CONSTRUCTION AND OPERATION

1. Introduction.—All the wheels of a locomotive are capable of exerting traction, thereby developing drawbar pull, provided that a turning force can be imparted to them. The general practice has been to use only the driving wheels for this purpose, and make no use of the trailing truck or the tender truck wheels. The steam pressure in the cylinders is transmitted through the main rods to the main drivers, from which the turning effort is transmitted to the other drivers through the side rods. Obviously, only wheels of the same diameter, and hence of the same circumferential speed, can be connected by side rods, and this makes it impossible to couple up the wheels of the trailing truck, which carry a considerable part of the weight of the locomotive, to the rear driving wheels. Therefore, a turning impulse must be imparted to the truck wheels by other means, as by the locomotive booster.

2. Purpose.—The purpose of the locomotive booster is to increase the drawbar pull of the locomotive. It is a simple non-reversible two-cylinder engine, which is mounted on the trailing truck, and is so arranged as to transmit through a system of gears a turning impulse to the trailing-truck wheels, when cut into service. A greater drawbar pull is required to start trains than to haul them, therefore the use of the booster enables heavier trains to be started, and thereby increases the hauling capacity of the locomotive. Also, the booster makes it possible to start trains more smoothly, to bring them up to
speed more quickly, and to pull trains on grades where a helper otherwise would be required.

3. Types of Boosters.—The first type of locomotive booster, manufactured by the Franklin Railway Supply Company, Inc., was known as the type C. A later type was known as the C-1, and a still later type as the C-2. The principal difference in the different types is in the booster control or the parts concerned with the cutting-in and the cutting-out of the booster. Only the type C-2 locomotive booster will be treated here.

4. Names of Parts.—A view of the locomotive booster mounted on the trailing truck, together with the various valves and the piping necessary for its operation, is shown in Fig. 1. The names of the valves are as follows: Booster throttle valve and throttle operating cylinder, located in the steam-inlet pipe to the booster; the preliminary throttle valve, piped to the cab turret; the dome pilot valve in the steam-inlet pipe; and the reverse-lever pilot valve, located at the reverse lever.

The exhaust pipe to the booster engine, which is only partly shown, is placed on the right side of the locomotive, and the steam-inlet pipe is placed on the left side. Hence Fig. 1 shows the piping as viewed from the right side with the boiler removed. The exhaust pipe at the rear is flexibly connected to an exhaust manifold on the right side of the booster, and the steam-inlet pipe is connected to a similar manifold, not shown, on the other side of the booster. With the arrangement shown in Fig. 1, the booster engine is operated by superheated steam taken from the steam chests of the locomotive.

5. General Arrangement.—In Fig. 2 (b) is shown the arrangement, at the front end of the locomotive, of the steam pipe through which steam is conveyed to the booster engine, as well as of the exhaust pipe that conveys the steam away from the booster engine. An opening is provided in each steam chest, into which are screwed the fittings a, connected by the pipe b so that steam will be drawn equally from each steam chest. The steam-inlet pipe c, view (a), is connected to the
pipe \( b \) by a steel \( T \), and leads back along the left side of the locomotive to the booster engine. The exhaust pipe \( d \), on the right side of the locomotive, conveys the exhaust steam from the booster engine to the exhaust pipe. A steam separator \( e \) with a drain pipe is installed in the exhaust piping, and a drain pipe \( f \) is also tapped into the pipe \( b \). Flexible joints are provided at \( a \) and \( b \), Fig. 1, in the exhaust piping as well as at the upper end of the vertical length \( c \), so that this pipe as well as the pipe to the manifold, can accommodate themselves to the varying positions of the booster as the trailing truck is rounding curves or is moving up and down on its springs. The steam-inlet pipe is also provided at the rear with three flexible joints similar to the joints in the exhaust piping. The steam and exhaust pipes have an internal diameter of 3½ inches.

