

Aug. 8, 1950

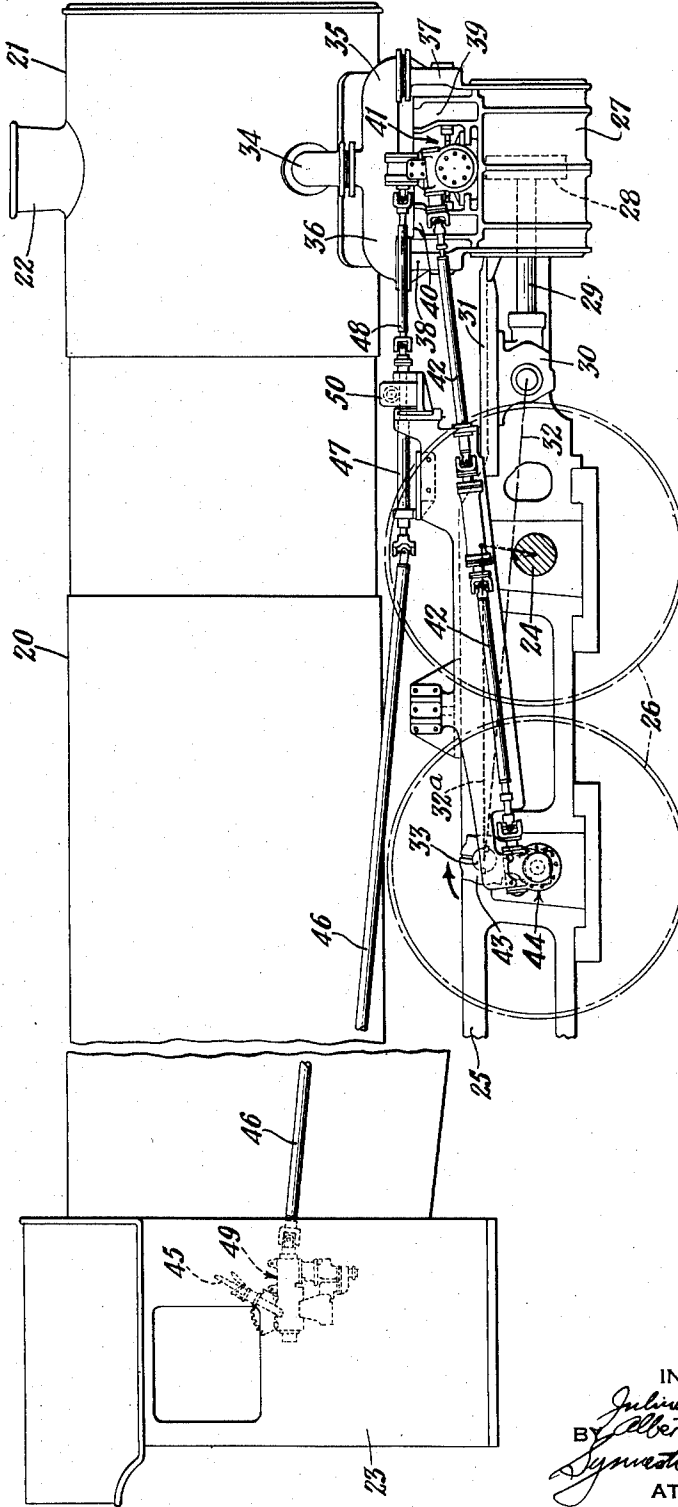
A. J. TOWNSEND ET AL
LOCOMOTIVE CONSTRUCTION PROVIDING IMPROVED
TRACTION EFFORT CHARACTERISTICS

2,518,403

Filed Sept. 13, 1947

6 Sheets-Sheet 1

Fig. 1.



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Aug. 8, 1950

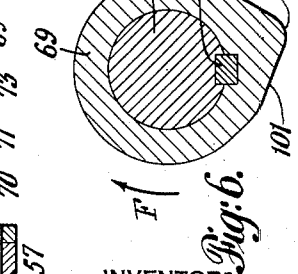
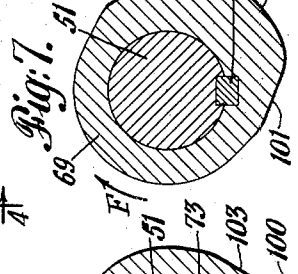
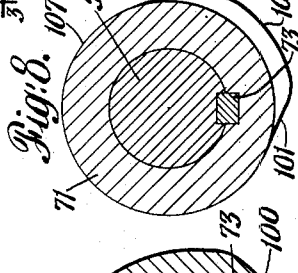
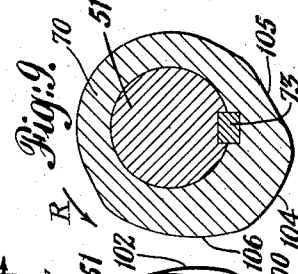
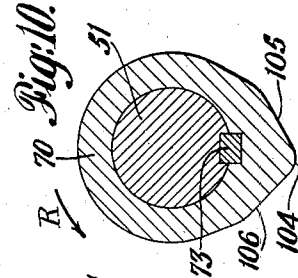
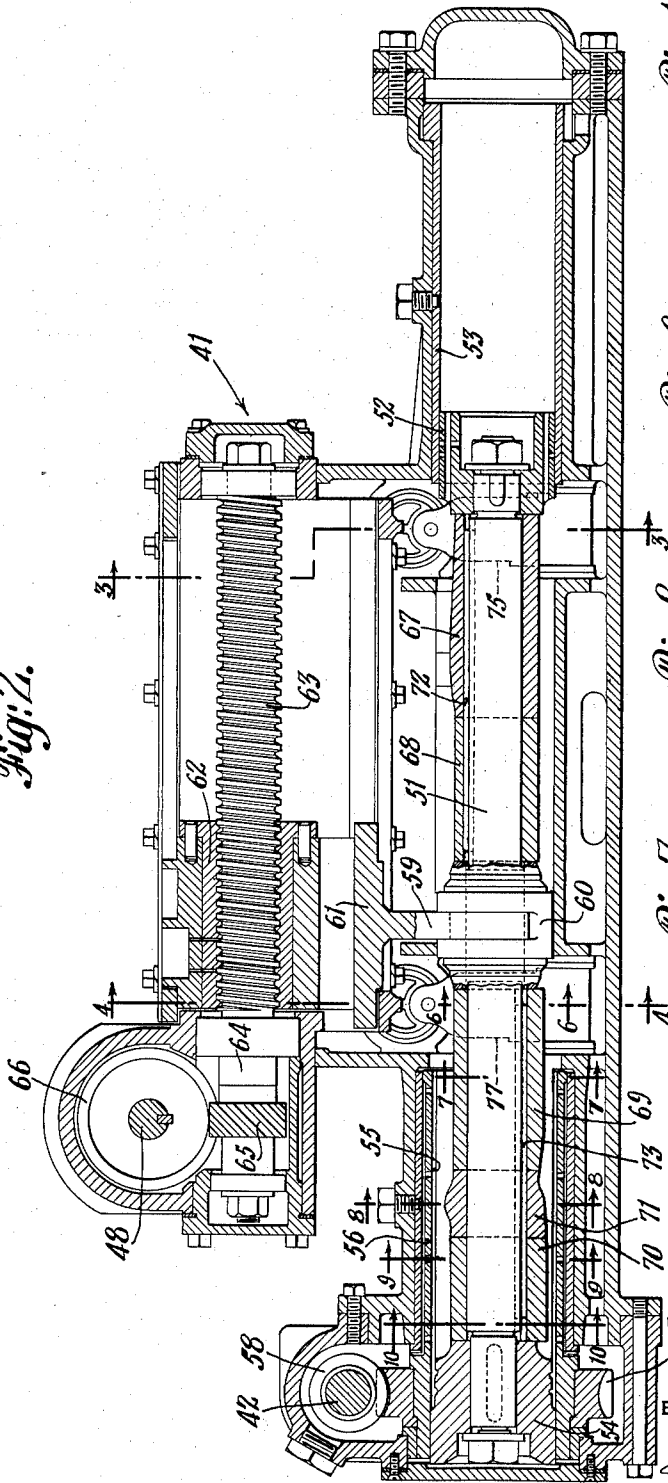
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Filed Sept. 13, 1947

