Oct. 28, 1941. L. B. JONES 2,260,458

LOCOMOTIVE STEAM DISTRIBUTION SYSTEM

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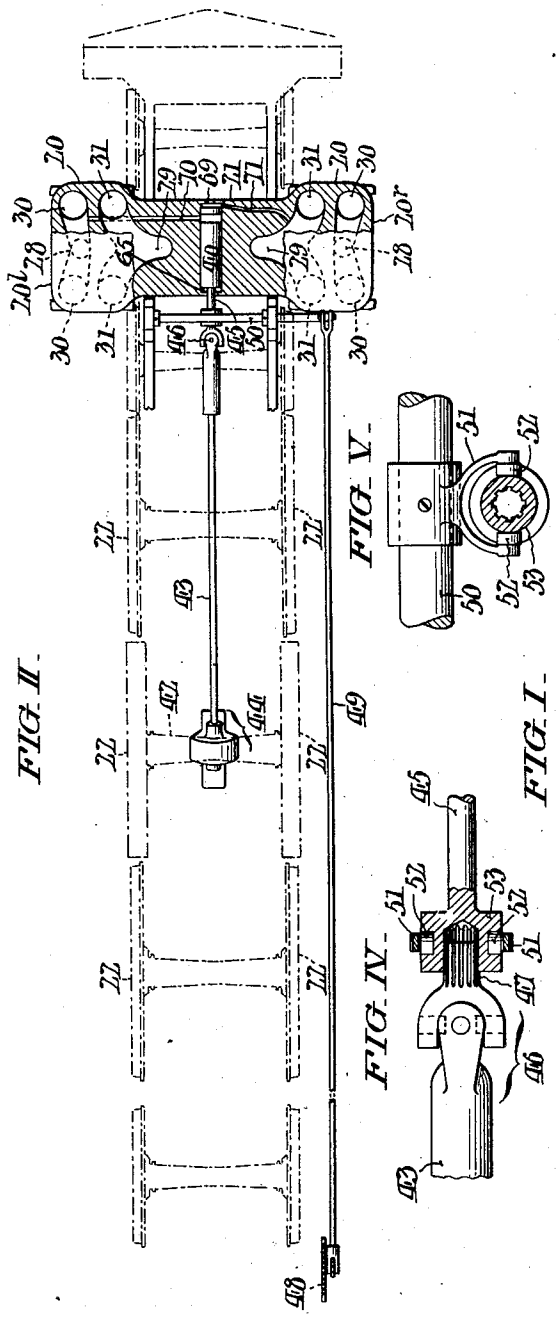


FIG. II.



FIG. V.



FIG. IV.

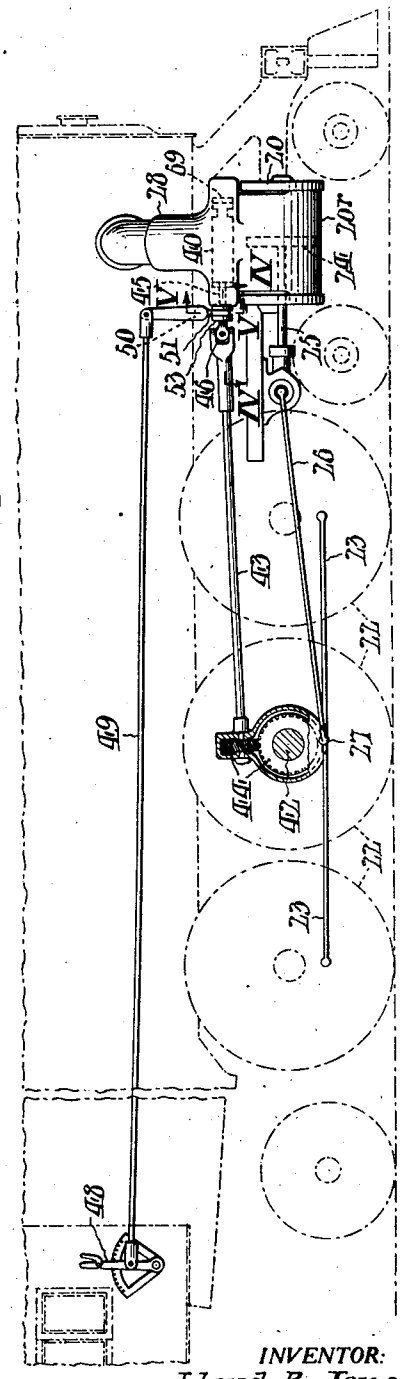


FIG. I.

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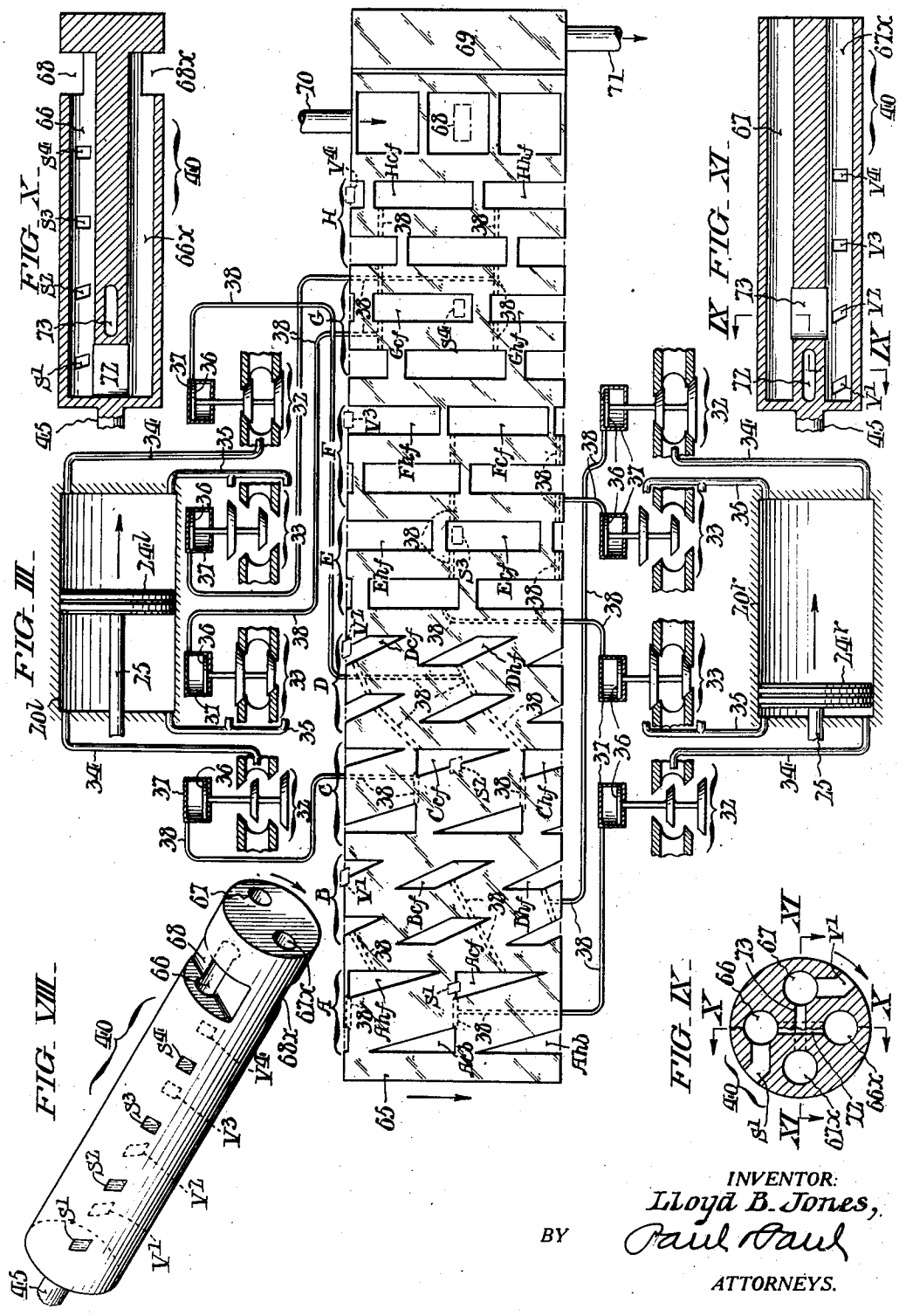
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LOCOMOTIVE STEAM DISTRIBUTION SYSTEM

Filed Jan. 28, 1939 5 Sheets-Sheet 2



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LOCOMOTIVE STEAM DISTRIBUTION SYSTEM

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FIG. VII.