Three air pipes are connected to a manifold \( d \), which in turn is connected to the booster by means of the flexible air hose shown. One pipe leads to the reverse-lever pilot valve, another leads to the dome pilot valve with a branch to the throttle operating cylinder of the main booster throttle, and the third pipe connects to the timing reservoir and then leads to the dome pilot valve. The air supply for the operation of the various valves is taken from the main reservoir through the pipe \( f \) that connects to the reverse-lever pilot valve. An air pipe \( g \) connects the reverse-lever pilot valve to the preliminary throttle valve, and a steam pipe \( h \) leads from this valve to the steam-inlet pipe to the booster; also, a pipe connects the preliminary throttle valve to the cab turret. A pipe that leads to the lubricator and another that leads to the steam gauge are tapped into the steam-inlet pipe.

6. General Operation of Booster.—The complete locomotive booster comprises two principal units, the booster engine and the booster control. It will be found more convenient when studying the general operation of the booster to disregard the booster control and consider the booster engine only. A conventional arrangement of the booster engine that will make the arrangement and general operation of this part more
easily understood is shown in Fig. 3. The booster engine bed, which is represented by the lines \(a\), is placed on the frame of the trailing truck, indicated by the lines \(b\). The engine bed makes a bearing with the cross-member of the truck frame at \(e\) and with the trailing-truck axle at \(c\) and \(d\). The bearing at \(e\) is spherical and is so arranged that as the trailing-truck axle tilts on curves and moves momentarily independent of its frame, the booster engine bed can roll freely on the point \(e\). The booster engine proper consists of two steam cylinders \(g\) and two steam chests \(g'\) with pistons and valves and connecting-rods as shown, the latter being connected to cranks on the crankshaft \(h\). The valve rods are connected through rockers \(r\) and eccentric rods \(s\) to eccentric on the crank-shaft cranks. The cylinders are bolted to the engine bed and the crank-shaft turns within the bearings \(i\) in the bed. A gear \(j\) is cut on the crank-shaft \(h\), and a gear \(k\) is pressed on to the trailing-truck axle. An idler gear \(l\) is connected to an idler-gear rocker \(m\) that is pivoted at \(n\).

7. When the locomotive is running with the booster cut out, all the parts of the booster engine are stationary and the trailing-truck axle \(f\) turns freely within the bearings \(d\) and \(c\) of the engine bed. As soon as the booster is cut in, steam enters the steam chests and is distributed by the valves to the cylinders, as with any steam engine. The pistons accordingly are moved to and fro in the cylinders, and the connecting-rods transmit a turning movement to the crank-shaft \(h\) and the gears \(j\) and \(l\), in the direction shown by the arrows. At about this time, air is admitted to the clutch cylinder \(p\), the piston within it is forced up and the idler gear \(l\) is brought into mesh with the trailing-truck axle gear \(k\). The idler gear now connects the two gears \(j\) and \(k\), hence the force exerted by the booster engine in turning the shaft \(h\) is transferred through the gear \(k\) on the trailing-truck axle to the trailing-truck wheels, thereby converting them into driving wheels. The arrow on the trailing-truck axle gear shows its direction of movement. The booster is cut out by releasing the air from the cylinder \(p\), the spring \(q\) then returns the piston to release position, and the
idler-gear rocker pulls the idler gear \( l \) out of mesh with the gear \( k \).

8. Booster Engine Not Reversible.—The booster runs in one direction only and cannot be reversed; that is, the booster, when cut in, will assist the locomotive to move forwards, but will oppose any movement of the locomotive to move backwards. The eccentrics cranks and hence the valves of the booster engine are so set that the crank-shaft \( h \), Fig. 3, and the crank-shaft gear turn in the direction shown by the arrow when the booster is cut in. This causes the idler gear \( l \) and the trailing-truck axle gear \( k \) to turn in the direction shown by their arrows and a turning impulse will be imparted to the trailing-truck wheels with the locomotive moving forwards. Therefore, it is useless to cut the booster in when running backwards because its turning impulse is then contrary to the direction of motion of the locomotive. The booster when operated according to instructions cannot be cut in when backing up.

