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APPARATUS FOR SETTING OUT THE SLIDE-VALVES OF STEAM-
ENGINES.

No. 176,461.

Patented April 25, 1876.

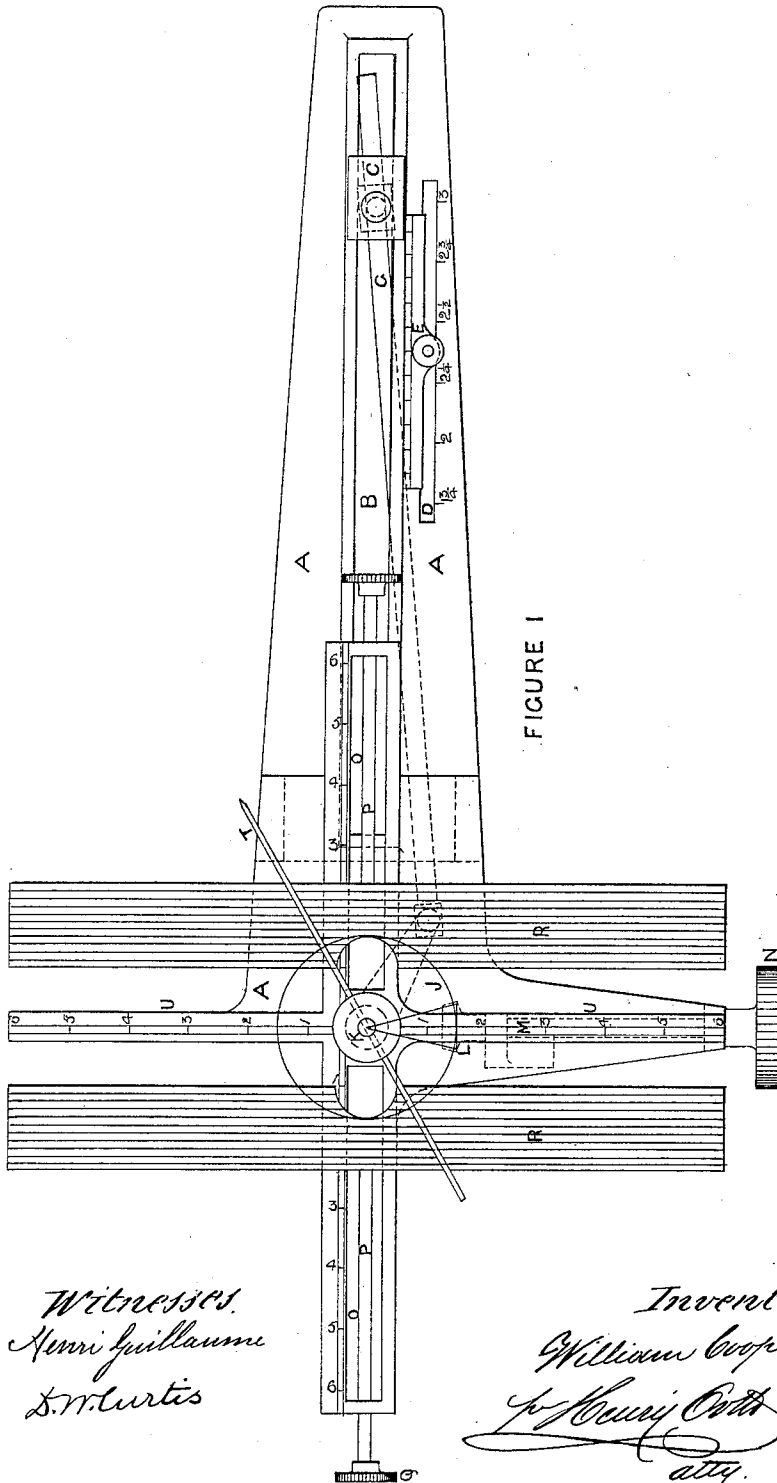


FIGURE 1

