(No Model.) 2 Sheets—Sheet 1.

W. M. HENDERSON.

STEAM ENGINE INDICATOR.

No. 528,226. Patented Oct. 30, 1894.

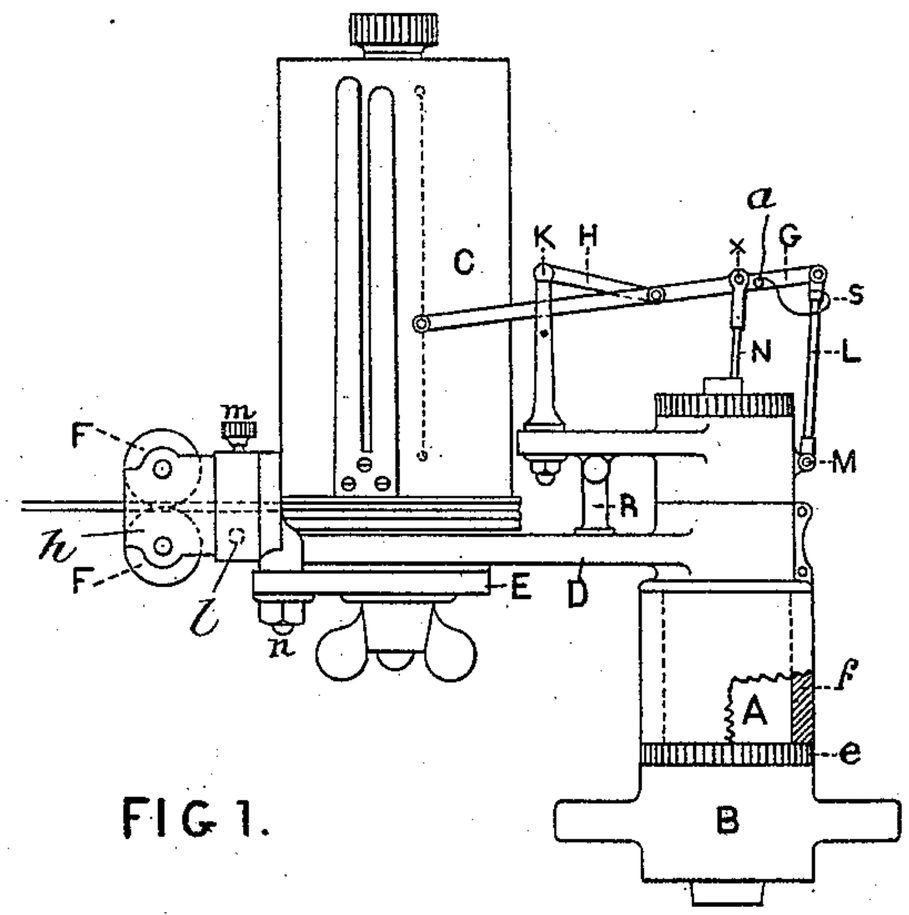


FIG 1.

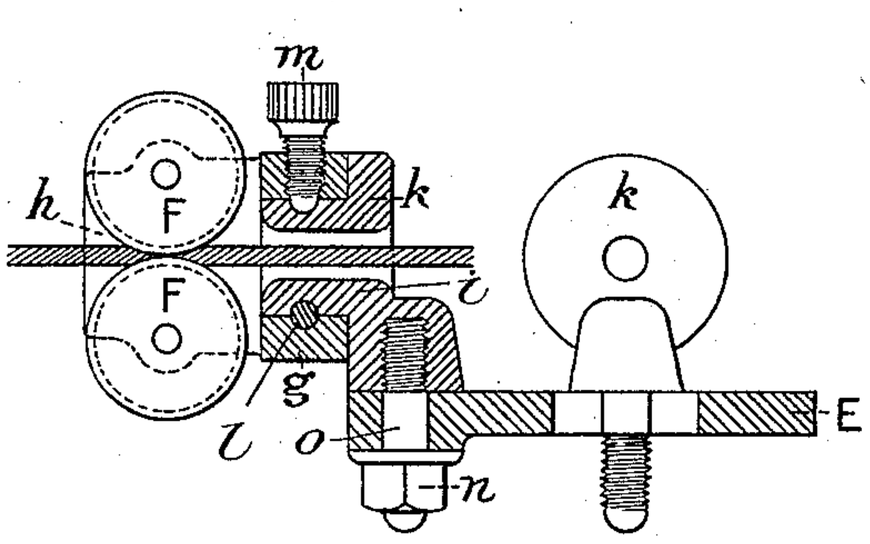
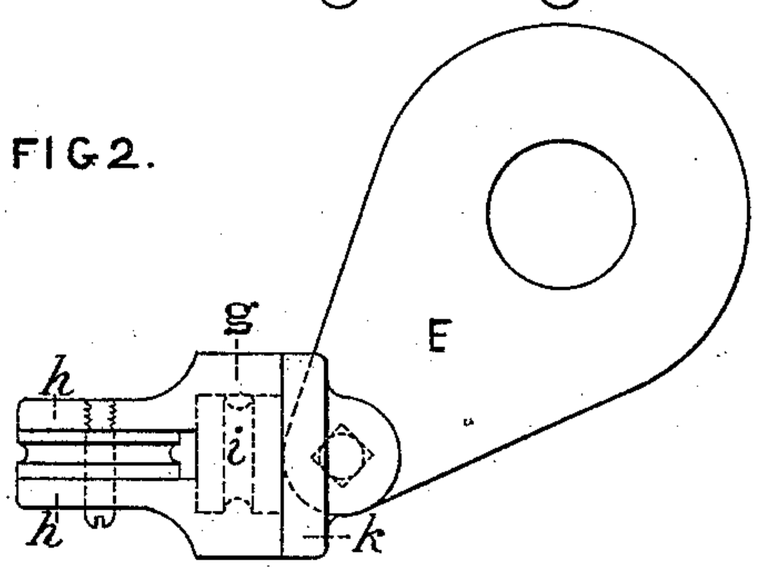