**DESCRIPTION OF PARTS**

**BOOSTER ENGINE**

9. Engine Bed.—The engine bed of the booster engine rests on the trailing truck. A perspective view of the engine bed is shown in Fig. 4 (a) and a view of the axle bearing cap is shown in (b). The engine bed is covered on the sides and the top by cover-plates, here shown removed.

The engine bed is carried on the trailing truck on three points, two of which are on the trailing-truck axle and the third one on the cross-member of the trailing-truck frame at the rear. Suitable bearings are provided in the engine bed at the two points where it is carried on the axle. The bearing at the rear is spherical and it therefore permits a free movement of the booster on the cross-member of the frame according as one or the other of the trailing-truck wheels raises or lowers. Owing to this movement, the lubrication of this bearing should not be neglected.

The engine bed is held in position on the axle by the axle bearing cap. This cap is also provided with bearings so that,
when bolted in place, the bearings in the cap and in the bed constitute two complete bearings that encircle the trailing-truck axle.

10. The engine bed is secured to its spherical bearing on the cross-member of the truck frame by a pin that passes through the opening \( a \), Fig. 4 \((a)\). The cylinders of the booster engine are bolted to the face \( b \) of the bed, and the openings \( c \) are provided for the valve rods, and the openings \( d \) for the
piston rods. The crosshead guides are shown at \( e \) and the half bearings for the booster engine crank-shaft are shown at \( f \); the large gear on the trailing-truck axle projects into the opening \( g \) in the engine bed. The engine bed on the top and sides is covered by a casing that is held in position by studs and nuts.

A side view of the front part of the engine bed is shown in Fig. 5, with the axle bearing cap \( b \) bolted to it by the bolts and studs \( c \). Each end of the axle bearing cap is provided with an oil cellar, the outline of one being shown by the dash line \( d \). Each oil cellar is connected to the trailing-truck axle through a slot \( e \) that is cut through the bearing in the axle bearing cap. The cellars are filled with oil-soaked waste through the two covers \( f \) that are held closed by the springs \( g \). Each cellar can be drained of oil by removing a plug \( h \), but the plug has only to be turned part way out to allow any water that may have accumulated to drain out. With the top and side cover-plates
applied, the engine bed becomes an oil-tight case, so that the splash method of lubrication is employed to lubricate all the moving parts of the engine except the pistons and the valves. Car oil is used, and this is poured in through two oil-filling plugs, placed at the back outside corners of the back top cover-plates. Two oil overflow drain cocks at the front end of the engine bed indicate the height at which the oil should be maintained. Before replenishing the oil supply, the oil plugs in the crank-pits and the axle bearing cap should be backed out a turn or two to permit any water to drain out through the small holes in the plugs. The oil plugs should not be removed unless necessary to drain off the oil.

11. Cylinder Casting.—A perspective view of the cylinder casting that contains the cylinders and the steam chests as viewed from the rear is shown in Fig. 6. No front cylinder heads are used, the front ends of the cylinders being made in one piece with the casting. This construction permits the part of the casting that contains the cylinders to be bolted directly to the engine bed, thereby providing a fastening directly in line with the main thrust of the pistons. The back ends of the cylinders are closed by cylinder heads, and the steam chests are closed by large plugs a, which are screwed into the casting. The covers c are connected to the cylinder heads as shown. The plugs b were formerly used for core fixing and cleaning when casting but are not found in the latest castings.

The steam from the steam pipe enters the casting through the inlet manifold and thence passes through passages in the casting to the steam chests. The exhaust steam passes from the cylinders through passages in the casting to the exhaust manifold and to the exhaust pipe. The inlet and exhaust manifolds are separate and are bolted to the cylinder casting. The cylinders are 10 inches in diameter; the stroke is 12 inches.