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Fig. 2.



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Aug. 8, 1950

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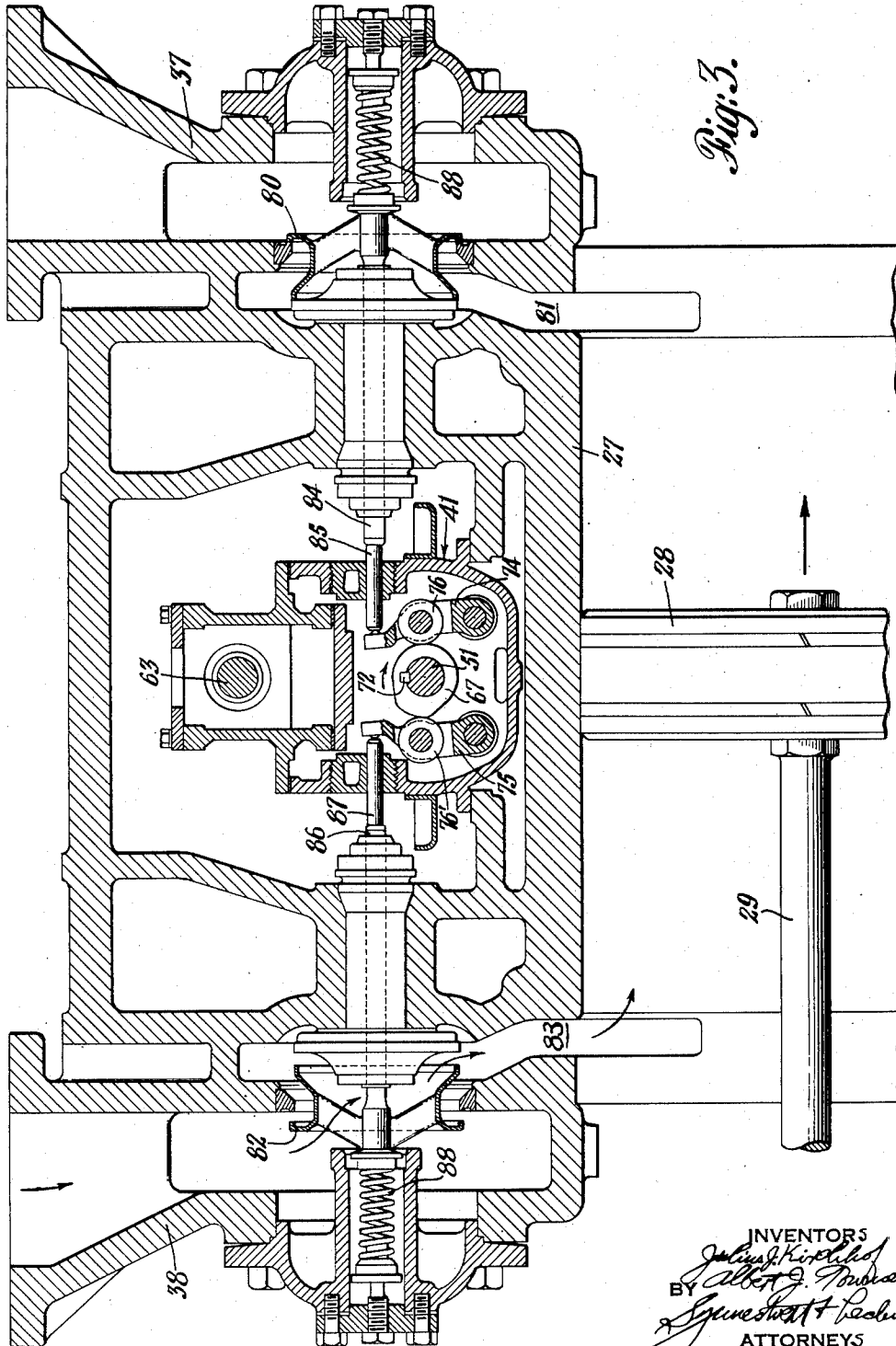


Fig. 3.

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TRACTIVE EFFORT CHARACTERISTICS