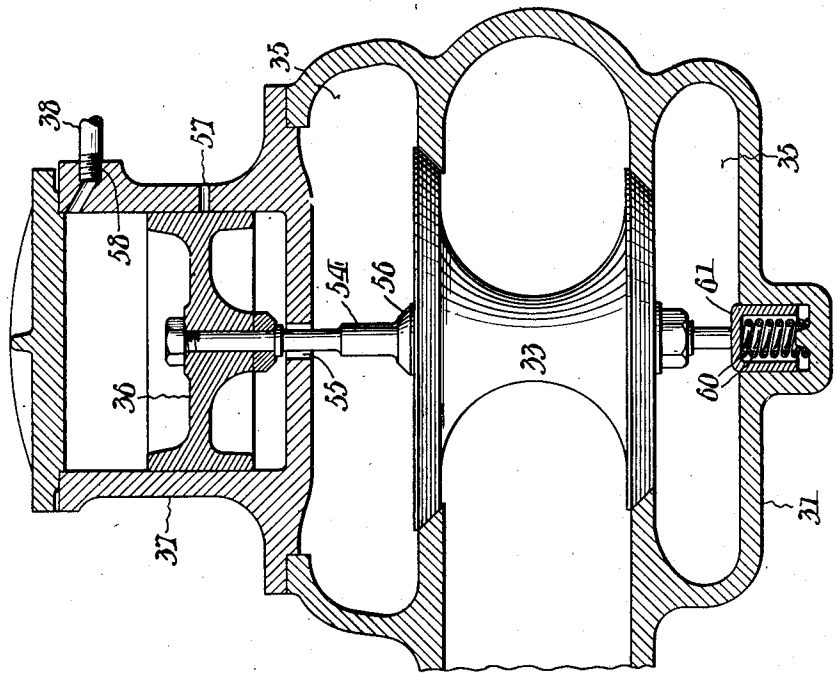
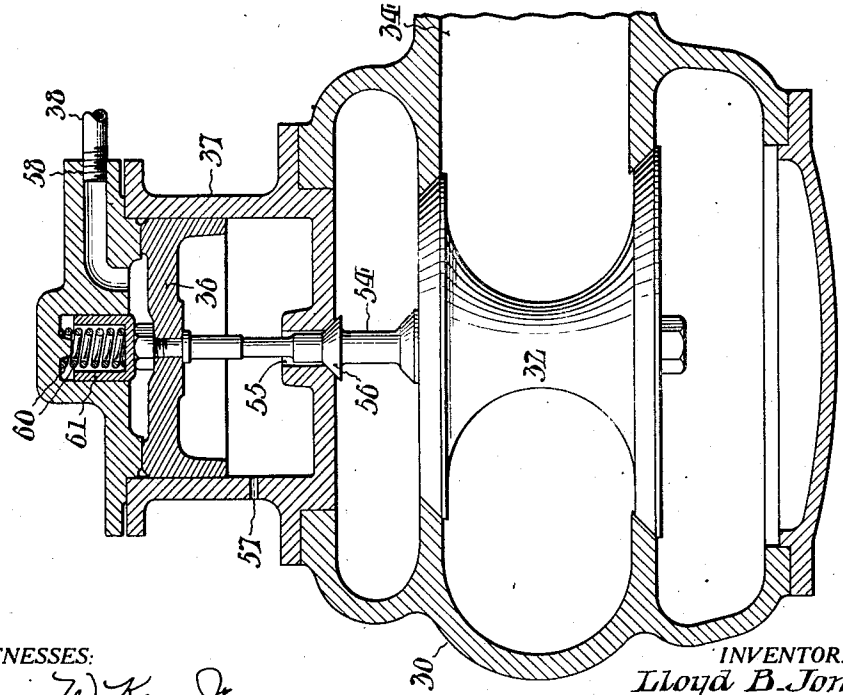



FIG. VI.




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LOCOMOTIVE STEAM DISTRIBUTION SYSTEM

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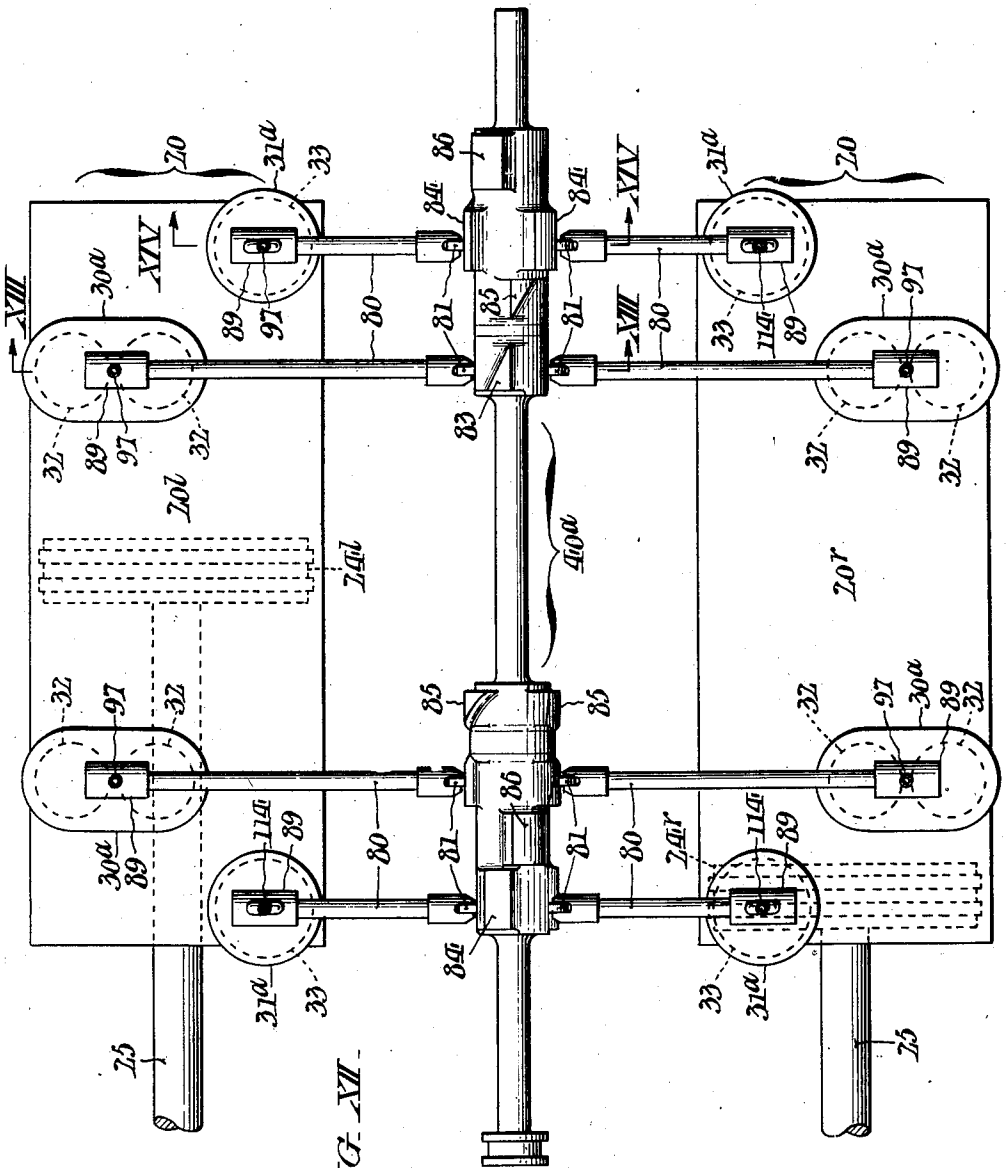



FIG. XII.