FIG 2.



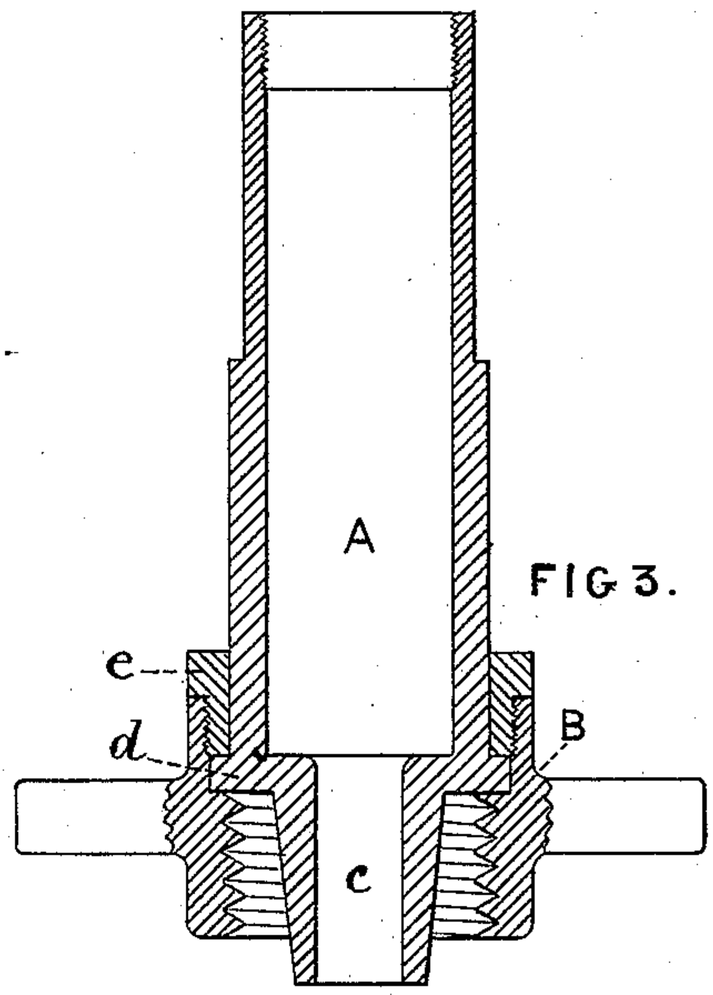


FIG 3.

WITNESSES

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(No Model.) 2 Sheets—Sheet 2.

W. M. HENDERSON.

STEAM ENGINE INDICATOR.

No. 528,226. Patented Oct. 30, 1894.