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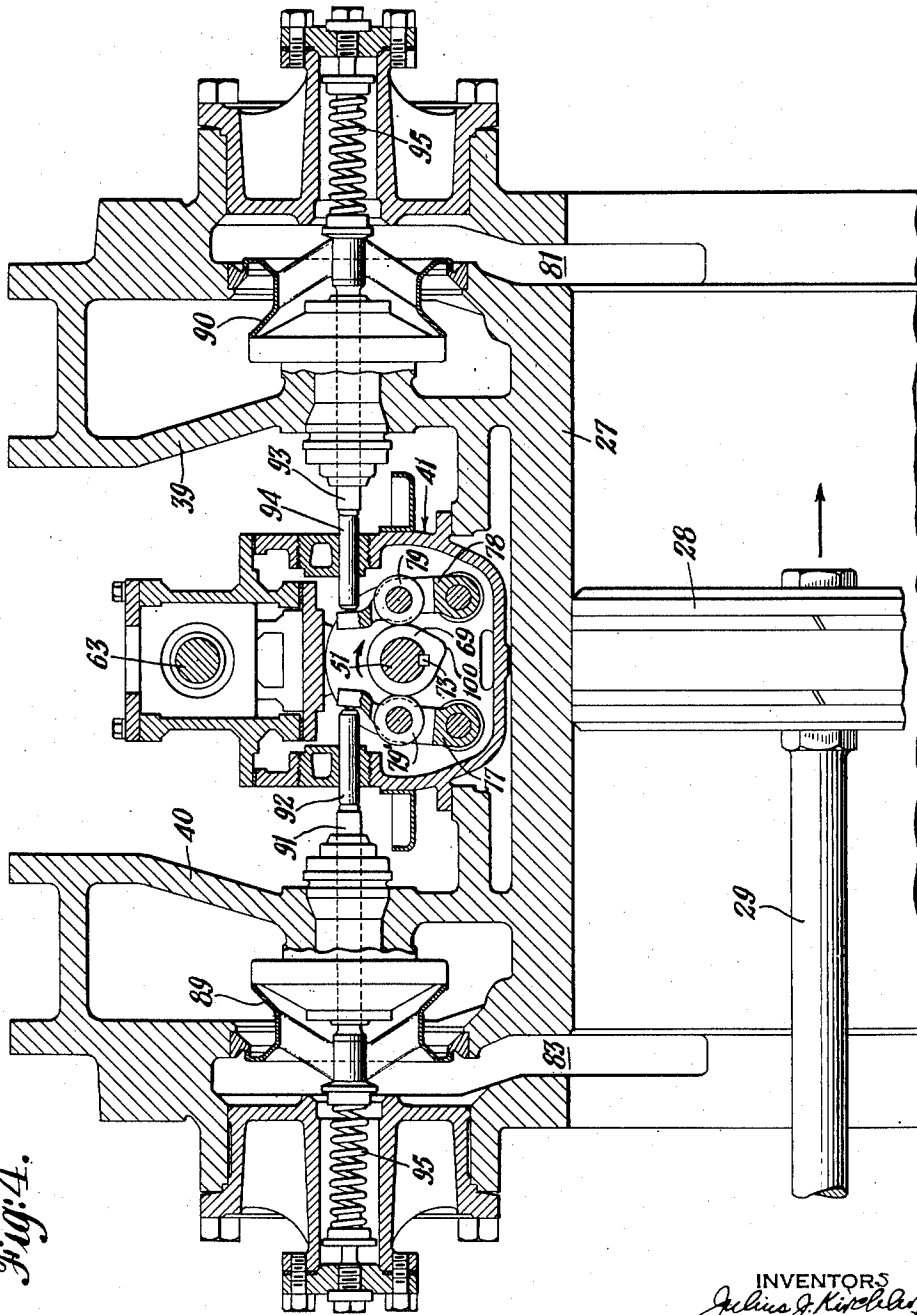


Fig. 4.

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Fig. 5.

EXHAUST CAM ASSEMBLY

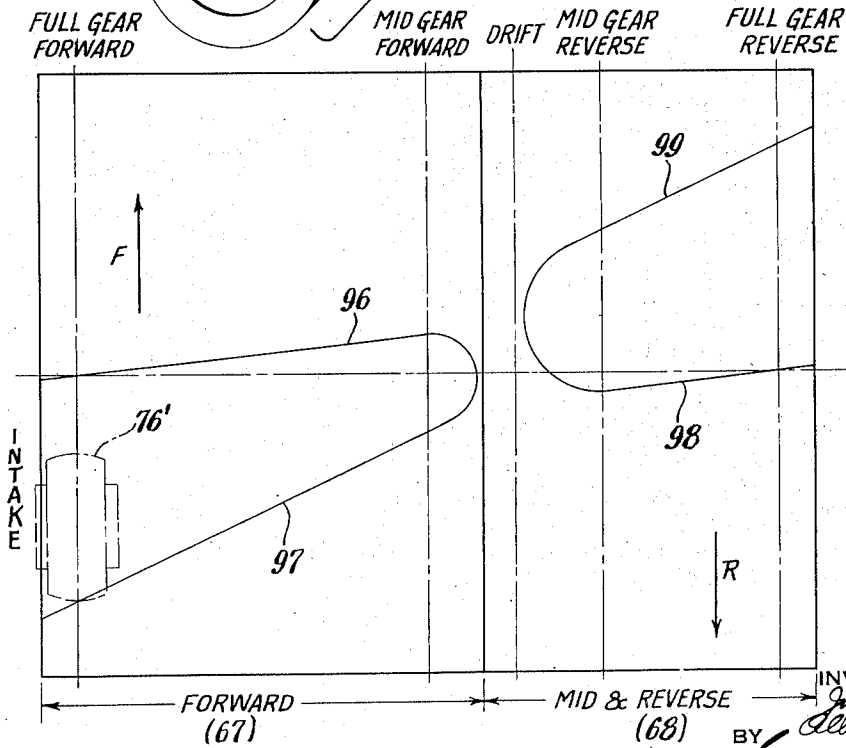
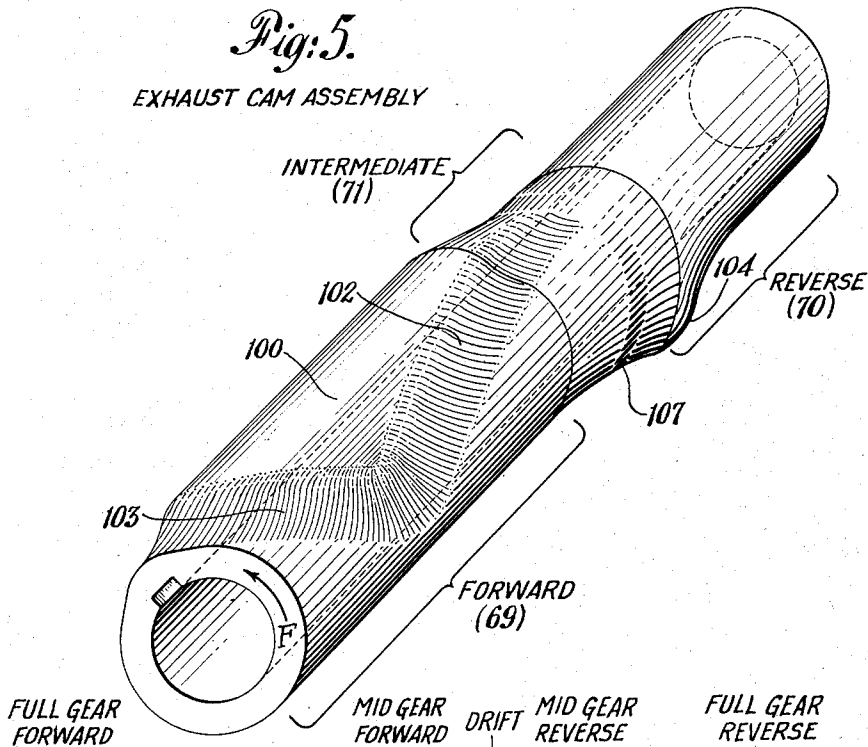


Fig. 11.

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Fig. 12.