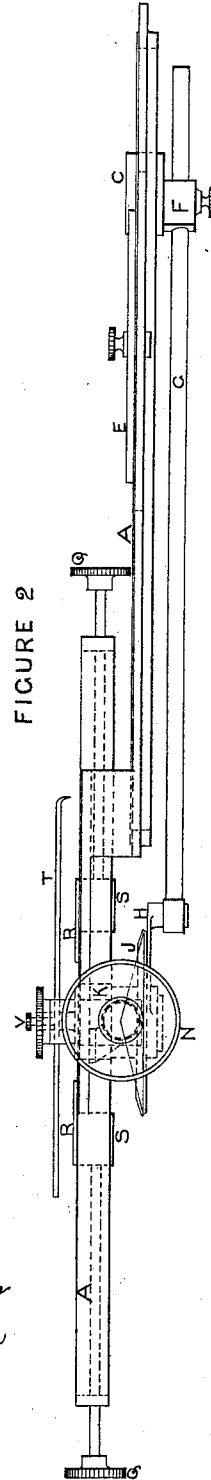


FIGURE 2

Witnesses
Henri Guillaume
L. M. Curtis

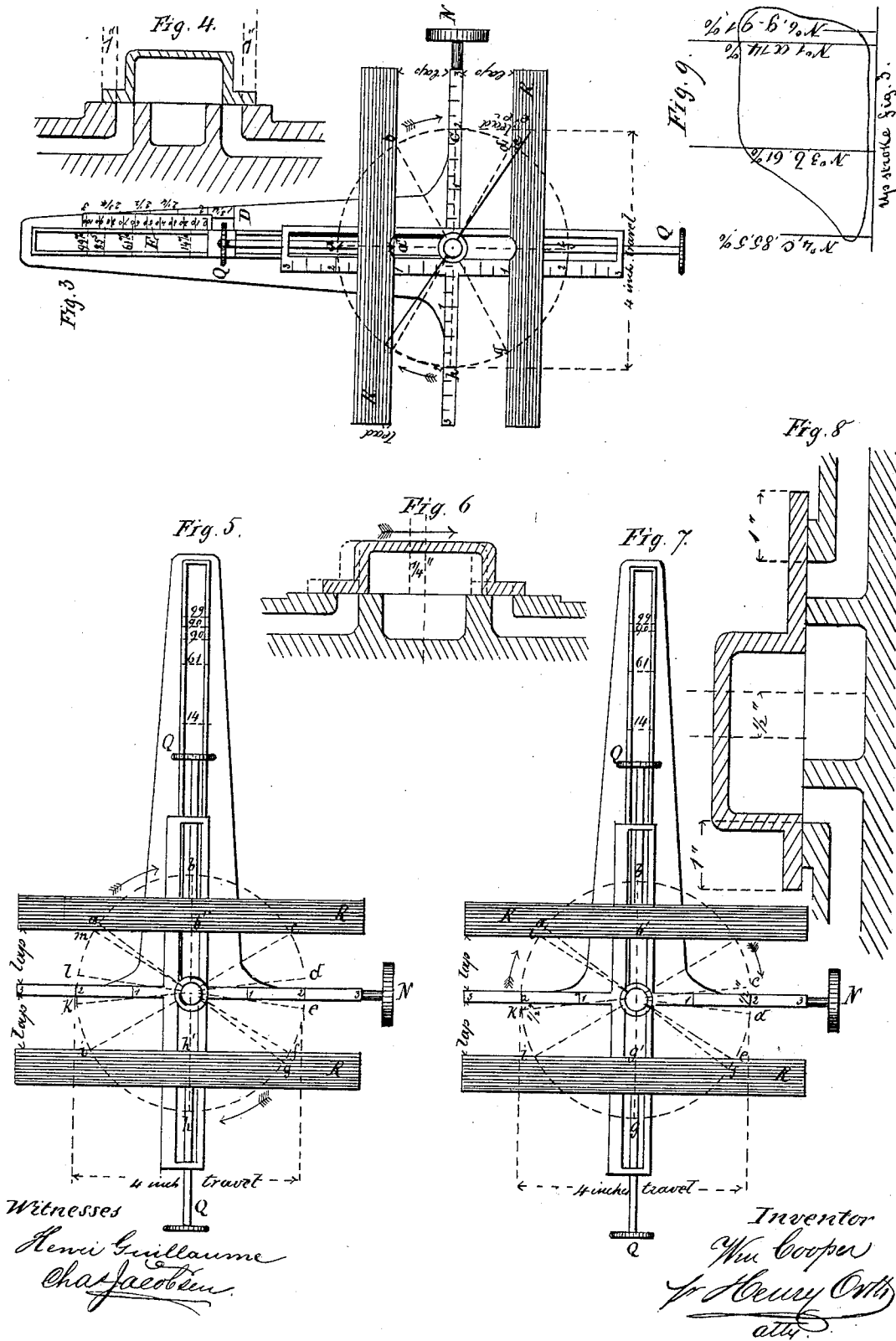
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UNITED STATES PATENT OFFICE.