12. Crank-Shaft and Crank-Arms.—A perspective view of the crank-shaft h, Fig. 3, and the crank-arms, is shown in Fig. 7. The crank-shaft and the gear a are made in one piece; that is, the shaft is forged with a raised portion in the center in which the gear-teeth are then cut. The bearing parts of the
shaft, or the parts adjacent to the crank-arms $c$, turn partly in the bearings in the engine bed and partly in the caps that, when bolted in position, secure the shaft to the bed. The crank-arms $c$ and their pins on which the connecting-rods $d$ are mounted, are made in one piece. The crank-arms, which have counterbalances $a$, are pressed onto the ends of the crank-shaft and each is further secured by two keys. Each eccentric crank $f$ is secured to its crankpin by a four-key spline $d$, Fig. 8, that passes through and meshes with keyways machined in the crankpin. The eccentric crankpin $g$, Fig. 7, is made in one piece with the eccentric crank.

13. Valve Gear.—A view of the valve gear of the booster engine is given in Fig. 8. The valve gear for each cylinder comprises an eccentric crank, an eccentric rod, a rocker-arm, a
wristpin block, a valve stem, and a valve. The valve stem can be lengthened or shortened by driving out the tapered pin \( a \), loosening the locknut \( b \), and then turning the valve stem in the proper direction in the wristpin block. No packing rings are used on the valves, which are inside admission. The part \( c \) of the rocker-arm rotates in a bearing in the engine bed. The valves of the booster engine are set to cut off the admission of steam to the cylinders at either 75 per cent. or 50 per cent. of the stroke. In the latter case the valves are modified so as to obtain the same cylinder pressure when starting as with the longer cut-off, but after the speed increases slightly the valves then operate at a 50-per-cent. cut-off. With this valve arrangement, the booster engine is said to have the limited cut-off feature. The reason for the use of this feature is the large saving in steam that results, which more than offsets the lesser power developed by the booster, especially at low speeds.

14. The changes in the valve necessary to obtain a 50-per-cent. cut-off when running at speed, and a long cut-off when starting' is shown in Fig. 9. In this connection it should be remembered that an increase in the steam lap of a valve shortens the cut-off and that a decrease lengthens it. In Fig. 9 the valve has a steam lap, that is, the inside edges of the valve
extend over the ports; also these portions of the valve have been reduced at \( a \).

With the valve moving slowly as when starting the booster, the effect of the reduced portion of the valve will be the same as if the steam lap had been reduced, because the steam will continue to pass by the reduced end even after the edge \( b \) moves over the edge \( c \). In this case the edge \( d \) governs the cut-off. With the valve moving more rapidly, as when the speed of the booster increases, the steam does not have as much time to pass by the part \( a \); the edge \( b \) then governs the cut-off, which is thereby reduced, because the valve is now operating with a greater steam lap than at slow speed.

**BOOSTER CONTROL SYSTEM**

15. Purpose. The purpose of the booster control system, which comprises an arrangement of valves, piping, and other parts, is to provide a means of cutting the booster into and out of operation. The parts that make up the booster control system, shown in section, as well as the air piping arrangement, is shown in Fig. 10. The parts comprise the idler-gear rocker, the idler gear, and the clutch cylinder, all of which parts are in the engine bed: the reverse-lever pilot valve, the preliminary throttle valve, the dome pilot valve, the main booster throttle with a throttle-operating cylinder, and the cylinder-ock operating cylinder.

16. Idler-Gear Rocker and Gear.—The purpose of the idler-gear rocker is to move the idler gear into and out of mesh with the gear on the trailing-truck axle. The purpose of the idler gear is to cut the crank-shaft gear into and out of mesh with the gear on the trailing-truck axle.