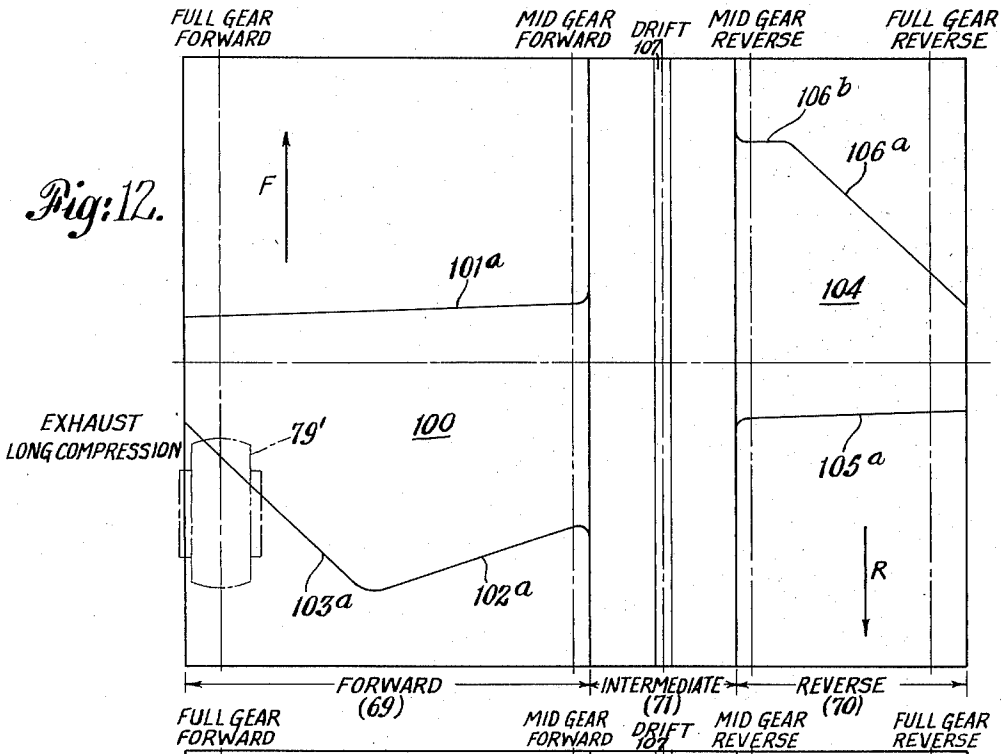
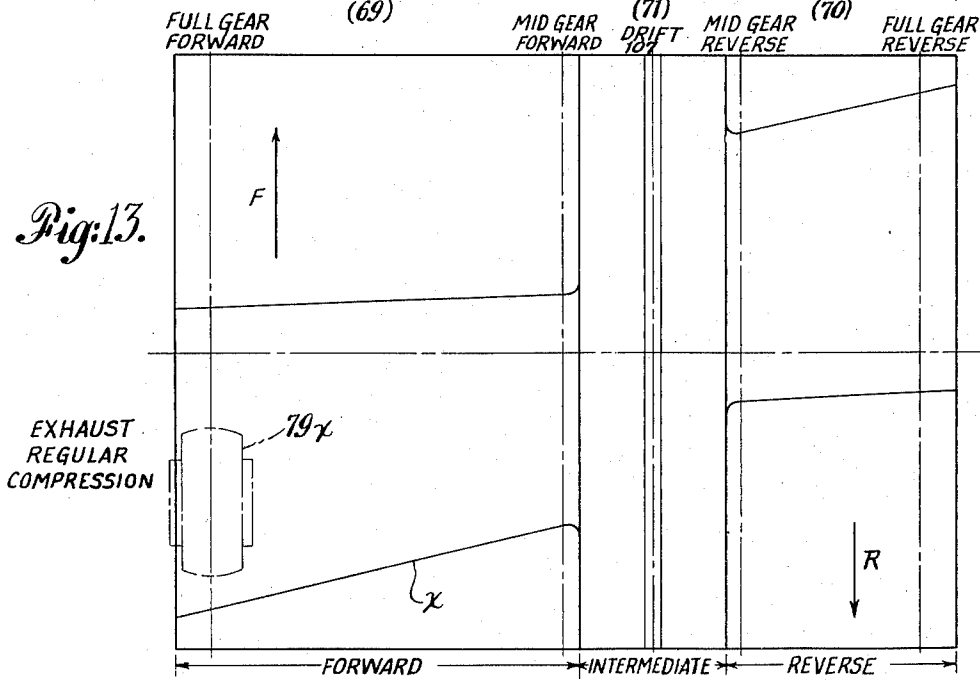


Fig. 13.



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UNITED STATES PATENT OFFICE

2,518,403

LOCOMOTIVE CONSTRUCTION PROVIDING
IMPROVED TRACTIVE EFFORT CHARACTERISTICS

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Application September 13, 1947, Serial No. 773,838

15 Claims. (Cl. 121-127)

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This invention relates to steam engines, especially locomotive steam engines of the type having double-acting cylinders and pistons, equipped with valves and control means providing for reversal of operation and also for adjustment of various valve events, such as admission, cut-off, release and compression, and in its preferred embodiment the invention involves locomotive construction providing improved tractive effort characteristics with normal manipulation of the reverse gear.

The invention is particularly directed to the provision of mechanism which will secure automatically coordinated adjustments of certain admission and exhaust valve events (notably cut-off and compression), so as to obtain in practice the best possible results from the method heretofore disclosed by one of the present joint inventors, (i. e. by Albert J. Townsend in his copending application No. 579,093, filed February 21, 1945), which method involves, among other things, the imposition of a braking force upon the locomotive engine means, at start and at low speeds, e. g. by subjecting the working steam, when the engine is operating at late cut-off, to the opposition of steam under compression in the opposite end of the cylinder, whereby the locomotive may be rendered less slippery at start and in the lower part of the speed range, and/or the average tractive power may be increased in a practical manner.

Although the said copending application points out how the said method may be practiced (to a limited degree) by manual manipulation of certain known equipment, for example, by suitable manipulations of independent reversing levers for separate admission and exhaust valve gears of the prior art (an example of which art is illustrated in the Small and Freeman Patent No. 1,512,317), the present invention contemplates obtaining, to the maximum, all of the benefits of said method, in a very much easier way, by providing an extremely simple mechanism, efficient and reliable in operation, which automatically coordinates, in any desired predetermined relationship, the admission and exhaust valve events, under the control of a single control member, such as an ordinary power reverse lever in the cab, so that the desired exhaust valve events, both for starting and slow running, and also for high-speed operation, are always secured, with no special effort or attention on the part of the engineman.

More specifically, we contemplate by the present invention the provision of such a mechanism

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which will secure the desired extended compression (at start and low operating speeds) by automatically advancing the timing of the exhaust valve closure, relative to piston stroke, when the mechanism is set to provide late cut-off of the admission valve; the mechanism being designed to do this without any substantial corresponding alteration of the release event or the admission event. Furthermore, the mechanism of the present invention effects automatically a progressive reduction of the period of compression along with a progressive reduction of the period of admission, until a predetermined cut-off adjustment has been reached, whereupon, as the cut-off adjustment is progressively further advanced, the period of compression is again lengthened, by advancing the timing of the compression event, progressively, preferably to the point of minimum or earliest cut-off adjustment (corresponding to the highest speed of operation of the locomotive).

To bring out more fully the nature and advantages of the invention, it will be helpful to review briefly some characteristic features of locomotive practice, as follows:

In a typical engine, a relatively late cut-off, say at 75 or 80% of the piston stroke (or even more) is utilized at start and at low running speeds; but the period of admission may be shortened by advancing the point of cut-off, either stepwise or continuously, to a minimum of say 25% (or, with poppet valves, say 20% or even 15% or less) of the piston stroke, the cut-off usually being progressively advanced as the running speed of the locomotive increases. Beyond the point of cut-off, the steam admitted to the cylinder works expansively, and as the cut-off is advanced to provide progressively shorter periods of steam admission, the period during which the steam works expansively is progressively increased.