WILLIAM COOPER, OF NORTH SHIELDS, ENGLAND.

IMPROVEMENT IN APPARATUS FOR SETTING OUT THE SLIDE-VALVES OF STEAM-ENGINES.

Specification forming part of Letters Patent No. **176,461**, dated April 25, 1876; application filed December 30, 1875.

To all whom it may concern:

Be it known that I, WILLIAM COOPER, of North Shields, in the county of Northumberland, England, engineer, a subject of the Queen of Great Britain, have invented or discovered new and useful Improvements in Apparatus to be used for Setting Out the Slide-Valves of Steam-Engines, and for indicating the working of such valves; and I, the said WILLIAM COOPER, do hereby declare the nature of the said invention, and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement thereof—that is to say:

My invention of improvements in apparatus to be used for setting out the slide-valves of steam-engines, and for indicating the working of such valves, consists of a frame-work and various moving parts corresponding to the parts of steam-engine slide-valves and connections, each part being capable of independent adjustment and motion. From their individual and united action sufficient data may be experimentally obtained for setting out slide-valves of new engines, and if the apparatus be applied to engines already at work their whole action may be readily shown.

The frame, which is made of brass or other suitable metal, is in shape similar to an inverted cross, having three vertical slots. The slot at the long end of the cross acts as a guide for a sliding block, which corresponds in its action to the piston of a steam-engine cylinder. Another and smaller slot runs parallel with the first, and is graduated on one side, so that an adjustable slide moving in this slot may be readily fixed at any required point corresponding to the relative length of the connecting-rod to the stroke of the piston. Fixed to the piston-block by a swivel-coupling is a rod, circular or other shape, in section, which may be varied in length. The other end of the rod works on a crank-pin fixed to a bevel-wheel, from which it receives motion similar to the connecting-rod of an engine, the bevel-wheel revolving on a center stud. Gearing into the bevel-wheel is a small pinion, fixed to a shaft running in bearings under the frame, and actuated by a milled wheel.

The remaining slot carries two rods—one at each end, the outer end of each rod having a

milled knob. Across the slots are transverse plates, one on each side of the center stud, and connected to the rods by means of a sliding block. These plates are termed lap and lead plates, and are marked on their upper surfaces with equidistant parallel lines, by which a pointer passing through the center stud may be adjusted according to the required lead of the valve. The side of the slot is graduated in each direction from the center, so that each plate by means of its milled knob may be fixed in the required position for the proposed lap of the valve.

The cross-arms of the frame are also graduated each way from the center for the purpose of adjusting the length of the pointer, which has to correspond with half the travel of the valve. The pointer being set to the required length, and the plates to the proposed lap, on turning the large milled wheel the pointer indicates the position of the valve at any part of the stroke, the piston-block at the same time indicating, by the graduated adjustable slide, the percentage of travel of the piston at any position of the valve.

And in order that my invention may be better understood, and more easily carried into operation, I will now proceed to describe the sheet of drawings hereunto annexed, similar letters having reference to similar parts in the two views.

Figure 1 is a plan looking on the top of the instrument. Fig. 2 is a side elevation. Figs. 3, 4, 5, 6, 7, and 8 are diagrams of the instrument and of various slide-valves, serving to illustrate the operation of said instrument; and Fig. 9 represents an indicator-diagram.

A A is the frame-work, carrying the various moving parts. B is a long slot in which slides the slide-block C, corresponding to the piston of the cylinder. D is a small slot parallel with the long slot, and graduated on one side, giving various lengths of connecting-rod relative to the length of the stroke. E is an adjustable graduated slide, on which may be read off the various positions of the piston or slide-block. F is a swivel-coupling for fixing in any required position the connecting-rod G. H is a crank-pin for giving motion to the connecting-rod, and is fixed to the bevel-wheel J. K is a center stud carrying the bevel-wheel.