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LOCOMOTIVE STEAM DISTRIBUTION SYSTEM

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FIG. XIV.

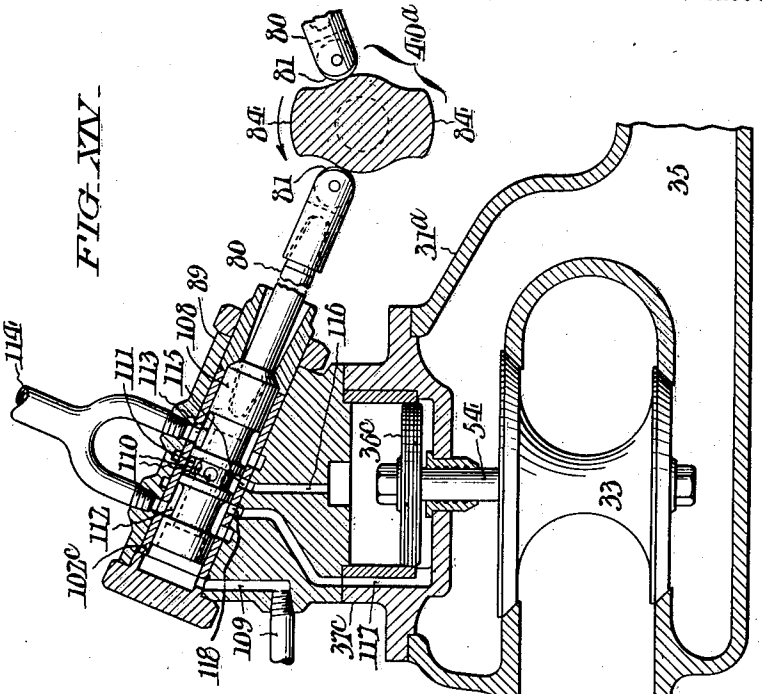
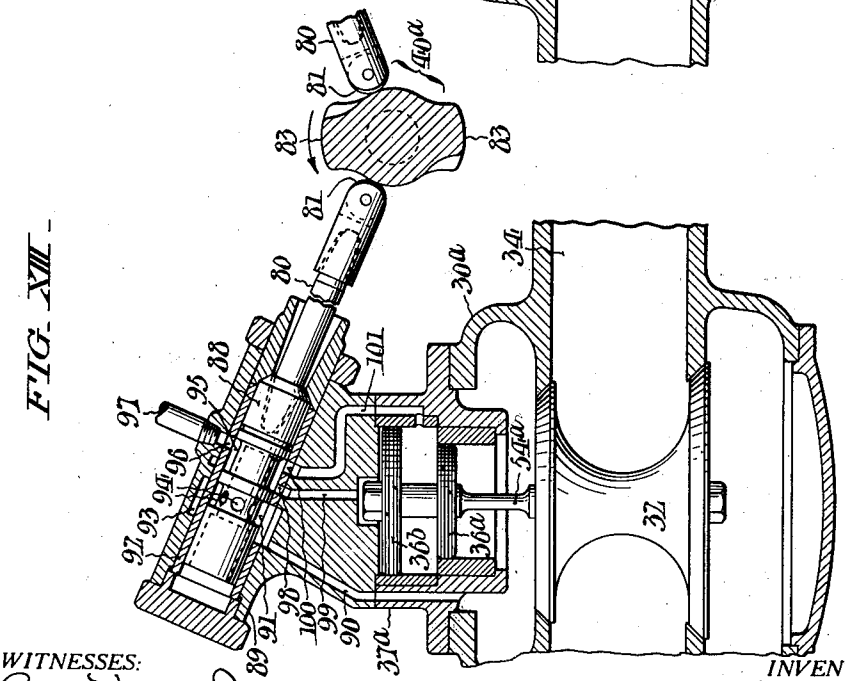



FIG. XIII.




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Patented Oct. 28, 1941

2,260,458

# UNITED STATES PATENT OFFICE

2,260,458

## LOCOMOTIVE STEAM DISTRIBUTION SYSTEM

Lloyd B. Jones, Hollidaysburg, Pa.

Application January 23, 1939, Serial No. 253,296

14 Claims. (Cl. 121—126)

This invention relates to locomotives, particularly steam or elastic fluid locomotives driven by reciprocating engines, and is especially concerned with the admission and exhaust of steam to and from the engine cylinders. The invention aims at improving the steam distribution, and the resulting mean effective pressure and engine efficiency.

Steam locomotives now in general use in America have a single valve for admitting and exhausting steam to and from both ends of an engine cylinder, this valve being usually of reciprocating piston type, and being operated by a valve gear (commonly of the Walschaert type) adjustable to vary the proportion of the piston stroke during which steam is admitted to the cylinder. While it is only desired to vary the point of the stroke at which the admission of steam to the cylinder is cut off, yet with just a single valve controlling all the events of the stroke, any change in the cut-off (retardation or advance) is accompanied by a similar change in the other events of the stroke,—the admission of live steam, the beginning of exhaust of spent steam, and the ending of exhaust, when compression of spent steam remaining in the cylinder begins. Under most conditions, therefore, the events of the stroke are not all correctly timed, and the efficiency is consequently lowered. The inertia and frictional resistance of a single large reciprocating valve also result in considerable distortion of the timing at high locomotive speeds, with resulting loss of efficiency. Furthermore, the opening of the steam admission port to the cylinder is gradual, so that the entering steam is throttled and an appreciable part of the working stroke takes place without full steam pressure on the piston, resulting in further lowering of mean effective pressure and efficiency. The lowering of efficiency from these two causes—incorrect timing, and throttled admission—means that locomotive cylinders must be considerably larger than would otherwise be necessary, in order that the locomotive may develop the required power.

Besides the loss of efficiency and power due to incorrect timing and throttled steam admission, the inertia and frictional resistance of a large reciprocatory valve and its valve gear result in considerable non-propulsive consumption of power, especially during operation of the locomotive at high speeds; and this is of course a dead loss, requiring further increase of cylinder size to obtain the desired tractive power. Furthermore, the forces involved in the adjustment of the cut off and in the reversal of the locomotive are so large that a power-operated reversing gear is necessary, adding to the complication and cost of the equipment, as well as to the non-propulsive consumption of power.