The release event marks the point in the stroke at which the exhaust valve opens, and the compression event takes place at the point in the piston stroke at which the exhaust valve closes. It has of course been customary to progressively lengthen the period of compression as the running speed of the locomotive increases.

Attention is now called to the known fact that efforts to increase the tractive effort of locomotives, as by increasing the locomotive boiler pressure or the cylinder diameter, tend to cause or aggravate slipping of the driving wheels at start and at low running speeds of the locomotive, because of the resulting reduction in the factor

of adhesion. As above mentioned, at start and at low running speeds, a late cut-off is utilized, and this results in admission of steam to the cylinder at full boiler pressure throughout most of the piston stroke, including those points at which the maximum peaks occur in the starting and slow-running tractive effort curves.

With the foregoing factors in mind the present invention further has as an object the provision of an improved locomotive steam engine, of simplified construction and operation, which combines the characteristics of relatively reduced slipperiness at start and low speeds, with relatively increased average tractive effort throughout the range of running speeds and especially in the mid-portion of the operating speed range in which relatively high tractive effort is of particular advantage in facilitating acceleration of heavy trains.

Thus, the locomotive with the improved valve gear of this invention may be constructed to have a given average tractive effort, but reduced slipperiness at start and low speeds; or may be constructed to have increased tractive effort throughout the speed range, without corresponding increase in slipperiness at start and at low speeds.

To achieve this favorable combination of characteristics, the invention provides valve actuating and control means serving to extend the compression period at least under conditions of start, when the admission valve is adjusted for late cut-off, and preferably also during those adjustments of cut-off which are normally employed throughout about the lower one-half of the speed range of the locomotive, and to do this in a fully automatic manner, as least so far as coordination of the desired compression and cut-off events is concerned. In effect, this extension of the compression period applies a braking force to the piston in predetermined coordination with the maximum admission, which acts to resist initiation of wheel slippage and also to stop slipping of the wheels. Thus, in one of its broader aspects, the invention contemplates the provision of means automatically acting to apply a braking force to an operating part of the engine under conditions of starting and at low running speeds of the locomotive.

Since, according to the invention, the braking force is derived from an extension of the period of compression, the braking force is applied by the pressure of (otherwise exhausted) steam acting directly on the piston, in opposition to the steam which is then performing the working stroke, and the braking force is therefore effective not only to stop slippage but also to resist initiation of slippage.

In a typical locomotive steam engine according to the invention, the progressive adjustment of cut-off, say from 75% of the piston stroke (for starting) to 20% of the piston stroke (for high speed running), is accompanied by a predeterminedly-coordinated progressive adjustment of the period of compression from a relatively long period (for starting) to a relatively short period (for about mid-running speed), the period of compression then being again progressively lengthened (for high speed running). Advantageously the period of compression utilized with late or starting cut-off is even longer than that utilized for high speed running of the locomotive.

Still more specifically, the invention contemplates the simplest type of control means positively coordinating the adjustments of the periods

of admission and compression in the relationship above discussed, so that movement of the engineer's control, e. g., the customary reverse lever, to the "Full Gear" position will concurrently provide both late cut-off and long compression for starting, and so that subsequent movement of the control progressively toward the "Mid Gear" or neutral position will progressively adjust the periods of admission and compression, this progressive adjustment of said periods being in like sense (both periods shortened) to about the middle of the range of adjustment, and then being in opposite senses (the period of admission shortened and the period of compression lengthened) as the mid gear or neutral position is approached.

The invention further contemplates operation of this novel mechanism not only in forward operation of a reversible locomotive steam engine, but also in reverse operation, at least to the extent of an automatically lengthened compression period at late cutoff; although in locomotives especially adapted to road service where there is little running in reverse, the compression period need not be lengthened at early cut-offs.

In accordance with another aspect of the invention the foregoing features are incorporated in a locomotive engine equipped with poppet type steam distributing valves. An engine so equipped is especially suited to the attainment of the operating characteristics above described, since separately movable poppet valves are utilized for admission and exhaust of steam, and such separately movable valves may readily be actuated in the required relation to the piston stroke providing the desired predetermined interrelation between the periods of admission and compression.

Still further the invention contemplates employment of cam mechanism for actuation of the steam distributing valves, this being particularly desirable when employing poppet type valves. Cam mechanism is especially suited to the attainment of the operating characteristics described, since the desired variations of and coordinated interrelation between the periods of admission and compression may be achieved merely by utilizing appropriately shaped cams, driven in synchronism, and adjusted in common by a single manual control member. In a typical cam actuated poppet valve engine, the positive coordination of the admission and exhaust valve events in the interrelation described above is desirably accomplished by utilizing a cam shaft which is rotatively driven in timed relation with the piston movements, the cam shaft carrying cams having differently configured cam surfaces for actuating the separately movable admission and exhaust valves; the coordination of progressive adjustment of the admission and exhaust events, especially the events of cut-off and compression, being preferably accomplished by employment of cams having surfaces of varying contour axially of the cam shaft and by arranging the cam shaft for axial shifting movement to bring differently shaped portions of the cam surfaces into effective cooperation with the admission and exhaust valves.

How the foregoing and other objects and advantages are attained will appear more fully from the following description referring to the accompanying drawings, in which—

Figure 1 is an outline side elevational view of portions of a two-cylinder steam locomotive, equipped according to the present invention;

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Figure 2 is a vertical sectional view through a cam box for housing cam mechanism for actuating the valves of one of the cylinders of the locomotive engine, the view being taken in a plane transverse the locomotive and containing the axis of the cam shaft mounted in the cam box above the right hand cylinder of the locomotive;

Figure 3 is a vertical sectional view taken substantially in the plane indicated by line 3—3 on Figure 2, to an enlarged scale, and illustrating not only the cam mechanism but also an associated pair of poppet-type admission valves which are arranged one toward each end of the cylinder, a portion of which latter also is shown (but without the cylinder heads);

Figure 4 is a view similar to Figure 3 but taken in the plane of a pair of poppet-type exhaust valves, as indicated by the section line 4—4 on Figure 2;

Figure 5 is a perspective view of an exhaust cam assembly according to the invention, the view being taken from adjacent the inner end of said assembly;

Figures 6 to 10 inclusive are transverse sectional views through the exhaust cam assembly, the sections being taken as indicated by the section lines 6—6 to 10—10 on Figure 2, but being enlarged;

Figure 11 is a view somewhat diagrammatically representing a development of an intake assembly, showing also the cam follower for the crank-end intake valve, this view indicating the points in the cycle of operation of the piston in the cylinder at which the crank-end admission valve opens and closes;

Figure 12 is a development view similar to Figure 11, of an exhaust cam assembly according to Figures 5 to 10 inclusive and showing the cam follower for the crank-end exhaust valve; and

Figure 13 is a development view similar to Figure 12 but based on a different form of exhaust cam assembly.