L is a bevel-pinion, gearing into and driving the bevel-wheel. M is the pinion-shaft, worked by the milled wheel N. O is a center slot, in which are placed two rods and sliding blocks, P P, and worked by small milled knobs Q Q. R R are transverse sliding plates to indicate the lap and lead of the valve. They are worked by the rods P P, fixed to the sliding blocks S S. T is a sliding pointer, fixed in position by the small screw V. U U are cross-arms, graduated for adjusting the length of the pointer.

From what has been said above, any one acquainted with the slide-valve and its office will readily understand the operation of the instrument; but that those slightly acquainted with the subject may be enabled to ascertain its mode of working, I will proceed to explain the same in detail by aid of the diagrams shown on Sheet 2 of the accompanying drawings, on which I have indicated the preparatory or first position of the moving parts in full lines, and their various subsequent positions in dotted lines, marked with the necessary letters of reference, required for the full explanation of the movements of the indicator and piston.

It will, however, be necessary first to indicate what information the instrument will give, viz: First, how far the piston has traveled when the steam-port is full open; second, the width of the steam-port opened—that is, in the same direction as the valve's motion—and how much this varies by using the reversing-link as a means of expansion; third, what point in the stroke the valve closes, cutting off the steam, and expansion begins; fourth, what point of the stroke expansion ceases by the opening of the steam-port to the exhaust; fifth, what portion of the stroke has been completed under the expansive action of the steam; sixth, the point in the stroke when the exhaust-port closes and compression begins; seventh, the portion of the stroke performed against the compressive action of the steam; eighth, the point in the stroke where the steam-port is opened by lead before the piston completes its stroke and steam is admitted in opposition to it and compression ceases; ninth, the portion of the stroke performed against the steam admitted by lead; tenth, the lead having been either assumed or taken from an existing engine for one end of the cylinder the instrument will give it at the other end; eleventh, when used in connection with indicator-diagrams from the cylinder, the whole or any of the above data may be marked thereon, thus insuring a correct diagram, as it will show at once if it has been tampered with to please the eye; twelfth, it will also show the effects of various lengths of connecting-rods in cutting off the steam, &c., and that the admission, cut-off, &c., for the upstroke is quite different to the downstroke, and that the difference varies with the length of the connecting-rod, and one valve may thus be com-

pared in all the foregoing essential points with another in a few minutes.

The size of cylinder, stroke of piston, whether single or double ported valve, length of connecting-rod in units of the stroke, stroke of the slide-valve, the lap, the lead at top and bottom, the inside lap or lead, or the unequal lap or lead, and the way the engine has to run, either with or against the sun, being assumed for setting out slide-valves, or known or taken from an existing engine for verification or comparison; also, whether the engine is to be or is fitted with a reversing-link, and whether such is to be or is used as an expansion gear, in which case the valve must be measured with the link in different positions, as required in working expansively. With these data known or assumed, the operation of the apparatus for obtaining the above-recited information is as follows: The instrument being in the position shown in Fig. 3, I will now give example 1, Figs. 3 and 4: A slide-valve with four-inch travel, one inch lap at each end, one-fourth inch lead at the bottom, (edge nearest the crank-shaft,) length of connecting-rod two strokes, neither inside lap nor lead. (This valve is shown by diagram, Figs. 4.)

I may here observe that the instrument always supposes single ports, and if double the width of port opening and lead as given must be doubled.

The device being held as shown in Figs. 1, 5, and 7, the crank being at the bottom center, and traveling in the direction of the arrow, the sliding-scale E is moved until its zero-mark is opposite No. 2 on the fixed scale of the frame—that is to say, two strokes. The top of the sliding block, representing piston, is then moved to coincide with the bottom zero of scale E, (relative length of connecting-rod two strokes.) The lap and lead plates R are each moved one inch from the center or zero-mark of their respective scales by means of the rods P and milled knobs Q Q, indicating one inch lap. The needle or pointer is then set with its point at Fig. 2 on the left horizontal scale, indicating one-half travel of valve, the point thereof, being then turned upward, (without, however, moving the crank,) passed the edge of the upper lead plate R one-fourth of an inch, indicating the lead, the point of the indicator being now in the same relative position to the crank as the center of an eccentric sheave would be. The apparatus is now in position to operate.

