc 14 15 at those points. The lead, in backing, will be the same as in going ahead, if the travel is the same. If the travel is less, the lead will be diminished proportionately. The reversing hand-gear must be arranged so as to lock the centre 3 in the position determined by the drawing, for backing, and in the position 1 for going ahead, and in the position 2 when the valves are to be held still with both exhaust-ports partially open.

The next problem is to transfer the motion thus obtained upon the end of a hanger or rocker-arm to the valve. The throw of the hanger-pin will be dissimilar on the opposite sides of the radius arc, but it is desirable that the travel of the valve should be equal at each portion of its throw from the engine-centres. It is, therefore, necessary to convert the unequal throw of the block-pin into an equal throw of the valve, which is done as follows: Construct the rocker-arm, H 16, to which the valve is to be connected, so as to throw equal distances each side of a perpendicular, and with a total throw equal to the desired travel of the valve. From the centre, H, lay off an arc, 17 18, of about the same radius as H 16. Select a point, 18, on that arc for the extreme throw of the rocker-arm, and with a pair of dividers connect that point with the point 15. Then remove the dividers, retaining their distances, so that one of the points will touch 14, and mark on the arc, 17 18, where the other point touches it. The points 17 18 will be the extreme throw; and if the angle 17 H 16 has been correctly assumed, the rocker-arm may be so constructed; in order to ascertain which, place one of the divider-points on the lead-points 4 and 5, successively, and mark with the other one where the rocker-arm will be when the block-pin is at 4 and 5, which will be found at 19 and 20. Then measure the distances 17 19, and 18 20, and if they agree, the connecting-rod length is correct; if not, spread the dividers more or less and repeat the experiment, assuming new points on the arc 17 18 till they do agree, when the length of the rod, 15 18, and the angle between the two rocker-arms, H 17 and H 16, will be correct. If the arm H 17 is found not to be short enough to give the throw required at 16, its length may be altered, and a new arc drawn for experiment, as before, until the proper length of all the parts and the proper angle of the rocker-arms are ascertained.

If no intermediate hanger is employed, but the block is hung on one end of the rocker-arm, and the valve

is worked from the other end, as in fig. 2, then the motion of the valve will be equalized by adjusting the angle which the valve-rocker arm makes with the block-rocker arm, and that adjustment will be made experimentally as follows: Construct a movable paper sector, having drawn upon it the lines 1, 14—1 15—1, 4—and 1, 5—and pin it on the drawing at the centre, 1, so that it will coincide with the lines which it imitates. Turn it till it occupies the position of 16 16, and with the dividers measure off and mark upon the line of the valve-stem, 21 22, near the chest, the points 21, 25, 26, and 22, being equidistant from the points 16, 23, 24, and 16, respectively. If the distance 21 25 is the same as the distance 22 26, the sector has been placed at the right angle with the line 1 14; if not, move it around the centre, 1, to another position, and repeat the experiment until the lead and travel of the valve agree. The length of the arm 1 16 may require to be varied to suit the desired valve-travel, which can be done as in the other case. In this case the valve-arm will not vibrate equal distances each side of a line perpendicular to the valve-rod, but will fall lower on one side than the other; the valve-motion, however, will be true, and an unequal eccentric-throw will be converted into an equal valve-travel.

The four valves and valve-seats, colored blue, red, black, and green, represent the four positions of the valve at its points of lead and full throw, the blue and red colors representing the position of lead on both centres. The opening made by the lead amounts to a very small triangle, three-sixteenths of an inch wide and two inches and five-eighths of an inch long, but the elasticity of the valve-gear and the loss of motion in the joints will reduce this small opening materially, and it is not desirable to have any opening until the engine reaches its centre. If there were no elasticity or lost motion, I would make the valve so much longer than it is here shown as to cover the port when the engine is on the centre, and only open it afterward. The rapidity with which the main valve is opened by this valve-gear is such that, notwithstanding the great portion of the travel occupied in opening the V-part of the port, the pressure upon the piston is not diminished, except where it is desirable to diminish it in order to save the loss of the friction while it is greater than the power, and the shock is prevented without expense of power.