A perspective view of the idler-gear rocker with the idler gear mounted on it is shown in Fig. 11. The idler gear turns on a shaft \( b \) that is held in the rocker by a bolt in each end. The idler-gear rocker is connected to the engine bed by a pin \( a \), Fig. 10, that passes through the opening \( a \), Fig. 11. The relation of the idler gear to the crank-shaft gear and the trailing-truck axle gear is shown in Fig. 10. The idler gear is always
in mesh with the crank-shaft gear, but the idler gear meshes with the gear on the trailing-truck axle only when the booster is cut in. In such an event the idler gear connects the crank-shaft gear with the trailing-truck axle gear, thereby transferring the force that the booster engine is transmitting to the crank-shaft, to the trailing-truck axle gear and to the trailing-truck wheels. At this time the idler-gear rocker carries the idler gear into mesh with the trailing-truck axle gear when cutting in the booster. When the booster is being cut out, the idler-gear rocker carries the idler gear out of mesh with the trailing-truck axle gear.

17. Clutch Cylinder.—The purpose of the clutch cylinder is to move the idler-gear rocker and bring the idler gear into mesh with the trailing-truck axle gear. An exterior view of the clutch cylinder is shown in Fig. 12. The clutch cylinder is placed in position by inserting the upper cylindrical portion up through an opening in the bottom of the engine bed, where it is secured by bolts through the bolting flange. The cap nut \(a\) is prevented from turning by the locking arrangement \(b\).
A sectional view of the clutch cylinder as well as a part of the idler-gear rocker is shown in Fig. 13; the only moving part is the piston $j$. The passages $a$ and $b$ in the engine bed connect with the passages $c$ and $d$ in the clutch cylinder when the latter is bolted in place. This arrangement permits the clutch cylinder to be removed and applied without disturbing the pipes. The clutch cylinder cannot be applied without the air passages in the engine bed matching with the air passages in the clutch cylinder, owing to the fact that the rear clutch-cylinder stud in the engine bed between the air ports is longer than the other studs. The gasket $e$ prevents leakage between the air passages, and care should be taken when applying the gasket to see that the holes in the gasket match with those in the engine bed. Otherwise, one or both ports will be blanked and the booster will not operate.

The idler-gear rocker is brought back to normal position after operation by the two clutch springs $f$, the lower ends of which rest in shoes cast with the rocker. The springs are housed in the clutch-spring retainer $g$, which is bolted to the engine bed. The springs are held in place by retainer caps $h$. 
which are prevented from backing off by wire locks \( i \) through the caps and the retainer casting.

18. The admission of compressed air to the clutch cylinder through the passage \( c \) forces the piston \( j \) upwards as in Fig. 13 (a), and causes it to engage the lifting post \( k \) in the idler-gear rocker \( l \), thereby lifting the rocker and bringing its gear into mesh with the trailing-truck axle gear. The upward movement of the rocker also places the clutch springs under compression.

The upward movement of the piston uncovers the ports \( m \) in the bushing and permits the air to pass to passage \( d \) and to the dome pilot valve and the throttle-operating cylinder. Any leakage by the piston is prevented by its seating airtight on the gasket \( n \). When the air is exhausted from the clutch cylinder through the pipe that connects to passage \( a \), the clutch springs force the idler-gear rocker and the piston back to normal position, as in view (b). The air in passage \( b \) and in the piping connected to it passes around the central part of bushing \( o \), which is machined below its fit diameter, and escapes through the ports \( p \) in the bushing and the open end of the cylinder to the atmosphere. The ports \( p \) are closed by the piston when it moves upwards and the air that enters around the bushing at this time from ports \( m \) is prevented from escaping.