Turn the milled wheel N until the needle is in a vertical position at *a*; the position of the piston on scale E will indicate fourteen per cent. of the stroke, as answer to information paragraph 1. Then measure from the zero-edge of the lead-plate (upper) R to the point of the indicator, the distance being indicated by *a a'*, which you will find to be one inch, as answer to paragraph No. 2. If, now, the motion be continued until the point of the indicator reaches *b*, and the reading taken

from scale E, sixty-one per cent. of the stroke will be indicated by the piston, as answer to paragraph 3. The needle is then moved until its point is at *c*. In this case the valve is at its midstroke and opens the port to the exhaust, closing at the same time the port on the other side to the exhaust, and compression begins. The piston will then indicate 85.5 per cent. of the stroke, as an answer to paragraphs Nos. 4 and 6. When the point of the indicator has reached the point *d* the piston will indicate 99 per cent. of the stroke, which will be the answer to paragraph No. 8. The upstroke is now finished by turning the wheel until the crank is at the top center. The indicator will now stand at *e*, or nine thirty-seconds of an inch lead, to be entered under the head of downstroke.

Of course, it will be understood that the readings for the up and down strokes are entered under their respective heads. The above operation is repeated, and by subtracting the amount of paragraph No. 3 from that of No. 4, an answer to No. 5 is obtained, viz: $85.5 - 61 = 24.5$. Subtracting No. 6 from No. 8, $99 - 85.5 = 13.5$ per cent., an answer to No. 7; and, finally, subtracting No. 8 from unity, $1 - .99 = .01$ the answer to paragraph No. 9 of the information desired. Therefore, we have the following tables for the upstroke and downstroke, the paragraphs of information being given by their respective numbers.

Piston making upstroke—lead one-fourth inch:

No. 1,	<i>a</i>	.14 per cent. of stroke.
No. 2,	<i>a a'</i>	1 inch.
No. 3,	<i>b</i>	.61 per cent. of stroke.
No. 4,	<i>c</i>	.855 " "
No. 5,	<i>c - b</i>	.245 " "
No. 6,	<i>c</i>	.855 " "
No. 7,	<i>c - d</i>	.135 " "
No. 8,	<i>d</i>	.99 " "
No. 9,	$1 - d$	1 " "

Piston making downstroke—nine thirty-seconds of an inch lead:

No. 1,	<i>e</i>	.21 per cent. of stroke.
No. 2,	<i>e' e''</i>	1 inch.
No. 3,	<i>f</i>	.72 per cent. of stroke.
No. 4,	<i>g</i>	.91 " "
No. 5,	<i>f - g</i>	.19 " "
No. 6,	<i>g</i>	.91 " "
No. 7,	<i>h - g</i>	.085 " "
No. 8,	<i>h</i>	.995 " "
No. 9,	$1 - h$	.005 " "

Example No. 2, diagram figures 5 and 6:

In this case the valve is to have four inches travel, one inch lap, one-fourth inch lead at the bottom and connecting-rod, two strokes in length, with one-fourth inch inside lap at both ends.

When this valve is at midstroke both steam-ports are closed to the exhaust-port by an amount equal to the inside lap—that is to say, one-fourth of an inch. If, during the upstroke of the piston its motion were stopped when the valve has assumed the position shown by dotted lines (and its motion by the

arrow) we observe that the top steam-port is now closed to the exhaust, and the valve has one-fourth of an inch to travel before reaching the center of its stroke. Therefore take the readings *b b' c*, and allow the needle to approach the central line within one-fourth of an inch, when it will be at *d*. Take the reading No. 6; then if we continue the piston's motion during the time it takes the slide-valve to travel one-half of an inch from its former position, we find that the valve is now one-fourth of an inch past the middle of its stroke, and which would put it in such a position that the bottom steam-port would be opening to the exhaust-port. Therefore, when the needle has passed the central line by a distance equal to the inside lap it will be at *e*, which will give the answer to No. 4, and proceed in the usual way, finishing the stroke, and, proceeding with the downstroke, taking the reading No. 6 from K and No. 4 from *l*, finish the stroke, and make the usual subtractions, when the following will be obtained:

Piston making upstroke—one-fourth of an inch lead:

No. 1,	<i>b</i>	.14 per cent. of stroke.
No. 2,	<i>b b'</i>	1 inch.
No. 3,	<i>c</i>	.61 per cent. of stroke.
No. 4,	<i>e</i>	.90 " "
No. 5,	<i>e - c</i>	.29 " "
No. 6,	<i>d</i>	.805 " "
No. 7,	<i>f - d</i>	.185 " "
No. 8,	<i>f</i>	.99 " "
No. 9,	$1 - f$	.01 " "

Piston making downstroke—nine thirty-seconds of an inch lead:

No. 1,	<i>h</i>	.21 per cent. of stroke.
No. 2,	<i>h h'</i>	1 inch.
No. 3,	<i>i</i>	.727 per cent. of stroke.
No. 4,	<i>l</i>	.935 " "
No. 5,	<i>l - i</i>	.208 " "
No. 6,	<i>k</i>	.87 " "
No. 7,	<i>m - k</i>	.125 " "
No. 8,	<i>m</i>	.995 " "
No. 9,	$1 - m$	.005 " "

Example 3, diagrams Figs. 7 and 8: Valve, four-inch travel; lead on bottom, one-fourth of inch; outside lap at the bottom edge of valve, (admitting steam to end of cylinder nearest the crank-shaft,) one and one-half inch; and on top one-half inch, neither inside lap nor lead, and the length of the connecting-rod two strokes. First add the two laps together, viz., $1\frac{1}{2} + \frac{1}{2} = 2$ inches. Divide this by 2, to take a mean, which gives one inch lap. Proceed to set the instrument as in the first example, but note Fig. 5, which shows the valve lifted up, having now equal laps outside, but the center of the valve is higher than the center of the exhaust-port by an amount equal to the distance the valve was lifted. At the same time the top steam-port is open and the bottom one is closed to the exhaust by the same amount, viz., one-half an inch. Therefore, when the piston is making the upstroke, the valve will be late in exhausting, and, of course, at the same time will close the top port

to the exhaust, causing compression, and on the downstroke will be correspondingly early. Having set the instrument, proceed until the indicator comes to d , when it will be past the horizontal central line one-half an inch; take the reading No. 4 and enter same for No. 6, and bear in mind that the exhaust will be early for the downstroke. Therefore, when the needle is at K , take the reading for Nos. 4 and 6, continue until the revolution is finished and the readings noted, make the subtractions, and the following will be obtained:

Piston making upstroke—lead one-fourth of an inch:

No. 1,	b	.14	per cent. of stroke.
No. 2,	b'	1	inch.
No. 3,	c	.61	per cent. of stroke.
No. 4,	d	.94	" "
No. 5,	$d-c$	.33	" "
No. 6,	d	.94	" "
No. 7,	$e-d$	.05	" "
No. 8,	e	.99	" "
No. 9,	$1-e$	.01	" "

Piston making downstroke—lead nine thirty-seconds of an inch:

No. 1,	g	.21	per cent. of stroke.
No. 2,	s	1	inch.
No. 3,	i	.71	per cent. of stroke.
No. 4,	k	.83	" "
No. 5,	$k-i$	.12	" "
No. 6,	k	.83	" "
No. 7,	$l-k$	.025	" "
No. 8,	l	.995	" "
No. 9,	$1-l$	.005	" "

For engines with link-motion used as a means of expansion, it is necessary only to obtain the stroke of the valve, using the lap and lead, proceeding as in any of the foregoing examples, according to the nature of the valves.

The following table will give the values for the valves of example 1, but the stroke shortened by using the link for expanding the steam. Travel of valve, three inches; lap at each end, one inch; lead at bottom, one-fourth inch; connecting-rod, two strokes in length, neither inside lap nor lead.

Upstroke—one-fourth of an inch lead:

No. 1,	a	.6	per cent. of stroke.
No. 2,	a'	$\frac{1}{2}$	an inch.
No. 3,	b	.35	per cent. of stroke.
No. 4,	c	.72	" "
No. 5,	$c-b$	.37	" "
No. 6,	c	.72	" "
No. 7,	$c-d$	.255	" "
No. 8,	d	.975	" "
No. 9,	$1-d$	.025	" "

Downstroke—one-fourth of an inch full:

No. 1,	e	.9	per cent. of stroke.
No. 2,	$e e'$	$\frac{1}{2}$	of an inch.
No. 3,	f	.475	per cent. of stroke.
No. 4,	g	.81	" "
No. 5,	$f-g$	.335	" "
No. 6,	g	.81	" "
No. 7,	$h-g$	.175	" "
No. 8,	h	.985	" "
No. 9,	$1-h$	.015	" "

By comparing the above with the table ob-

tained with the value in example No. 1, the various points of interest and their differences may be noted, thus showing the evil effects of using the reversing-link as expansion-gear.