As seen in Figure 1 the locomotive comprises a boiler 20 having a smokebox 21 toward its forward end with a discharge stack 22. The locomotive cab appears at 23 toward the left in Figure 1. Driving axles such as indicated at 24 are mounted in the main frame members 25, pairs of driving wheels 26 being associated with the driving axles. For purposes of illustration, it is assumed that the steam engine of the locomotive shown in Figure 1 incorporates a pair of double-acting cylinders, one of which appears at 27. A piston 28 reciprocates in each cylinder, each piston having a rod 29 extended through the end wall of the cylinder to the crosshead 30 which is carried by crosshead guide 31. The crosshead is adapted to be coupled by a connecting rod diagrammatically indicated at 32 with the main crank pin 33 which is associated with one of the driving axles 24. Side rods such as diagrammatically indicated at 32a serve to interconnect driving wheels.

Steam, under the control of the main throttle (not shown), is delivered through the supply pipe 34 and through branches 35—36 to the admission steam chests 37—38 at the head and crank ends of the cylinder 27. Steam is exhausted at each end of cylinder 27 through chests 39 and 40 and connected passages adapted to carry the exhaust steam for ultimate discharge through the exhaust nozzle (not shown) in the smokebox 21.

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As described more fully herebelow with particular reference to Figures 2, 3 and 4, the admission and exhaust valves employed in the chests 37—38 and 39—40 are preferably of the poppet-type, adapted to be actuated by cam mechanism mounted and housed in a cam box generally indicated in Figure 1 at 41. The cam mechanism is driven in timed relation with the reciprocating motions of the piston, for which purpose drive shafting 42 is extended forwardly to the cam box from a gear box 44 associated with a return crank 43 which is carried by the main crank pin 33. The gear box or drive unit 44 serves to drivingly couple the shafting 42 with a pin on the return crank 43 in a manner which need not be considered in detail herein since it forms no part of the present invention per se, such a drive unit, however, being fully disclosed in the copending application Serial No. 525,180, filed March 6, 1944, of one of the present applicants and one Raymond P. Delano, Jr., which application issued as Patent 2,441,199. It is here noted, however, that the drive unit 44 provides for rotation of shafting 42 in timed relation to the driving wheels of the locomotive and thus also in timed relation to piston stroke. At the end of the drive shafting 42 associated with the cam box 41, the shaft 42 is geared to the camshaft in the manner described shortly below.

As further seen in Figure 1, an engineer's reverse lever 45 is arranged in the cab 23 and provides for control of the cam mechanism by rotational adjustment of the interconnected shafts 46, 47 and 48, a power reverse gear 49 being employed for this purpose. A gear box 50 is associated with shaft 47 to provide for the connection of a transverse shaft which, in turn, is associated with a shaft similar to that shown at 48 for control of the cam mechanism for the valves of the cylinder at the opposite side of the locomotive. The manner in which shaft 48 is associated with the cam mechanism is described herebelow.

It is here noted that shafting 42 (for driving the cam shaft) and shafting 46—47—48 (for reversal and adjustment of valve events) are provided with appropriate flexible and slip joints which need not be discussed herein.

Turning now to Figures 2, 3, and 4, it will be seen that the cam box 41 serves to enclose and mount the camshaft 51. The camshaft 51 is supported for rotation and also for axial shifting movement. For this purpose, toward its right hand end, as viewed in Figure 2, the camshaft is provided with a bearing 52 adapted to rotate and slide in a bearing sleeve 53. At the opposite end of the camshaft (toward the left in Figure 2), the camshaft carries a member 54 provided with external splines adapted to cooperate with complementary splines 55 formed internally on the rotative sleeve 56. The splined connection between the parts 54 and 56 permits axial shifting movement of the camshaft but constrains the camshaft to rotate with the sleeve 56. Sleeve 56 is adapted to be driven by a worm wheel 57 fixed thereto, which worm wheel meshes with a worm 58 fixed on the shaft 42 above described.

For the purpose of shifting the camshaft axially, a depending fork 59 straddles the camshaft and engages a cooperating non-rotative member 60 which is fixed as against axial movement with relation to the camshaft but within which the camshaft may freely rotate. The fork 59 depends from a support 61 which is connected

with an internally threaded member 62 cooperating with a rotative screw threaded shaft 63. An extension 64 of this shaft has a spiral gear 65 fixed thereto, which gear meshes with a complementary gear 66 fixed on the control shaft 48 above described.

The camshaft 51 is adapted to carry cams for actuation of the admission and exhaust valves at each end of the cylinder with which the cam mechanism is associated. Thus, as seen in Figure 2 the camshaft carries an admission cam 67 for forward operation and an admission cam 68 for reverse operation; and also an exhaust cam 69 for forward operation, an exhaust cam 70 for reverse operation, together with an intermediate cam member 71 having transition surfaces interconnecting those of the forward and reverse exhaust cams. The cams for admission and for exhaust are, for convenience in manufacture, made up of the several cam members above referred to, although it should be understood that this subdivision of the admission and exhaust cams has no bearing upon the subject-matter of the present invention. The cam members 67 and 68 are desirably provided with keyways adapted to cooperate with a key 72 associated with the camshaft; and similarly the cam members 69, 70 and 71 are provided with keyways adapted to cooperate with key 73.

The cam box also serves to support intermediate or follower levers 74 and 75 carrying follower rollers 76 and 76' adapted to cooperate with the forward intake cam member 67 and the reverse intake cam member 68, according to the axial adjustment of the camshaft. Similarly, intermediate or follower levers 78 and 77 carrying follower rollers 79 and 79' are adapted to cooperate with exhaust cam members 69, 70 and 71, according to the axial adjustment of the camshaft.

The admission valves at opposite ends of cylinder 27 are shown in Figure 3, from which it will be seen that admission valve 80 controls the flow of steam from the admission chest 37 to the cylinder port 81, the admission valve 82 at the opposite end controlling admission of steam from the chest 38 to the port 83. Valve 80 has a stem 84 projecting inwardly to cooperate with the tappet 85 adapted to be actuated by the intermediate lever 74. At the other end of the cylinder, valve 82 has a stem 86 adapted to cooperate with tappet 87 which is actuable by the intermediate lever 75. Return springs 88 urge the valves 80 and 82 toward their closed positions.

The arrangement of the exhaust valves (Figure 4) is similar to that described above with reference to the intake valves. Exhaust valve 89 controls discharge of steam from the cylinder port 83 to the exhaust passage 40, the valve 90 controlling exhaust from the port 81 to the exhaust passage 39. Valve 89 has a stem 91 extended for cooperation with tappet 92 which is actuable by the intermediate lever 77; and valve 90 has a stem 93 cooperating with a tappet 94 which is actuable by the intermediate lever 78. Return springs 95 normally urge the exhaust valves toward their seats.

With the arrangement of valves and cams above described, rotation of the camshaft and the cams carried thereby serves to open and close the valves, and axial shifting movement of the camshaft serves to reverse the timing of the valve events and also to adjust the timing according to the conditions of operation of the

locomotive, for instance as between conditions of start and high running speed.