I have devised a valve system for a locomotive which obviates these drawbacks of present practice. For this purpose, the single reciprocating valve now used is replaced with separate fluid-operated poppet valves for admitting and exhausting steam to and from each cylinder or active cylinder end,—making, say, four such valves for the usual double-acting engine cylinder. This affords a flexibility of operation that allows all the events of the stroke to be correctly timed, and permits of varying or adjusting one event without changing any of the others, since the operation of each valve can be controlled quite independently, so as to give any desired timing for the events which it produces. Valves of poppet type actuated by steam or elastic fluid can be opened and closed very quickly, so that throttled admission or exhaust of steam to or from the cylinder is entirely done away with. Moreover, such valves can be made so light as to operate with very little friction and inertia. The operating fluid for all the poppet valves of a locomotive can be controlled by a light rotary master controller, operating without inertia effects and with very little friction, so that the power used for valve actuation is very small, and the valves and operating mechanism have no distorting effects on the timing. The adjustment of the master controller and the reversal of the locomotive require but small force, and can be effected with light rigging, operated directly by hand. The rotary master-controller may consist of a master valve (or group of valves) controlling the action of actuating fluid on the poppet valves, or of a master cam (or set of cams) performing this function through suitable small pilot valves.

As regards lightness and quick operation of the admission and the exhaust poppet valves, the maximum advantage can be gained by using several small fluid-actuated admission poppets or exhaust poppets for each active cylinder end, rather than one larger admission or exhaust poppet giving an equivalent area for the passage of the steam. This is because the smaller poppets can be made lighter than the single large poppet, and will operate to and fro more rapidly. The advantages of the subdivision of function (admission or exhaust) amongst several small valves are not offset by any corresponding complications

of the master control means required, since a single master controller agency (whether a single rotary-cam-operated pilot valve, or a seat-port of a rotary master valve) can control the operating fluid for several poppet valves, just as readily as for one single poppet valve.

Other features and advantages of the invention will appear from the following description of species or forms of embodiment, and from the drawings.

In the drawings,

Fig. I is a side view, partly diagrammatic, of valve mechanism embodying my invention, a portion of a gear case and axle being shown in section, and associated parts of the locomotive being shown in dot-and-dash lines; and Fig. II is a plan view of the mechanism with the locomotive boiler and cab removed, and with the cylinder blocks and the saddle of the locomotive partly in horizontal section, the showing being largely diagrammatic.

Fig. III is a general diagram of the parts involved in my invention, including the locomotive cylinders, pistons, admission and exhaust valves, and part of a master controller for the valves.

Fig. IV is a fragmentary side view of the driving connection for the master controller shown in Fig. I, with one of the parts partly in longitudinal mid-section as indicated by the line and arrows IV—IV in Fig. I; and Fig. V is a fragmentary view of certain parts, at right angles to Fig. IV, one of the parts being in section as indicated by the line and arrows V—V in Fig. I.

Fig. VI shows a vertical mid-section through one of the main steam admission valves of the locomotive; and Fig. VII is a similar view of one of its exhaust valves.

Fig. VIII is a tilted or perspective view of a master controller valve; Fig. IX shows a cross section through the valve, taken on two different planes substantially as indicated by the line and arrows IX—IX in Fig. XI; and Figs. X and XI show longitudinal sections through the valve, taken as indicated by the lines and arrows X—X and XI—XI in Fig. IX.

Fig. XII is a somewhat diagrammatic plan view of locomotive cylinders with a master controller consisting of a rotary cam operating pilot valves which directly control the action of the poppet valves.

Fig. XIII shows a vertical mid-section through one of the main steam admission valves such as indicated in Fig. XII, together with its push rods and master controller cam; and Fig. XIV is a similar view of one of the exhaust valves with the controller cam. These sections are taken as indicated by the lines and arrows XIII—XIII and XIV—XIV in Fig. XII; but the position of the master controller cam in Fig. XIV is different from that in Fig. XII.

Figs. I and II illustrate the application of my invention to an ordinary type of steam locomotive having a pair of double-acting cylinders **20** carried by a front saddle **21**,—and conveniently distinguished, according to their right and left positions in Fig. II, as **20***r* and **20***l*. The locomotive has a number of pairs of driving wheels **22** interconnected as usual by side rods **23**, and driven by the pistons **24** in the cylinders **20**, **20** through piston rods **25**, connecting rods **26**, and crank pins **27**,—these pistons being conveniently distinguished as **24***r* and **24***l*, on the same bases as the cylinders **20***r* and **20***l*. Merely for simplicity of illustration, the cylinders **20** and the saddle **21** are diagrammatically shown as one block of metal, rather than as separate parts bolted together. Live steam from the locomotive boiler may be supplied to the cylinders **20** (as usual) through pipes and ducts **28**, and spent steam from the cylinders may be exhausted through ducts **29**, leading to the usual exhaust nozzle (not shown), or to any desired exhaust discharge. At each end of each cylinder **20**, casings or housings **30**, **31** are diagrammatically indicated, for the fluid-actuated poppet valves that admit and exhaust the steam or motive fluid to and from the cylinders,—though these valves themselves are not shown in Figs. I and II.

Fig. III shows the admission and exhaust valves **32** and **33** with their connecting ducts **34**, **35** to the ends of the cylinders **20***r*, **20***l* whose pistons **24***r*, **24***l* there appear in relative positions corresponding to the setting of their crank pins **27** at an angle of 90° apart, as usual. Fig. III also shows pistons **36** in cylinders **37** for operating the valves **32** and **33**, with fluid supply and relief connections or ducts **38** from the cylinders **37** to the valve means of a master controller for controlling the action of operating fluid to open and close the poppets **32** and **33**. It will be understood, of course, that cylinders **20**, valves **32**, **33**, cylinders **37**, and ducts **34**, **35**, **38**, etc., do not appear in their true relative proportions or positions in Fig. III, owing to the highly diagrammatic character of this figure.

Figs. I and II show a master controller **40** for the valves **32**, **33** arranged to revolve continuously in the saddle **21** about an axis extending fore and aft (lengthwise of the locomotive) between the cylinders **20***r*, **20***l*, and embodying (or actuating) valve means for controlling the action of the operating fluid to open and close the valves **32** and **33**. Preferably, the master controller **40** is driven from one of the axles **42** of the driving wheels **22** through a longitudinal (fore and aft) shaft **43** whose rear end is geared to said axle through (worm) gearing **44**, and whose forward end is connected to the controller shaft or spindle **45** through a universal joint **46** and a splined connection **47**. The splined connection **47** allows the rotary controller **40** to be shifted axially or fore and aft (relative to the saddle **21** and associated parts), which may be done manually from the locomotive cab (Figs. I, II, IV, and V) by means of a latch-and-segment reverse lever **48** connected through a reach-rod **49** to a rocker arm on a transverse horizontal shaft **50** whose forked arm **51** carries rollers **52** that engage in a groove in the enlarged hollow splined end **53** of the valve spindle **45**. By shifting the master controller **40** axially as just described, the point of cut-off can be adjusted, or the locomotive reversed, as will presently be explained. The particular master controller **40** illustrated in Figs. III and VIII–X being laid out to make one revolution for one revolution of the drive wheels **22**, the gearing **44** for driving it should have a one-to-one ratio.