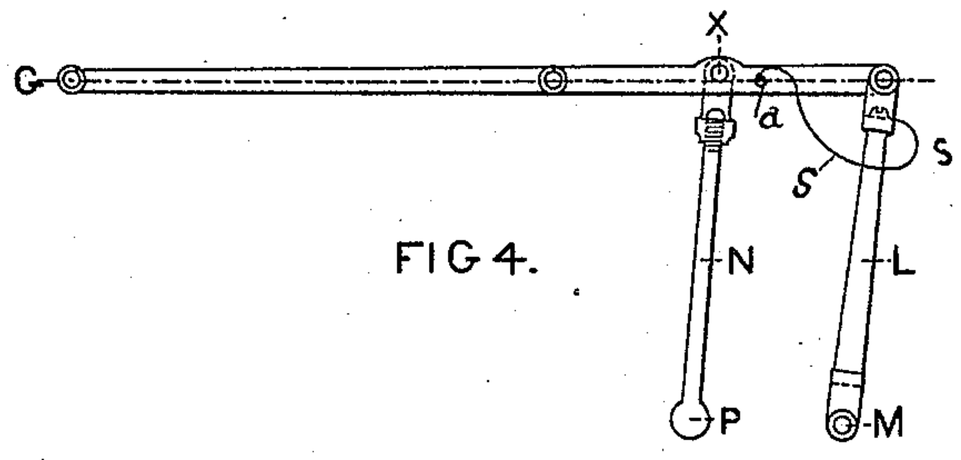


FIG 4.

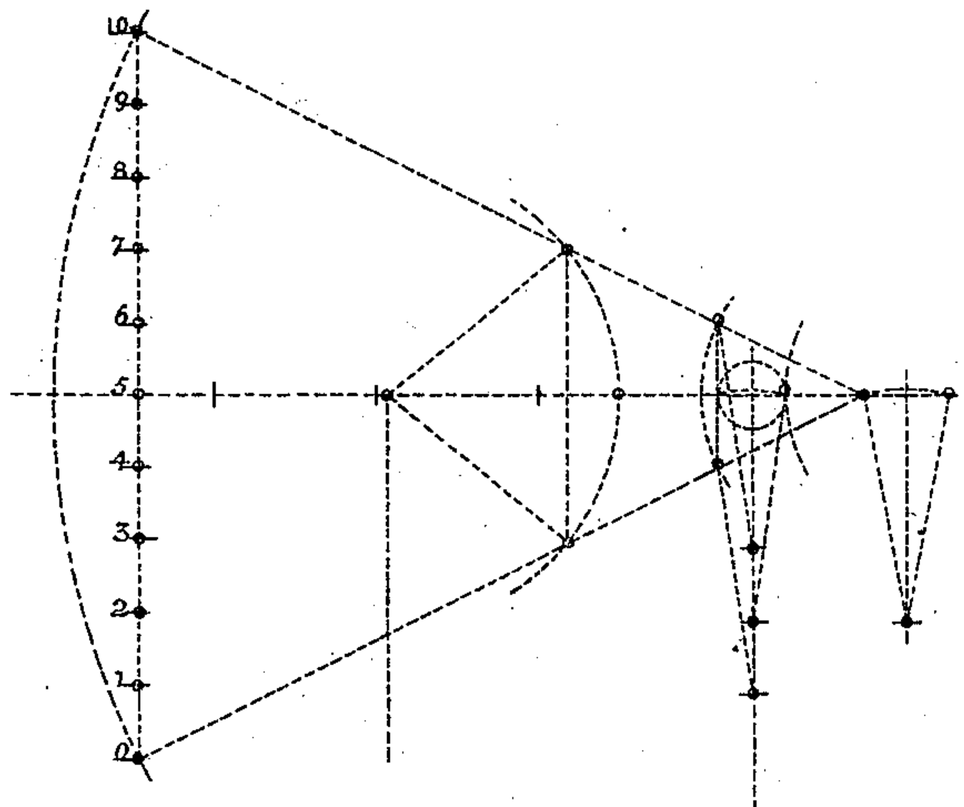
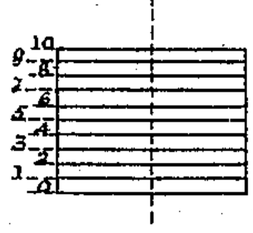


FIG 5.



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UNITED STATES PATENT OFFICE.

WILLIAM M. HENDERSON, OF PHILADELPHIA, PENNSYLVANIA.

STEAM-ENGINE INDICATOR.

SPECIFICATION forming part of Letters Patent No. 528,226, dated October 30, 1894.

Application filed January 3, 1894. Serial No. 495,534. (No model.)

To all whom it may concern:

Be it known that I, WILLIAM M. HENDERSON, residing at Philadelphia, State of Pennsylvania, have invented certain new and useful Improvements in Steam-Engine Indicators, of which the following is a specification.