While the specific configuration of an assembly of exhaust cams according to the invention is illustrated in Figures 5 to 10 inclusive, it is not thought necessary herein to illustrate the specific configuration of an assembly of intake cams. It is noted, however, that the development view of Figure 11 diagrammatically illustrates the reversal and adjustment of timing of the events of an admission valve obtainable with a cam assembly of the type illustrated at 67-68 in Figure 2. Figure 12 similarly diagrams the reversal and adjustment of timing obtainable with an exhaust cam assembly such as shown in Figures 5 to 10 inclusive.

Referring to Figure 11, the diagram there shown represents the admission cam assembly as though the cam surfaces thereof were slit axially of the camshaft and then flattened to the plane of the drawing. The figure also shows an admission follower roller 76' superimposed upon the diagram of the cam assembly. Bearing in mind that the camshaft is axially shiftable in accordance with adjustment in position of the engineer's reverse lever 45 (Figure 1), it will be understood that such axial shifting movement effects relative shift of the cam assembly and the follower roller 76', to provide for engagement of the follower roller with the cam members at various axial positions. The position marked Drift in Figure 11 corresponds to the mid or neutral setting of the engineer's reverse lever. The operating range for forward operation of the locomotive extends between the Mid Gear Forward position and the Full Gear Forward position. A similar, though shorter, operating range is provided for reverse operation. The forward admission cam 67 is provided with a lobe the leading edge of which is indicated at 96 in the diagram of Figure 11, the trailing edge being indicated at 97. Lines 96 and 97 respectively illustrate the points, for any given axial adjustment of the camshaft, at which the admission valve opens and closes, the arrow F designating the direction of movement of the cam surfaces with respect to the follower roller 76'. Lines 98 and 99 applied to the reverse cam 68 correspond respectively to lines 96 and 97, for reverse operation, i. e., movement of the cam surfaces with respect to the follower roller 76' in the direction of the arrow R.

From the diagram of Figure 11 it will be seen that when the engineer's reverse lever is adjusted to the Full Gear Forward position the period of admission is relatively long, the cut-off (occurring along the line 97) taking place at about 75% of the stroke of the piston in one direction. As the engineer's control is adjusted toward the mid gear range, the period of admission is progressively shortened, the point of cut-off being progressively advanced to about 20% when the control is in the Mid Gear Forward position. Although the matter is not of direct concern with the present invention, it will also be seen from the diagram of Figure 11 that, as the engineer's control is adjusted from the Full Gear Forward position to the Mid Gear Forward position, the point of admission (occurring along line 96) is progressively advanced, so as to provide a limited extent of pre-admission, for purposes well understood in this art.

Referring now to Figures 5 to 10 inclusive, it will be seen that the exhaust cam 69 for forward operation is provided with a lobe 100 having a flank 101 at its leading side, and also having two

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relatively angled flanks 102 and 103 at its trailing side. Thus, upon rotation of the cam member 69 in the direction indicated by the arrow F in Figures 5 to 7 and 12 each of the follower rollers 79, 79' of the intermediate levers 78 and 77 for the exhaust valves, rides up flank 101 to the cam lobe 100 and then down one or the other of the flanks 102 and 103, depending upon the position of axial adjustment of the camshaft. The effect of this is described more fully herebelow with reference to Figure 12. Here note, however, that the exhaust cam member 70 for reverse operation similarly has a lobe 104 with a leading edge flank 105 and a trailing edge flank 106. The configuration of this reverse cam member will also be described more fully below with reference to Figure 12.

The intermediate cam member 71 of the exhaust cam assembly includes a central cylindrical surface 107 (see Figures 8 and 12) having a radius somewhat greater than that of the base circle of the cams, so as to provide for retaining the exhaust valves in partially open positions when the engineer's reverse lever is adjusted to the neutral or Drift position. The intermediate member 71 also has transition surfaces extended from the cylindrical surface 107 to the cam surfaces of the forward and reverse cam members 69 and 70.

Referring now to the diagram of Figure 12, the line 101a (applied to the exhaust cam member 69 for forward operation) indicates the point in the cycle of operation at which the exhaust valve follower roller 79' (or 79) commences to ride up upon the flank 101 of the lobe 100, thereby opening the exhaust valve. Lines 102a and 103a represent the points at which the follower roller 79' leaves the flank 102 or 103, depending upon the position of axial adjustment of the camshaft, it being understood that the associated exhaust valve closes at the time when the follower roller 79' crosses the line 102a or the line 103a.

Corresponding lines 105a and 106a are applied to the exhaust cam member 70 for reverse operation. As will be seen from the diagram of Figure 12, the lobe 104 of the reverse cam member 70 also is configured to provide a line 106b at the trailing edge of the lobe which is angled with respect to line 106a and in which region axial shifting movement of the camshaft does not appreciably alter the point at which the exhaust valve closes.

Since, in forward operation, the associated exhaust valve remains open only during the time when the follower roller 79' is riding on the cam surface between lines 101a and 102a—103a, it will be seen that in positions of adjustment toward the Full Gear Forward setting, the exhaust valve remains closed throughout the major portion of a stroke of the piston, thereby providing an extended or lengthened period of compression acting as a brake upon movement of the piston in the cylinder under the influence of steam being admitted to the opposite end of the cylinder. A similar condition prevails for reverse operation of the engine, as will readily be apparent from the diagram of Figure 12.

The diagram of Figure 13 illustrates, by way of comparison, an exhaust cam configuration arranged to provide the more conventional progressively shortened period of compression as the engineer's reverse lever is moved to the Full Gear position. Here it will be seen that the line x provides a progressively later exhaust valve closure as the engineer's reverse lever is adjusted toward the Full Gear position.

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Attention is now called to the fact that in Figures 11, 12 and 13, follower rollers 76', 79' and 79x, respectively, are illustrated in the positions they would occupy with the same adjustment of the engineer's control (Full Gear Forward), and with the cams in the same rotative position, i. e., a position corresponding to about 50% of the stroke of the piston in one direction. With the parts in the positions just mentioned, it will be seen from Figure 11 that the admission valve associated with the follower roller 76' is open and will remain open to a cut-off point at about 75% of the piston stroke. With the conventional exhaust events diagrammed in Figure 13, and with the parts in the positions mentioned the exhaust valve is open; whereas with the extended compression diagrammed in Figure 12 the exhaust valve is closed, with the parts in the positions mentioned (see valve 90 in Fig. 4).

The foregoing comparison of Figures 12 and 13 shows a marked contrast between the exhaust events conventionally employed and the exhaust events provided by the arrangement of the present invention. Thus, whereas the conventionally employed exhaust events provide a progressive decrease in the period of compression as steam admission is lengthened, according to the present invention the compression point is progressively advanced in the range of cutoff adjustments provided for low running speeds and for starting, in automatic coordination with the adjustment of the valve gear toward full-gear position.

The invention thus provides for predetermined coordination of the events of cut-off and compression in a manner utilizing compression of steam in the cylinder as a brake upon the operation of the piston at start and at low running speeds. In a locomotive of given overall tractive effort the automatic braking action effected by the mechanism of the present invention results in an increase of the factor of adhesion and thus a reduction in the slipperiness of the locomotive at start and at low running speeds. On the other hand, the benefit of the invention is exploited more fully if, at the same time, the overall tractive effort of the locomotive is increased, as by increasing the boiler pressure or the cylinder diameter. In this way, the overall tractive effort may be increased without reducing the factor of adhesion at start and at low speeds, and, moreover, the increase in overall tractive effort may be concentrated in the intermediate range of running speeds, in which such increase is of especial advantage in facilitating the acceleration of heavy trains; all of this being accomplished in a substantially automatic manner, by the mechanism of this invention, upon the usual manipulation of the ordinary reverse lever.