A preferred type of admission valve is illustrated in Fig. VI as comprising a double-headed poppet **32** whose heads close and seat upward on ports in diaphragms across the interior of the valve casing **30**. Live steam from the duct **28** is supplied above and below the two valve heads, while the space between them is connected through the duct **34** to an end of one of the locomotive cylinders **20**, Figs. I, II, and III. The stem **54** connecting the valve **32** to the operating piston **36** extends up through an opening

in the wall separating the upper steam space in the casing 30 from the operating cylinder 37, with a clearance at 55 around the stem sufficient to permit leakage of steam up into the cylinder under the piston 36, to lift the valve 32 to its seats and cut off steam from the locomotive cylinder; and the valve 32 is thus biased to close. When the valve 32 is thus seated, the leakage clearance at 55 is closed by a conical valve head 56 on the stem 54, which seats coincidentaly with the valve 32. There is a leakage vent 57 from the lower end of the cylinder 37 to the atmosphere; but this is overtraveled and closed by the piston 36 when the valve 32 opens. The fluid supply and relief duct 38 to the master controller 40 is connected at 58 into the upper end of the cylinder 37, above the piston 36. It is practicable to use steam or elastic motive fluid from the supply to the main cylinders 20 as operating fluid above the piston 36, as well as below it, since with equal pressures above and below this piston, the valve 32 will drop open by its own weight. To cushion the closing upward movement of the valve 32 and its piston 36 when pressure above the latter is relieved, an elastic cushion is preferably arranged to receive its impact and absorb its momentum near the end of its upward movement. As shown, this elastic cushion comprises a helical compression spring 60 acting between the centrally bossed upper end of a bore in the top of the cylinder 37 and a cup-like plunger 61 that slides in said bore and engages the upper end of the valve stem 54 above the piston 36. This spring 60 also acts to initiate the downward movement of the valve 32, assisting gravity against any tendency of the valve to stick. The downward expansion of the spring 60 may be suitably limited by stop means (not shown) for engaging the plunger 61.

It will be seen, therefore, that when fluid pressure is admitted above piston 36 exceeding or equalling that below it, valve 32 drops open; while when such pressure above piston 36 is relieved, the pressure of the fluid which has leaked under the piston through the clearance at 55 overcomes spring 60 and automatically closes the valve 32. However, after valve 56 closes clearance 55, the confined pressure fluid below piston 36 can gradually leak away at 57, thus ultimately allowing valve 32 to drop open. This, however, does not happen during the continuous running of the locomotive, but only when pressure is altogether shut off from the valve 32.

A preferred form of exhaust poppet valve 33 illustrated in Fig. VII is similar to the admission valve of Fig. VI, except that the double valve heads close downward, so that pressure below piston 36 tends to open the valve 33, and pressure above to close it; valve 56 closes leakage clearance 55 when valve 33 opens; and the connections between the valve casing 31 and the engine cylinder are reversed as compared with Fig. VI: i. e., the space between the poppet valve heads is connected to exhaust, while the spaces above and below these heads are connected to the engine cylinder duct 35, as indicated in Fig. III. The helical compression spring 60 is mounted in the bottom of the valve casing 31, to cushion the gravitational downward-closing movement of the valve 33 when operating pressure is admitted above the piston 36, and to assist in initiating the upward-opening movement of the valve, as against any sticking tendency. Valve 33 is biassed to open by the leakage pressure below it, and does open automatically when the pressure above piston 36 is relieved; but when pressure is altogether shut off from the valve 33, it automatically drops shut.

As shown in Fig. III, the controller 40 and its bore or seat in the saddle 21 directly embody valve means for controlling the action of operating fluid on the operating means or pistons 36 of the valves 32, 33 belonging to the two engine cylinders 20r, 20l, such valve means comprising annular rows of ports in the internal surface 65 of the valve bore or seat,—which is shown as unrolled or developed into the flat in Fig. III,—and corresponding ports S1, S2, etc., and V1, V2, etc., in the external surface of the master controller 40, which is thus in effect a rotating valve body. It will of course be understood that in showing the interior surface of the valve bore or seat 65 developed or unrolled in Fig. III, some of the ports and other features are necessarily shown divided,—part at the upper edge of the seat 65 and part at its lower edge,—although the actual cylindrical surface 65 is continuous, and its ports which appear divided are really simple openings like the rest.

As shown in Figs. VIII, IX, X, and XI, the master-valve-body 40 has therein a longitudinal live-steam bore 66 whence steam supply ports S1, S2, S3, S4 open through the external valve surface in a longitudinal row, and also has therein a longitudinal relief bore 67 whence a longitudinal row of relief or vent ports V1, V2, V3, V4 open through the external valve surface, diametrically opposite the row of steam ports. As shown in Figs. I and III, the steam bore 66 opens into an open recess 68 in one side of the valve body 40, while the relief bore 67 opens directly through the end of the valve into a chamber 69 consisting of an extension of the valve bore in the saddle 21.

The recess 68 is always supplied with steam through an annular row of ports in the internal surface 65 of the valve bore (these ports being wide enough to cover the recess 68 in any longitudinal position of the valve body 40), and through a duct 70 (Figs. I and III) which may be connected into one of the main steam supply ducts 28; and the relief chamber 69 is always open to exhaust, as through a duct 71 connected into one of the main exhaust ducts 29.

Preferably, there is a duplicate longitudinal steam bore 66x in the valve 40, diametrically opposite the bore 66 and opening into a duplicate recess 68x at the other side of the valve body from the recess 68, and in communication with the duct 66 through a diametric cross passage 72 in the opposite end of the valve body from the recess 68. This duplicate steam bore 66x not only assures an abundant supply of steam to the ports S1, S2 at the opposite end of the valve body from the recess 68, but also equalizes the effects of temperature and pressure changes due to the presence or absence of steam, so that these changes have no tendency to distort or bend the valve body. As shown in Figs. VIII, IX, and XI, the relief duct 67 is also duplicated by a diametrically opposite relief duct 67x opening through the end of the valve into the relief chamber 69, and also connected into the duct 67 through a diametric cross passage 73: this serves the same double purpose as the duct 66x and cross passage 72.

For coacting with the steam ports and relief ports of the rotating valve body 40, the valve seat or bore 65 has ports which are shown in Fig. III as arranged in eight groups A, B, C, D, E, F, G, H. The valve seat ports of the groups A and B coact

with the valve ports S1 and V1, admitting and exhausting steam to and from the cylinders 37 of the admission valves 32 for the cylinder 20*r*; the valve seat ports of the groups C and D coact with the valve ports S2 and V2, admitting and exhausting steam to and from the cylinders 37 of the admission valves 32 for the cylinder 20*l*; the valve seat ports of the groups E and F coact with the valve ports S3 and V3, admitting and exhausting steam to and from the cylinders 37 of the exhaust valves 33 for the cylinder 20*r*; and the valve seat ports of the groups G and H coact with the valve ports S4 and V4, admitting and exhausting steam to and from the cylinders 37 of the exhaust valves 32 for the cylinder 20*l*. To provide for reversing the locomotive, each group of ports A, B, C, D, E, F, G, H comprises a double annular row (or pair of rows) of ports, one single annular row of ports for forward motion, and the other annular row of ports for backing. Corresponding ports of the adjacent groups A and B, C and D, E and F, G and H are connected by a common duct 38 to the operating cylinder 37 of a particular valve 32 or 33 which these ports serve.

Hereinafter, each port in the valve seat or bore 65 is distinctively designated, where individual reference is necessary, by a combination of three symbols indicating its role in the operation of the locomotive: A, B, C, D, E, F, G, or H, according to the group to which it belongs; *c* or *h* according to whether such poppet serves the rear or "cab" end or the front or "head" end of such engine cylinder; and *f* or *b* according to whether the port in question is active in forward or backing movement of the locomotive. For example, the port at the extreme left of Fig. III extending upward from about the middle of the valve seat 65 is designated A*cb*. For convenience in explanation, the various ports S1, S2, etc., and V1, V2, etc., of the rotating master valve 40 are marked in dot-and-dash lines on Fig. III,—in longitudinal positions on the valve seat 65 corresponding to a setting of the valve body 40 for forward travel of the locomotive with cut-off at half-stroke, and in transverse (or circumferential) positions corresponding to the illustrated positions of the pistons 24*r*, 24*l* in the cylinders 20*r*, 20*l*. The arrow at the left of Fig. III corresponds to those in Figs. VIII and IX and indicates the direction of movement of the surface of valve body 40 and its ports S1, S2, etc., and V1, V2, etc., relative to the valve seat surface 65.