Figure 1 is an elevation of the indicator with improvements attached; Fig. 2, a sectional elevation, and plan of double leading off pulleys with the end view of standard superimposed on the sectional elevation; Fig. 3, a vertical section of indicator cylinder, showing cock connection; Fig. 4, a pencil arm, showing steadying spring; Fig. 5, a diagram of parallel motion, showing piston and pencil arm graduations.

A is the steam cylinder; B, cock connection; C, paper drum; D, drum base plate; E, pivot plate for leading off pulleys; F, leading off pulleys; G, pencil arm; H, radius car, with fulcrum at K; L, back link, with fulcrum at M; N, connecting rod, with ball joint at P; R, pencil stop.

Ever since Walt invented the parallel motion, it has been known that there was a slight difference in the powers of its range, which however did not impair its usefulness as applied to guiding, in a straight line, the piston rod of a steam engine; but when this device is employed to guide the pencil of a steam engine indicator, not only in a straight line, but that the pencil shall move exactly in time with the piston throughout its full range, the effect of this difference in the powers of its range upon an indicator card, unfortunately produces an untruthful representation of the real state of affairs within the steam engine cylinder, the secret we are seeking to learn.

To correct this defect is the primary object of this invention.

A second improvement consists in providing means for counteracting the disposition of the pencil arm to fling upon steam induction.

A third improvement relates to the manner of forming the swivel cock connection, and a fourth improvement is on a double leading off system of pulleys for the actuating cord, all of which will hereinafter be fully described.

The discrepancy between the indications of the piston, and pencil arm, I have ascertained proceeds from the vibration of the connecting rod, and back link. The distance between the two lines reached by its centers when vertical, is greater than between the two lines reached when slanted to either side of the vibration, by the amount of the versed sine of arc described.

It is a universal custom among engineers to halve the versed sine of vibration on each side of the center line, equalizing the variation on opposite sides to gain the mean effect, splitting the difference as the best remedy to overcome the difficulty. While this may answer in most engineering operations, this interfering with the true path of an indicator arm, causing it to meander five times below, and four times above its correct line, in the operation of taking one diagram, is fatal to correct indicating; for it is evident that supposing it is correct when on the true line, it must be incorrect at all other stages.

As the trouble is brought about by diverging on either side of the true center line, I propose to throw the whole of the versed sine of the arc of vibration of both connecting rod, and back link, above the true center line, as shown by diagram Fig. 5. There would then be three established points when the back link pin would be on that line, up, down, and on the center, and the indicator diagram at those three places would be marked correctly. The effect of the intermediate elongations of the connecting rod N is overcome in this way: As the rod is gradually elongating in approaching the vertical line, the back link pin is also gradually rising with it, nullifying the elongation as it occurs, so that as far as the lengthening out of the connecting rod is concerned, it is absorbed by counteraction of the back pin shifting its center, and holding the pencil point stationary, leaving the movement of the piston to be communicated to the pencil arm unaffected by the angular vibration of the connecting rod.

The peculiarities of this improvement may be thus summarized: It was found by experiment that when the whole of the versed sine of the arc described by the back link was thrown above the true center line, so that the center of the pin would never descend below it, and the whole of the versed sine pertaining to the vibration of the connecting rod

was thrown above the center line of pencil arm, so that the center of the pin *x*, would be above that center line, equal to the versed sine, at half stroke, as shown by the diagram Fig. 5, the ratio of the movement of the pencil arm was practically in unison with the movement of the piston throughout its entire range. The connecting rod N and back link L are preferably of the same length, but the vibration of the connecting rod is less than that of the back link, owing to the obliquity of the angles taken by the pencil arm when up and down. It will further be noticed, that the arc of vibration of the back link, being all above the center line, the pin *x* in the pencil arm is also above the center, on the right side of the line to match it.

Second improvement.—It is well known as a source of considerable trouble, that the inertia communicated from the piston of the indicator to the pencil arm, by the sudden steam induction, when the engine is taking steam, often throws the pencil arm above the actual steam line of pressure. In some cases as much as twenty per cent. of the scale of the spring, above the line it should mark has been recorded, even by the best instruments of the day. To overcome this disposition to fling, I apply a finely tensioned spring (*s*) to the pencil arm as shown on Figs. 1 and 4, which has the steadying effect desired.

This spring is preferably an elongated spring, one end secured to the back link, and the other end reaching out, and secured to a pin (*a*) on the pencil arm, close to the junction of the connecting rod. The back link and connecting rod vibrate together, carrying the spring in effect between them. The sole duty of this spring is to prevent the pencil arm from undue flinging, and its stiffness is calculated only to that end. Above the center line, throwing upward, the spring resists the rising, by accumulating tension. Below the center line, throwing downward, the action of the spring is reversed, and rendered almost *nil*, as a glance, at its outline will indicate, thus meeting the peculiar wants of the case.