We claim:

1. In a fluid-pressure locomotive engine having a double-acting cylinder and piston, means for admitting working fluid alternately to the head and crank ends of said cylinder in timed relation to the opposite strokes of the piston, means for altering the effective admission of working fluid, during running of the engine, from a relatively great to a relatively lesser admission, and means for causing fluid pressure opposition to at least a portion of a working stroke of the piston which opposition is substantially greater at start than at running speeds of the locomotive.

2. In a fluid-pressure locomotive engine having a double-acting cylinder and piston, means for admitting working fluid alternately to the head and crank ends of said cylinder in timed relation

to the opposite strokes of the piston, means for altering the effective admission of working fluid, during running of the engine, from a relatively great to a relatively lesser admission, means for causing fluid pressure opposition to at least a portion of a working stroke of the piston, means for altering the effective opposition, during running of the engine, in like sense with the alteration of effective admission, and means positively effecting a predetermined coordination of said alterations.

3. In a fluid-pressure locomotive engine having a double-acting cylinder and piston, means for admitting working fluid alternately to the head and crank ends of said cylinder in timed relation to the opposite strokes of the piston, adjustable means for altering the effective admission of working fluid, during running of the engine, from a relatively great to a relatively lesser admission, means for causing fluid pressure opposition to at least a portion of a working stroke of the piston, means for altering the effective opposition, during running of the engine, in like sense with the alteration of effective admission during a portion of the range of adjustment, and means for altering said effective opposition in a sense opposite to the alteration of effective admission during another portion of the range of adjustment, and means positively effecting a predetermined coordination of said alterations.

4. In a locomotive engine having a cylinder and piston, and valve means for effecting admission, cut-off, release and compression of the steam with respect to both the head end and the crank end of said cylinder in timed relation to the piston stroke, valve gear mechanism actuating said valve means comprising means for altering the timing of the cut-off from a relatively late cut-off to a relatively earlier cut-off with respect to each end of the cylinder, and means for effecting a relatively long compression with said late cut-off and a relatively shorter compression with said earlier cut-off, and a common control for all of said means.

5. In a steam locomotive engine having a cylinder and piston, and valve means for effecting admission, cut-off, release and compression of the steam with respect to both the head end and the crank end of said cylinder in timed relation to the piston stroke, valve gear mechanism actuating said valve means comprising means for altering the timing of the cut-off from a relatively late cut-off to a relatively earlier cut-off with respect to each end of the cylinder, means for effecting a relatively long compression with said late cut-off and a relatively shorter compression with said earlier cut-off, and means for effecting substantially normal timing of release with both said late and earlier cut-offs, and a common control for all of said means.

6. In a locomotive engine having a cylinder and piston, and valve means for effecting distribution of the steam with respect to both ends of said cylinder variably at least as to cut-off and compression with relation to the piston stroke, valve gear mechanism actuating said valve means comprising means for altering the timing of the cut-off from a relatively late cut-off to an intermediate cut-off and thence to a relatively early cut-off, and means for effecting a relatively short compression with said intermediate cut-off and a relatively long compression with each of said late and early cut-offs, and, for the last two mentioned means, adjusting mechanism

common to both whereby their operations are automatically effected in positively predetermined relationship.

7. In a locomotive engine having a cylinder, and valve means for effecting distribution of the steam with respect to both ends of said cylinder variably as to admission, cut-off, release and compression, valve gear mechanism actuating said valve means comprising means for effecting progressively longer compression with progressively earlier cut-off through a substantial portion of the range of cut-off adjustment and means positively coordinated therewith for effecting progressively longer compression with progressively later cut-off through another portion of the range of cut-off adjustment.

8. In a locomotive engine having a cylinder, and valves for effecting distribution of the steam with respect to both ends of said cylinder variably as to admission, cut-off, release and compression, valve gear mechanism actuating said valves comprising means for effecting progressively earlier timing of the admission, cut-off and release throughout a predetermined range, means for effecting progressively longer compression with progressively earlier cut-off through a substantial portion of the range of cut-off adjustment, and means for effecting progressively longer compression with progressively later cut-off through another portion of the range of cut-off adjustment, and a single control for adjusting all of said means together.

9. In a locomotive engine having a cylinder and piston, and valve means for effecting admission, cut-off, release and compression of the steam with respect to both the head end and the crank end of said cylinder in timed relation to the piston stroke, valve gear mechanism actuating said valve means comprising means for altering the timing of the cut-off from a relatively late cut-off to a relatively earlier cut-off with respect to each end of the cylinder, and cam means for controlling release and compression comprising a rotatable cam and a cam follower relatively shiftable with respect to each other axially of the cam, the cam having a lobe with a helical flank providing relatively long compression with said late cut-off and a relatively shorter compression with said earlier cut-off.

10. A construction according to claim 9 and further including means positively coordinating relative shifting of the cam and cam follower with timing of cut-off.

11. In a locomotive engine having a cylinder and piston, and valve means for effecting admission, cut-off, release and compression of the steam with respect to both the head end and the crank end of said cylinder in timed relation to the piston stroke, valve gear mechanism actuating said valve means comprising means for altering the timing of the cut-off from a relatively late cut-off to a relatively earlier cut-off with respect to each end of the cylinder, and cam means for controlling release and compression comprising a rotatable cam and a cam follower relatively shiftable with respect to each other axially of the cam, the cam having a lobe of greater circumferential dimension in an intermediate region lengthwise of the cam as compared with the circumferential dimension thereof in regions toward each end thereof.

12. A construction according to claim 11 and further including means positively coordinating relative shifting movement of the cam and cam follower with timing of cut-off.

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13. In a locomotive engine having a cylinder and piston, and valve means for effecting admission, cut-off, release and compression of the steam with respect to both the head end and the crank end of said cylinder in timed relation to the piston stroke, cam mechanism for actuating said valve means comprising a rotatable cam axially shiftable to alter the timing of the cut-off from a relatively late cut-off to a relatively earlier cut-off with respect to a working stroke of the piston, and a rotatable cam axially shiftable to effect a relatively long compression with said late cut-off and a relatively shorter compression with said earlier cut-off.

14. A construction according to claim 13 and further including means positively coordinating axial shifting movements of said cams.

15. For a locomotive valve gear adapted to operate separate admission and exhaust valves, a cam assembly comprising an admission cam with a progressive surface adapted to effect a progressive change in admission valve closure from late closure to early closure, and an exhaust cam with two oppositely progressing surfaces which

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are adapted sequentially to effect an early closure of exhaust valve means in conjunction with the aforesaid late closure of the admission valve means, a later closure of said exhaust valve means during an intermediate portion of the range of operation of said admission cam, and again a relatively early closure of said exhaust valve means in conjunction with said early closure of the admission valve means.

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