As regards the cylinder 20*r*, the steam supply port S1 of valve 40 is beginning its travel (downward) across valve seat port A*cf*, thus supplying steam to the cylinder 37 of the admission poppet 32 for the rear end of the cylinder 20*r*, to open this poppet and hold it open, which admits steam behind the piston 24*r* to move it forward in the cylinder, while the relief port V1 is not yet near the corresponding port B*cf*. The steam port S3 has begun its travel across port E*cf*, supplying steam to hold closed the exhaust poppet 33 behind the piston 20*r*, while the relief port V3 is not yet near the corresponding port F*cf*. However, this relief port V3 has begun its travel across port F*hf*, venting the cylinder 37 for the exhaust poppet 33 in front of the piston 24*r*, so that this poppet is open to exhaust, while the steam port S3 is not yet near the corresponding port E*hf*. The relief port V1 is traversing the port B*hf*, venting the cylinder 37 for the admission poppet 32 in front of the piston 24*r*, so that this poppet is closed, while the steam port S1 is not yet near the corresponding port A*hf*.

As to the cylinder 20*l*, the steam supply port S2 is about to end its travel across port C*cf* and thus cut off pressure from the cylinder 37 of the admission poppet 32 for the rear end of the cylinder 20*l*, and the relief port V2 is about to begin its travel across port D*cf* and vent this cylinder 37, so that this admission poppet is about to close and cut off the supply of steam to this end of the cylinder 20*l*. Steam port S4 is still traversing port G*cf* and supplying steam to hold the exhaust poppet 33 for the rear end of cylinder 20*l*, closed, and relief port V4 is some distance in advance of the corresponding port H*cf*, so that the exhaust poppet 33 for the rear end of the cylinder will not be opened till later in the forward stroke of piston 24*l*. Steam port S4 is some distance in advance of port G*hf*, while relief port V4 is still traversing the corresponding port H*hf*, so that the exhaust poppet 33 for the front end of the cylinder is being held open. Steam port S2 is not yet near port C*hf*, and exhaust port V2 is not yet near the corresponding port D*hf*, so that the admission poppet 32 for this end of this cylinder is closed and will be held closed for some time.

It will be observed that the valve seat ports of groups A and C for the supply of fluid pressure to open the admission poppets 32 have their leading edges parallel with the longitudinal valve axis, so that the valve ports S1 and S2 always start across them at the same point in the strokes of the pistons 24*r* and 24*l*,—no matter how much the valve body 40 may be shifted axially either way from the position indicated in Fig. III,—and the admission always occurs at the same point in the stroke. On the other hand, the trailing edges of these same ports slope relative to the valve axis, so that the termination of the travel of ports S1 and S2 across them is deferred by shifting valve 40 to the right, giving cut-off later in the piston stroke, and is advanced by shifting valve 40 to the left, giving cut-off earlier in the stroke. The leading and trailing edges of the valve seat ports of groups B and D for venting fluid pressure from the cylinders 37 of the admission poppets 32 both slope (at the same inclination) relative to the valve axis, so that while the proportion of the piston stroke during which the cylinder 37 is vented by them is always the same, this period occurs earlier in the stroke if the valve 40 is shifted lengthwise to the right, and later if the valve 40 is shifted to the left. The valve body ports S1, S2, V1, V2 have edges sloping in conformity with those of the corresponding valve seat ports, so as to give quickly a full admission or venting of steam to or from the cylinders 37, and quick operation of the valves 32. On the other hand, the leading and trailing edges of all the ports of groups E, F, G, H that control the supply or venting of actuating fluid for the exhaust poppets 33 are parallel with the valve axis, so that shifting the valve 40 lengthwise does not change the points in the stroke at which the valves 33 open and close,—which thus remain constant regardless of changes in the point of cut-off. Accordingly, the valve ports S3, S4, V3, V4 are rectangular, without any sloping edges, to give quickest operation of the valves 33.

It will be observed that if the master valve 40 is shifted axially further and further to the left in Fig. III, the path of the valve ports S1, S2, S3, S4 and V1, V2, V3, V4 will lie altogether clear of the corresponding valve seat ports, and the poppets 32 and 33 will not operate at all.

Thus these valves 32, 33 will be in positions corresponding to the mid-position of the usual locomotive piston valve, and the locomotive will stop as its momentum is used up. If, however, the master valve 40 is shifted yet further to the left, the paths of the valve body ports S*l*, etc., and V*l*, etc., will lie across the valve seat ports for backing; and such admission and exhaust poppets 32, 33 will be opened, and in such sequence, as to start and run the locomotive backward.

It will be apparent that the agroupment and arrangement of steam supply and relief ports in the master valve body 40 and in the valve bore or seat 65 as shown in Figs. III–IX is illustrative and to a certain degree arbitrary, and can be changed around as found most convenient. Likewise, the system can be adapted to a locomotive with more than two cylinders, by merely providing additional ports in the valve seat or bore 65, and driving the valve body 40 in proper relation to the piston strokes.

On the other hand, the shapes of the various valve and valve seat ports shown are functional as well as illustrative: i. e., changes in the port outlines can be made to produce variations of poppet-valve action. For example, if desired, the leading edges of the ports of groups A and C for supplying fluid to open the admission poppets 32 may be sloped or curved, so as to vary the point of the stroke at which admission occurs somewhat; or the leading or trailing edges of the ports of groups E, F, G, H that control the supply and/or relief of fluid to operate the exhaust valves 33 may be sloped or curved to vary the points of release and compression, where exhaust begins and ends. Slope or curvature of port edges may also be resorted to in order to correct the varying effects of constant time-lag on poppet operation at different locomotive speeds: i. e., the time required for a poppet 32 or 33 to open or close after opening of a valve seat port is constant, and hence occupies a larger fraction of the piston stroke at high locomotive speeds than at low speeds. As high speeds are normally accompanied by a shortening of the locomotive cut-off, the valve seat ports can be designed to produce slightly earlier opening (or closing) thereof for early cut-off, and vice-versa, so that the points of the stroke at which the other poppet operations occur shall be the same at all speeds.

It will be observed that when the steam supply is shut off at the locomotive throttle (not shown), to allow the locomotive to drift, all the admission poppets drop open, thus by-passing the two ends of the cylinders 20 through the ducts 28; whereas the exhaust valves 33 all close and prevent gases from the smoke-box from being drawn back into the cylinders during drifting.

As shown in Fig. XII, the rotary master controller valve 40 of Figs. I, II, and III is replaced with a revolving master controller 40*a* of cam type, that revolves about a longitudinal axis between the cylinders 20*r*, 20*l*, is shiftable longitudinally by means of a grooved collar 53*a*, and actuates pilot valves in casings 30*a* and 31*a* on the cylinders 20. In Fig. XII there are two relatively small admission poppets 32, 32 for each end of each cylinder 20*r*, 20*l*, to give maximum quickness of full port opening at admission, and maximum sharpness of cut-off. A single relatively large exhaust poppet 33 is shown for each cylinder end.