19. When the gear on the idler-gear rocker and the gear on the trailing-truck axle are fully in mesh, there is a clearance of from \( \frac{1}{16} \) inch minimum and \( \frac{1}{8} \) inch maximum between the top of the pin \( q \), Fig. 13 (a), in the piston and the lifting post \( k \). Therefore, the piston does not carry the rocker gear into complete mesh with the trailing-truck gear; it merely carries the rocker a portion of its travel from release to application position, and the rocker travels the remaining distance owing to the idler gear pulling itself fully into mesh by hooking under a tooth of the axle gear. The piston in the clutch cylinder is then held against the gasket by air pressure only. The forward movement of the rocker is limited by the flat faces of the idler-gear bearing pin, Fig. 11, striking the rocker stops in the engine-bed casting when the gears are completely in mesh.
The backward movement of the rocker is limited by the integral shoes for the clutch springs striking the machined pad on the engine bed.

The fact that the engagement of the gear-teeth is relied on to bring the gears into mesh causes the idler-gear rocker to move back and forth when the booster is removed from the trailing-truck axle and air is applied to the clutch cylinder. The reason is that when the axle gear is not present the clutch springs are of sufficient strength to cause the lifting post to move the piston away from its seat on the gasket. The release of the air that follows allows the rocker to return to its back stop, but the air pressure on the piston again moves the rocker
to its forward stops. This movement will continue unless the rocker is held in forward position by the hand.

20. **Arrangement at Reverse Lever.**—The arrangement of the parts at the reverse lever whereby the booster is cut in and out is shown in Fig. 14. The arrangement comprises a booster latch $a$, pinned on the reverse lever, a latch lever $b$, pinned to a steel plate fastened to the forward end of the reverse-lever quadrant, and a reverse-lever pilot valve $c$, which is also bolted to the steel plate. These parts control the cutting in and out of the booster in the following manner: With the reverse lever at or near the forward corner of the quadrant, Fig. 15, and with the booster latch $a$ raised as shown, the latch lever will be forced against and will depress the spring cage $d$ in the reverse-lever pilot valve. This action will result in the
admission of compressed air to the control system, and the booster will begin to operate.

The booster latch will remain in contact with the latch lever and the booster will continue to operate until the reverse lever has been drawn back to about a 66-per-cent. cut-off, as shown in Fig. 14. The booster latch then drops out of contact with the latch lever, and the spring cage returns to normal position. This action causes the compressed air to be exhausted from the control system and the booster is cut out of operation. Therefore, the booster cuts in when the spring cage is depressed and cuts out when the spring cage seats.

With the Precision reverse gear, Fig. 16, the reverse-lever pilot valve is applied as shown, and the booster latch $a$ is placed on an extension arm of the indicator block. With the indicator block at or near the forward corner, the booster latch when raised will engage with and depress the spring cage $d$, thereby cutting in the booster. As the indicator block is moved back by turning the hand wheel, the booster latch will drop out of contact with the spring cage and the booster will stop operating. The booster latch, if desired, can be knocked down out of contact with the latch lever at any time, hence the reverse lever does not always have to be drawn back to disengage the latch.

21. Reverse-Lever Pilot Valve.—The purpose of the reverse-lever pilot valve is to admit compressed air into the
control system of the booster when the booster latch is raised, thereby bringing about the operation of the various valves necessary to put the booster to work. Also, the reverse-lever pilot valve, when the booster latch is lowered or knocked down, exhausts the compressed air from the control system and causes the various valves of the system to so operate as to cut out the booster. An exterior view of the reverse-lever pilot valve in the proper position to be applied to the Precision power reverse gear is shown in Fig. 17. The valve handle $a$ is used to operate a plug valve called the idling valve. This valve has two positions; running position, with the handle as shown, and idling position, with the handle vertical. These two positions are indicated by the raised letters and the arrows on the body of the valve. Idling position is used to warm the booster engine up before cutting it into service. For example, before
the booster is to be used, the handle of the idling valve is placed in idling position. The booster engine then begins to turn over without going into gear with the gear on the trailing-truck axle. After the engine is warmed up, the handle is returned to running position, and this position when the booster latch is raised cuts the booster engine into gear with the trailing-truck axle gear. The booster latch cannot be raised when the handle of the idling valve is in idling position.