Third improvement.—In nearly all the indicators made it is usual to screw the cock connection either directly into the cylinder, or into an outer shell, sometimes screwing into the cylinder, and then screwing the cylinder into the shell. In some cases double threads are used, the nut screwing on and off one set of threads during the operation of coupling and uncoupling on the other, requiring extra care in manipulation. On high speed engines the first mentioned screw connections are apt to shake loose, and cause trouble which I desire to avoid. The manner in which I accomplish this will be seen by reference to Fig. 3. A is a vertical section of the cylinder with the cock connecting cone (*c*) all in one piece, including a collar (*d*). The nut B is chased at its lower end to fit the thread of the indicator cock, and a fine thread is chased for a short depth at the upper end down to the collar. A gland (*e*) is chased to screw into this recess, and bored to slip on the outside of the cylinder. This gland has a milled head, see Fig. 1, to screw into position in coupling up the nut, a special spanner being used for the purpose. When all together we have a perfect swivel nut, leaving the cylinder intact without any threads cut whatever. The working part of the cylinder is incased in a jacket of hard wood, rubber, or other non-conducting material, as shown at *f*, Fig. 1, which not only prevents radiation or loss of heat from the cylinder, but also permits the handling of the instrument without burning the fingers as is usual with indicators as now made.

Fourth improvement.—Fig. 2 shows the improved double leading off pulleys for guiding the actuating cord in any radial direction. The device is mounted on a pivot plate E, as usual in all indicators, and is capable of rotating round the drum, completing a circuit of about one hundred and eighty degrees. Two grooved pulleys F, F, are mounted on a circular shell, or sleeve *g*, having brackets (*h*) projecting to receive the axes of the pulleys, and still further projecting as a shrouding to the outer rim of the pulleys, for guiding the cord straight to the grooves on the pulleys. The peripheries are made to touch, or nearly touch each other. The double grooves form a circular hole for the cord to pass through, rendering it impossible for the cord to get astray, as is the case where only a single pulley is used. The sleeve *g*, is bored out, and fits on a boss or button (*i*) turned on the face of the standard (*k*). A semicircular groove is turned on the button, and a hole, corresponding to the groove, is drilled through the sleeve, in which a steel pin *l* is inserted, holding the pulley sleeve in position, and permitting it to rotate on the button. A set screw (*m*) is tapped through the sleeve, opposite the pin, with a rounded point fitting the groove, by which the pulleys can be secured in any position all round the circumference; but it will be noticed with this arrangement, one half turn is all that is required to encompass the full circle; for the one pulley will sweep through one hundred and eighty degrees, while the other is performing the same duty for the remaining one hundred and eighty degrees. The standard (*k*) has a stud *o* screwed into it, with a square below, fitting into a rectangular hole in the pivot plate E, where it is firmly secured in position by the nut (*n*) tangentially to the line of drum cord.

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

1. In a steam engine indicator, as a means to equalize the motion of the pencil to the motion of the piston, the combination of the connecting rod, pencil arm and back link, so arranged that the chord of the arc of vibration of the back link shall be coincident with the center line of the pencil arm at half

stroke, the pin x of the connecting rod being fixed above the center line of the pencil arm to match the rise of the arc of vibration, substantially as and for the purpose shown and described.

2. In a steam engine indicator, as a means to steady the throw of the pencil arm, in combination with the connecting rod, pencil arm, and back link, the spring S embraced between and moving with the back link and pencil arm, substantially as shown and described.

3. In a steam engine indicator, in combination with the cone c, and collar d, of the steam cylinder A, the nut B with screwed gland e for making a permanent swivel connection, substantially as shown and described.

4. In a steam engine indicator, in combination with the paper drum C, and pivot plate E, the two grooved pulleys F, F, mounted on shrouded bracket h of sleeve g, rotating upon boss i, laterally projecting from standard k, held in circular path by semicircular groove and pin o, and having a clamping screw m, substantially as shown and described.

5. In a steam engine indicator, in combination with paper drum C, and pivot plate E, the pulley bracket sleeve g rotating upon boss i laterally projecting from standard k, and provided with a semicircular groove and pin l, substantially as shown and described.

6. In a steam engine indicator, in combination with paper drum C, and pivot plate E, the pulley bracket sleeve g rotating upon boss i, laterally projecting from standard k, and provided with a semicircular groove and screw m, substantially as shown and described.

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SIDNEY S. EMERY.