The driving provisions for the rotary master cam 40*a* (not shown in Fig. XII) may be the same as for the rotary master valve 40 in Figs. I and II, except that as the particular cam 40*a* in Figs. XII to XIV is laid out to make one revolution for two revolutions of the locomotive drive wheels, the gearing in its driving connections should have a two to one ratio, as against a one to one ratio for the gearing 44 in Figs. I and II. The positions of the pistons 24*r* and 24*l* are the same in Fig. XII as shown in Fig. III, corresponding to the beginning of the forward piston stroke in the cylinder 20*r* and the middle of the forward stroke in the cylinder 20*l*, which is the condition of a left-lead locomotive when the lefthand crank pin is at the top of its path. Through longitudinally sliding rods 80 (shown as provided with rollers 81 for engaging the cam peripheries), the rotary master cam 40*a* operates longitudinally sliding pilot valves (of piston type) which control the admission of operating fluid to shift the admission and exhaust poppets 32 and 33. As shown in Fig. XII, there are two cam surfaces located 180° apart on the periphery of the master cam 40*a*, so that each push rod 80 is actuated twice for each cam revolution, or once for each single revolution of the driving wheels. As shown in Figs. XIII and XIV, the push rods 80 are angularly so arranged with respect to the actuating cam surfaces at 40*a* that an impulse to a push rod at the left is followed 45° later by an impulse to one at the right, which corresponds to 90° of rotation of the main driving wheels.

In a general way, the shapes of the cam surfaces of the master cam 40*a* correspond to those of the ports in the bore or valve-seat surface 65 of the rotary cam 40 in Fig. III. For example, the faces of the admission cam surfaces 83, 83 in Fig. XII are triangular, and it is evident that if the master cam 40*a* is shifted longitudinally to the right in Fig. XII, the push rods 80 actuated thereby will remain in their extreme outer positions longer than with the cam 40*a* in the position shown, giving a longer period of steam admission to the engine cylinders, and a later cut-off; while if the master cam 40*a* is shifted to the left, the corresponding push rods 80 will remain in their outer positions for a shorter time, giving a shorter period of steam admission to the cylinders, and an earlier cut-off. On the other hand, such longitudinal shifting of the master cam 40*a* will not affect the timing by the rectangular exhaust cam surfaces 84, 84. If the master cam 40*a* is shifted still further to the left, the valves 32, 33 will be on center, as explained above with reference to Fig. III or may even be reversed; the master cam 40*a* will rotate in the opposite direction, with its top portion moving from the bottom toward the top of Fig. XII; and the valve events will be controlled by similar cam surfaces 85, 85 and 86, 86 in the same manner as for the cam surfaces 84, 84 and 85, 85. Of course the various cam surfaces 83, 83, 84, 84, 85, 85, and 86, 86 may be varied in shape to produce somewhat different timing of other events for different cut-offs, if desired, or to compensate for the different effects of constant time-lag in valve operation at different speeds.

The admission poppet valve 32 shown in Fig. XIII differs somewhat from that shown in Fig. VI as regards its actuating arrangements. As shown in Fig. XIII, the valve stem 54*a* carries differential actuating pistons 36*a* and 36*b*, one above the other in a cylinder 37*a* forming an upward extension of the valve casing 30*a*, the smaller piston 36*a* always having its underside

exposed to the live steam pressure above the upper head of the valve 32. A pilot valve 88 controlling the action of operating fluid on the pistons 36a, 36b is longitudinally movable in a bore in a part 89 forming the head of the valve operating cylinder 37a. The pilot valve 88 is preferably biassed to move toward the cam 40a, as by unbalanced pressure of live steam on one end of the valve, and live steam for this purpose may be supplied through a port or duct 90 extending up from the upper stream space of the poppet valve casing 30a to an annular chamber 91 around the pilot valve 88, through ports in the valve bore liner 92 into an annular groove 93 in the valve, and through ports 94 and the hollow interior of the valve to the lefthand end of its bore. At the right of the steam groove 93, the valve 88 has an exhaust groove 95 which may be connected to any suitable point or region of discharge, through ports 96 in the liner 92 and a duct or pipe 97. As shown, the annular groove 95 is connected to the cylinder 37a between the differential pistons 36a, 36b through ports 100 in the liner 92 and a duct 101, and to the upper end of the cylinder 37a (above the upper piston 36b) through ports 98 and a duct 99.

With the valve 88 in the position shown, the upper side of the larger piston 36b is vented to exhaust, so that the valve 32 is held to its seat by the live steam pressure on the underside of the smaller piston 36a. When the cam 40a moves the valve 88 to the left, the valve covers the exhaust ports 96, cutting off the upper end of the cylinder 37a from exhaust; and on a further movement to the left, its annular groove 95 connects the ports 98 to the annular steam chamber 91, admitting live steam through the duct 99 to the upper side of the larger piston 36a to shift the admission poppet 32 downward to open it. During the latter part of this downward movement, the larger piston 36b overtravels and closes the port opening of duct 101, so that the fluid confined in the differential space between the pistons undergoes compression and cushions the further descent of the poppet valve, preventing any hammering at the end of the downward movement.

The exhaust valve 33 differs from the admission valve 32 just described in having but a single operating piston 36c in the cylinder 37c. The pilot valve 108 may be biassed to move toward the cam 40a by the unbalanced pressure of live steam supplied from any suitable source to one end of the valve bore, as through a duct and pipe connection 109. As shown, the valve 108 is hollow, and the stem supplied at 109 passes through its interior and out through ports 110 into an external annular groove 111 near its middle. At opposite sides of this steam groove 111, the valve 108 has annular exhaust grooves 112 and 113 which are connected to branches of an exhaust pipe 114 leading to any suitable point of discharge. With the pilot valve 108 in the position shown, steam from the valve groove 111 is supplied through ports 115 in the valve bore liner 102c and a duct 116 to the upper side of the piston 36c, to depress the latter and hold the valve 33 to its seat, while pressure is vented from beneath said piston through a duct 117 and ports 118 in said liner 102c, via the exhaust groove 112.

When the valve 108 is shifted to the left by the cam 40a, the ports 115 and the upper side of the piston 36c are connected to exhaust through the annular valve groove 113, venting the upper side of the piston 36c, while live steam from the annular valve groove 111 is supplied through the ports 118 and the duct 117 to the lower side of the piston which is thus raised to open the valve 33.

It will readily be seen that when the locomotive throttle is closed, shutting off steam from the admission valve 32, as well as from the duct 90, the admission valve 32 will drop open, and that, similarly, the exhaust valve 33 will drop shut. This allows free circulation between the ends of the engine cylinders 20r, 20l to permit the locomotive to drift without resistance to the pistons by compression of fluid in the ends of the engine cylinders, while preventing air, gas or smoke from being drawn into the cylinders from the locomotive smoke-box or other point of exhaust,—just as in the case of the valve arrangement already described.

In Figs. XII–XIV, various parts and features are marked with the same reference numerals as in Figs. I–XI, and particularly as in Figs. I, II, VI, and VII, as a means of dispensing with repetitive description—with the addition of a letter where such distinction appears necessary, —and similarly in Fig. XIV and Fig. XIII.

Having thus described my invention, I claim:

1. In a reciprocating engine locomotive, the combination with the front end locomotive structure, including the locomotive saddle and the cylinders thereon at opposite sides of the locomotive, and an axle driven by reciprocating pistons in said cylinders, of conduit means and poppet valves in said front end locomotive structure, for supplying and admitting motive fluid to the opposite ends of said cylinders, with fluid actuated means for shifting said admission poppet valves, poppet valves for exhausting motive fluid from the opposite ends of the engine cylinders, with fluid-actuated means for shifting said exhaust poppet valves, and a continuously rotating master controller driven from said axle and mounted in said front end locomotive structure between said cylinders, with valve means controlling the action of the locomotive operating fluid on said fluid actuated means to shift said poppet valves.