**Fig. 18**

**22.** A sectional view of the reverse-lever pilot valve is given in Fig. 18. Three pipes are connected to the valve; one pipe leads to the clutch cylinder, another to the preliminary throttle valve, and the third to the main reservoir. The reverse-lever pilot valve comprises the following parts: A spring cage $a$, a valve pusher $b$, and a pusher spring $c$, all held in position in the cage by the nut $d$; an inside check-valve with an
enlarged circular lower end, the bottom of which rests on the end of the valve pusher and the top of which makes a seat with the bushing above it when the valve closes; an outside check-valve \(e\), a check-spring \(f\), and a locking piston \(i\). As the spring cage is raised by the pressure of the booster latch against its projecting lower end, the inside check-valve is moved up against its seat by the valve pusher \(b\), and in so doing lifts the outside check-valve \(e\) from its seat. Then any further movement of the spring cage will carry the nut \(d\) upwards, with the result that the spring \(c\) will be compressed, thereby holding the inside check-valve firmly to its seat through contact with the valve pusher \(b\). With the outside check-valve unseated, the main reservoir will be connected to the clutch-cylinder pipe and the preliminary throttle-valve pipe. The spring cage will be forced back to normal position by the pusher spring when the booster
latch drops down; the inside check-valve will then open and the outside check-valve will close. With the inside check-valve open, the preliminary throttle-valve pipe and the clutch-cylinder pipe are connected through port $g$ to the atmosphere. With the idling-valve handle turned to idling position, the plug cock shown turns and connects the main reservoir pipe to the preliminary throttle-valve pipe, also air from the main reservoir passes through passage $h$ behind the locking piston $i$ and moves it forwards against the spring cage, preventing it from being depressed.

23. Preliminary Throttle Valve.—The purpose of the preliminary throttle valve is to admit a limited amount of steam to the booster engine when starting it. The preliminary admission of steam not only turns the engine over slowly and warms it up, but it also causes the idler gear to turn and exert enough tooth pressure to pull it into mesh with the trailer gear when both gears are brought into contact. The preliminary throttle valve also provides a safe means for idling the booster for inspection.

A sectional view of the preliminary throttle valve is shown in Fig. 19. Port $a$ is connected by an air pipe to the reverse-lever pilot valve, a steam pipe from the cab turret is connected at $b$, and a pipe connects the opening $c$ to the steam-inlet pipe.

The admission of compressed air above the piston $d$ forces it down to a seat at $e$ and prevents the leakage of any air that may pass by the packing ring. The downward movement of the piston compresses the spring $f$ and moves the spring seat down to its seat at $g$, at the same time opening the steam valve $h$. When the air pressure is released, the spring $f$ returns the piston to normal position, and the spring $i$ moves the spring seat upwards, thereby closing the steam valve. An opening, not shown, is provided to permit any steam to escape that may leak by, owing to a failure of the spring seat to make a joint at $g$.

24. Dome Pilot Valve.—The dome pilot valve controls the opening and the closing of the cylinder cocks. When starting the booster, the dome pilot valve delays the closing of
the cylinder cocks long enough to insure that the cylinders are free of water. Also, when cutting out the booster, the dome pilot valve exhausts the compressed air from the cylinder-cock piping, and permits the cylinder cocks to open.

The dome pilot valve as shown in the sectional view in Fig. 20 has three pipes connected to it. The pipe *a* leads to the throttle operating cylinder of the main booster throttle, the pipe *b* leads to the clutch cylinder, and the pipe *c* leads to the
cylinder-cock operating cylinder. The threaded end of the valve is screwed into the steam-inlet pipe that leads to the booster. The top of the valve is joined to the bottom by four ribs, hence the central portion of the valve is open to the atmosphere through the openings between the ribs.

To understand the action of the dome pilot valve, it must be remembered that the cylinder cocks of the booster engine close when compressed air is admitted to the cylinder-cock operating cylinder pipe, and that they open when the air is exhausted from the pipe.