In constructing a locomotive, I would advise the engineer not to finish the lap and exhaust-cavity of the valve till the valve-gear is all erected and the position of the eccentric is adjusted and fixed. When the parts are all in position, except the valves, let the engine be placed on one centre, and let the link be placed with its centre-pin coincident with the centre of the block-pin, as shown in sheet 2. Then, with the eccentric in a position nearly right, ascertain the position of the point 10, and mark it. Turn the engine to the other centre, and again mark the position of 10. If it should be the same as at first, the eccentric is in the right position; if not, turn the eccentric on the shaft, dividing the error in halves, and again try the position until the point 10 will come to the same exact position at both centres of the engine. Then key the eccentric in that position and never let it be changed again. Raise the link to the go-ahead position, as in sheet 1, and the rocker-arm will move the valve-stem to the lead. Apply a templet of thin sheet metal, of the shape of a longitudinal section, through the main valve, in the place of the valve to the valve-seat, so that it will be worked by the valve-stem as the wheels are turned, and mark upon it the points of the V-shaped ports, when the engine is on each centre. Measure from those points toward the centre of the templet an amount which is expected to be lost by elasticity and lost motion, one-eighth of an inch more or less, and those points will be the ends of the lap of the valve. From those points measure again toward the centre of the templet a distance equal to the breadth of the port from the point of the V to its opposite side, and the points thus ascertained will be the ends of the exhaust-cavity. Cut the valve to correspond with the templet thus made, and place it in the chest, and it will have the lead and travel which the drawing requires.

The link, instead of being curved, may be composed of two chords of arcs meeting at the centre, and a rectangular block will work in it, enough clearance being made at the angle of intersection to permit it to pass the centre, and, inasmuch as the link only uses a small portion of its length at each end, and in the centre, to give position to the valves, its other parts may be of irregular form, but a true curve is the best.

In running a locomotive constructed upon this plan, the throttle-valve and pipe, which should have an area of one-tenth of the area of the cylinder all the way to the chests, should be thrown wide open after the engine is fairly started, and the speed of the machine should be regulated entirely by the lever which controls the position of the cut-off, whereby the steam will always be admitted to the cylinder at a pressure very near to that in the boiler, and the greatest range of expansion which the load will permit will at all times be obtained, and consequently the greatest economy of steam will result.

By the use of this improvement the entire theoretical power which steam is capable of producing in a non-condensing engine of a given size, and performing a given work, will be produced in a locomotive-engine, with no deductions except those due to the "clearance," the radiation of heat, and the leakage from imperfect construction, and of the power thus produced much less will be absorbed by friction, when the engine is worked by my valve-gear, because there is no resistance by one piston against the other at each centre, as there is with the "link-motion," and because, there being no shock on the centres, the keys may all be slack, and so there will be no binding of the brasses. The loss by leakage, also, will be much diminished, because the travel of the valve is constant, whereas with the "link-motion" the valve is generally moving with a small travel upon the seat, which it wears down in the middle, and when the travel is increased, as it must be frequently, the valve runs against an elevation left by the reduction of the middle surface of the seat, and the effect is to wear the valve into a curved surface, touching the seat on its centre, and rocking either way. The steam then leaks under the ends of the valve, and is wasted, as may be seen in any "link-motion" engine which has been running a month, by setting the slides in the centre and opening the throttle-valve and cylinder-cocks.

What I claim as my invention, and desire to secure by Letters Patent, is—

1. A reversing-link, vibrated by one eccentric capable of being moved in the direction of its length for reversing, suspended at its neutral point by a radius-bar, or other equivalent device, upon which it vibrates, and

upon the opposite side of which it works the valve for the forward and backward motion of the engine, substantially as described, in combination with an independent cut-off apparatus of any sort, for closing the ports which it opens.

2. An independent cut-off apparatus, adjustable while the engine is in motion, by altering the angular position of the eccentric which works the independent cut-off slide, in reference to the line of the crank, substantially as described.

3. The combination of a pin or block fixed in the main shaft, with a pipe surrounding the main shaft to which the cut-off eccentrics are fixed, and with an exterior sliding-sleeve surrounding the said pipe, provided with two grooves, one of which receives the end of the fixed pin, and the other of which receives a block or pin fixed upon the eccentric-pipe, and one or both of which grooves are spiral, as a device for the purpose of varying the angular position of the cut-off eccentrics upon the main shaft, substantially as described.

4. A graduated opening through the main port or valve, in combination with the exhaust-openings, so arranged as that one exhaust-aperture will be opened before the other closes, and with an independent adjustable cut-off, for the purpose of preventing a "cushion" of the steam and the shock of sudden admission, without "wire-drawing" through the graduated opening in cutting off, substantially as described.

EDW. N. DICKERSON.

Witnesses:
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