I have also shown, Fig. 9, an indicator-diagram from an engine, as in example 1, with the various points marked on it. I may here remark that a perfect engine-indicator would take a diagram showing the steam-line on one side of the piston, and also the exhaust-line drawn by the indicator being in communication with the opposite side of the piston at the same time. Thus we should have the true work done of each stroke. Instead of that, the indicator-diagram shows the ingress and egress of the steam from one side of the piston only. Therefore, in using the slide-valve indicator, the exhaust and compression readings must be changed, No. 6 of the upstroke must be marked on the indicator-diagram showing the downstroke, and the reading for the downstroke marked on the upstroke-diagram.

Many more examples may be given, though the above will suffice to illustrate the working of the instrument, so that it may be employed for any desired slide-valve.

It is evident that by means of the apparatus the whole of the details of the working of slide-valves may be obtained in a few minutes, and there is no problem connected with the slide-valve that may not be readily solved. The instrument will also greatly assist in setting out new slide-valves by assuming the data as above stated, when each new combination may be tried to obtain the most suitable proportions for a valve to work under certain given conditions. Thus the instrument will supersede the use of full-sized models, either permanently or more roughly constructed, for the use of the drawing office, while, at the same time, it supplies managers and engineers, and others interested in the economical use of steam, with a portable instrument which combines accuracy with celerity.

Having now described and ascertained the nature of my invention, and how the same is to be carried into practical operation, I would have it understood that what I claim, and desire to secure by the hereinbefore in part recited Letters Patent, is—

1. An instrument for ascertaining the working of or setting out slide-valves for steam-engines, consisting essentially of a mechanism having a motion similar to the piston and its connections of a steam-engine, imparted thereto by suitable gearing, a fixed and an adjustable scale to determine the length of the connecting-rod and its ratio of travel in relation to that of the slide-valve, adjustable graduated plates and a suitable scale to set the instrument to the required or assumed lap and lead of the valve, and an indicator and suitable scale to determine the stroke or travel of the valve, all mounted on a suitable frame, and operating substantially as described.

2. The connecting-rod and sliding block and the swivel block F, operated so that their movements shall correspond to the movements of a piston and its connections, in combination with the adjustable scale E and fixed scale D of the frame A, for adjusting the relative length of the connecting-rod to the stroke of a piston-rod, and for ascertaining the position of such piston-rod at any point of its stroke, substantially in the manner and for the purposes specified.

3. The combination of the connecting-rod and sliding block with the bevel-wheel J, pinion L, and its shaft M, carrying a milled wheel, N, the adjustable scale E, and the slot-scale D and frame A, when constructed and combined to operate substantially as and for the purposes specified.

4. The combination of the adjustable lap and lead plates R, operating as described, with the graduated scale of the slot O of the frame, for adjusting said plates to the proposed lap of the valve, substantially as described, for the purpose specified.

5. The adjustable lap and lead plates R, having equidistant parallel lines formed on the faces, and the adjustable pointer or indicator T, operated as described, for adjusting

the latter to the desired lead of a valve, in the manner substantially as specified.

6. The adjustable pointer or indicator, operated as described, in combination with the graduated scales of the cross-arms U of the frame, for adjusting the length of the pointer relatively to the travel of the valve, in the manner substantially as specified.

7. The frame A, having slots B D O, the latter two of which are provided with graduated scales, the graduated cross-arms U, the center stud K, and adjustable graduated scale E, in combination with the lap and lead plates R R, the pointer T, and the operating mechanism, constructed and operating together in the manner substantially as described, for the purpose specified.

8. The combination of the adjustable lap and lead plates with the adjustable pointer, the graduated scales on the cross-arms U, the slots O, and the operating mechanism, substantially as described, for the purpose specified.

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Witnesses:

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