2. A rotary master controller valve, for controlling the operation of fluid-actuated engine valves, comprising a revolving cylindrical valve body having therein a pair of diametrically opposite longitudinal motive fluid passages with openings to the periphery of said body for supplying operating fluid to move said engine valves, and a pair of diametrically opposite longitudinal relief passages with openings to the periphery of said body for venting the motive fluid supplied as aforesaid, whereby temperature changes due to fluid in said pairs of passages affect the valve body symmetrically, and hence do not warp it.

3. In a reciprocating engine locomotive, the combination with its engine cylinders and a rotating shaft driven by the reciprocating pistons in said cylinders, of conduit means and poppet valves for supplying and admitting motive fluid to the opposite ends of the engine cylinders, with fluid-actuated means for shifting said admission poppet valves; poppet valves for exhausting motive fluid from the opposite ends of the engine cylinders, with fluid-actuated means for shifting said exhaust poppet valves; and a continuously rotating master controller with valve means controlling the admission of the locomotive operating fluid to the said fluid-actuated means to shift said admission poppets and said

exhaust poppets, with means for driving said master controller from said rotating shaft.

4. The combination as set forth in claim 3 wherein the continuously rotating master controller and its valve means comprise a rotary cam with pilot valves actuated by said cam for controlling the supply and venting of motive fluid to move said poppet valves.

5. In a reciprocating engine locomotive, the combination with its engine cylinders and a rotating shaft driven by the reciprocating pistons in said cylinders, of conduit means and poppet valves for supplying and admitting motive fluid to the opposite ends of the engine cylinders, with fluid-actuated means for closing said admission poppet valves; poppet valves for exhausting motive fluid from the opposite ends of the engine cylinders, with fluid-actuated means for opening said exhaust poppet valves; and a continuously rotating master controller with valve means controlling the admission of motive fluid from said supply conduit means to the said fluid-actuated means to close said admission poppets and to open said exhaust poppets, with means for driving said master controller from said rotating shaft.

6. In a reciprocating engine locomotive, the combination with its engine cylinders and a rotating shaft driven by the reciprocating pistons in said cylinders, of conduit means and poppet valves for supplying and admitting motive fluid to the opposite ends of the engine cylinders, with fluid-actuated means exposed to the motive fluid when said admission poppet valves are in one extreme position for shifting said valves to their other extreme position; poppet valves for exhausting motive fluid from the opposite ends of the engine cylinders, with fluid-actuated means exposed to the motive fluid when said exhaust poppet valves are in one extreme position for shifting said valves to their other extreme position; a continuously rotating master controller with valve means controlling the admission of operating fluid to said fluid-actuated means to shift said admission and exhaust poppet valves to their other extreme position as aforesaid; and means for driving said master controller from said rotating shaft.

7. In a reciprocating engine locomotive, the combination with its engine cylinders and a rotating shaft driven by the reciprocating pistons in said cylinders, of conduit means and poppet valves for supplying and admitting motive fluid to the opposite ends of the engine cylinders, with fluid-actuated means for shifting said admission poppet valves; poppet valves for exhausting motive fluid from the opposite ends of the engine cylinders, with fluid-actuated means for shifting said exhaust poppet valves; pilot valves controlling the action of the locomotive operating fluid on said fluid-actuated means to shift said admission and exhaust poppet valves; continuously rotating master controller cam means for actuating said pilot valves; and means for driving said master controller cam means from said rotating shaft.

8. In a reciprocating engine locomotive, the combination with its engine cylinders and a rotating shaft driven by the reciprocating pistons in said cylinders, of conduit means and poppet valves for supplying and admitting motive fluid to the opposite ends of the engine cylinders, with fluid-actuated means for shifting said admission poppet valves; poppet valves for exhausting motive fluid from the opposite ends of the engine cylinders, with fluid-actuated means for shifting said exhaust poppet valves; pilot valves controlling the action of the locomotive operating fluid on said fluid actuated means, and themselves constantly exposed endwise to unbalanced pressure of said operating fluid tending to move them in one direction; a continuously rotating master controller cam for moving said valves in the other direction against this unbalanced endwise fluid pressure; and means for driving said master controller cam from said rotating shaft.

9. In a reciprocating engine locomotive, the combination with its engine cylinders and a rotating shaft driven by the reciprocating pistons in said cylinders, of separate poppet valves, for admitting and exhausting motive fluid to and from said cylinders, balanced with respect to the action of the motive fluid thereon, but biased to occupy one extreme position in the absence of actuating fluid pressure, with fluid-actuated means for shifting said valves to their other extreme position; a continuously rotating master controller with valve means controlling the admission of actuating fluid to said fluid-actuated means to shift the valves to their said other extreme position; and means for driving said master controller from said rotating shaft.

10. A poppet valve for the combination as set forth in claim 9, comprising a casing with valve seats and an operating cylinder, a poppet valve member including heads coacting with said seats and balanced with respect to the action of the motive fluid thereon, and a piston in said cylinder connected to said heads, there being a leakage port from the motive fluid space of the casing into the adjacent end of said cylinder, and said valve member being provided with means for controlling said leakage port, and means for supplying operating fluid to the other end of said cylinder.

11. The combination as set forth in claim 9 wherein the continuously rotating master controller comprises a rotary cam, with pilot valves actuated by said cam for controlling the supply of operating fluid to said fluid-actuated means to shift said poppet valves.

12. In a reciprocating engine locomotive, the combination with its engine cylinders and a rotating shaft driven by the reciprocating pistons in said cylinders, of conduit means and poppet valves for supplying and admitting motive fluid to the opposite ends of the engine cylinders, with fluid-actuated means for closing said valves, and means biassing said valves to open automatically in the absence of actuating fluid pressure; poppet valves for exhausting motive fluid from the opposite ends of the engine cylinders, with fluid-actuated means for opening said valves, and means biassing said valves to close automatically in the absence of actuating fluid pressure; and a continuously rotating master controller with valve means controlling the admission of motive fluid from said supply conduit means to the said fluid-actuated means to close said admission poppets and to open said exhaust poppets, with means for driving said master controller from said rotating shaft; so that when motive fluid is shut off from said supply conduit, the admission poppets open and by-pass the pistons in said engine cylinders through the supply conduit means, thus allowing the locomotive to drift easily, while the exhaust-poppets close and exclude gas of the exhaust region from the engine cylinders.

13. In a reciprocating engine locomotive, the combination with its engine cylinders and a ro-

tating shaft driven by the reciprocating pistons in said cylinders, of separate balanced poppet valves for admitting and exhausting motive fluid to and from said cylinders, and operating pistons for said poppet valves acted on at one side by confined leakage pressure of the fluid controlled by the respective poppet valves, valves operated by said poppet valves permitting the leakage to said pistons when the poppet valves are in one position and preventing such leakage when the poppet valves are in another position, a continuously rotating master controller with valve means controlling the admission and exhaust of motive fluid to and from the other side of said operating pistons, and means for driving said master controller from said rotating shaft.

14. In a reciprocating engine locomotive, the combination with the engine cylinders at either side of the locomotive, and a rotating engine shaft driven by the reciprocating pistons in said cylinders, of separate poppet valves associated with said cylinders for admitting and exhausting motive fluid to and from them, with fluid-actuated means for shifting said poppet valves; pilot valves movable transversely of said cylinders in paths inclined outward at an angle relative to one another, and controlling the action of operating fluid on said fluid-actuated means to open and close said poppet valves; a continuously rotating master controller shaft revolving about an axis extending lengthwise of the locomotive between said cylinders, and provided with pilot-valve-actuating cam projections at equal intervals around it; and means for driving said master controller shaft from said rotating engine shaft, at a fraction of the engine shaft speed corresponding to the intervals of the cams for each pilot valve around said master controller shaft.

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