In normal position of the dome pilot valve as shown, the cylinder-cock operating cylinder pipe $c$ is connected by way of the unseated inside check-valve $d$ to the atmosphere; therefore the cylinder cocks are open. The outside check-valve $f$ is held closed by its spring. The clutch-cylinder pipe $b$ and the throttle operating-cylinder pipe $a$ are always connected by a passage above the outside check-valve.

When starting the booster engine, the preliminary throttle valve opens, the engine begins to turn over slowly, and any condensed water in the cylinder discharges through the cylinder cocks, which are now open. At the same time air passes from the clutch-cylinder pipe $b$ to the throttle operating-cylinder pipe $a$, thereby causing the throttle operating cylinder to begin to open the booster throttle valve. Steam then enters passage $g$ in the dome pilot valve, forcing the piston $h$ upwards, and causing the valve pusher $i$ not only to close the inside check-valve $d$, but to open the outside check-valve $f$. Compressed air then passes from the clutch-cylinder pipe $b$ through a $\frac{1}{32}$-inch port $j$ in the outside check-valve bushing to the cylinder-cock operating cylinder pipe $c$ and causes the cylinder cocks to close. Therefore, the cylinder cocks remain open until steam begins to pass to the booster engine in a good volume.

The inside check-valve is held closed by the pressure of the pusher spring $k$ under the valve pusher, and thereby prevents the air in the cylinder-cock operating cylinder pipe from escaping to the atmosphere. When the booster is cut out, the steam pressure decreases in passage $g$ and the action of the springs $l$ and $m$ return the piston $h$ to normal position. The
outside check-valve \( f \) closes and unseats the inside check-valve \( d \), the air in the cylinder-cock operating cylinder pipe \( c \) escapes to the atmosphere past valve \( d \), and the cylinder cocks open, owing to the fingers pushing the balls from their seats.

25. **Booster Throttle Valve.**—The purpose of the booster throttle valve is to control the steam supply to the steam-inlet pipe that leads to the booster engine. The throttle valve is operated by the throttle operating cylinder.

A view of the throttle-valve body partly broken away so as to show the throttle valve \( a \) and the operating cylinder \( b \) is shown in Fig. 21. The valve rod \( c \) is pivoted to an arm of the operating lever \( d \) that is connected to the valve operating shaft \( e \) on the inside of the valve body. On the outside, the outside rocker-arm \( f \) connects the operating shaft to the end of the spring guide \( g \) that operates within the piston \( i \) in the operating cylinder.

The admission of compressed air through port \( h \) on top of the piston \( i \) forces the piston down until its seat and the bushing seat are in contact. The escape of air is thus prevented, although there may have been leakage past the piston ring. The spring guide is carried down with the piston, compressing the spring \( j \) and moving the end of the outside rocker-arm downwards, thus opening the throttle valve. When the air is
released, the spring carries the piston and the end of the outside rocker-arm upwards, thus closing the throttle valve. The spring guide has a spherical surface contact with the piston, which permits free piston movement.

The proper lift of the throttle valve is $\frac{5}{8}$ inch, and is governed by the travel of the piston. The valve operating lever and the outside rocker-arm are of the same length and this facilitates measuring and adjusting the valve lift from the outside.

Air should be used in the operating cylinder when adjusting the valve lift. If the throttle valve is opened by any other means the correct lift will not be obtained. To decrease and increase the valve lift, the adjusting nut $k$ should be screwed upwards and downwards, respectively. The steam supply can be shut off from the throttle valve by closing the turret valve $l$.

26. Cylinder-Cock Operating Cylinders. The cylinder-cock operating cylinders, Fig. 10, one on each side, are secured to bolting lugs on the booster cylinders. They are operated by an air pressure to allow the cylinder cocks to close when the booster is in operation, after the water has been blown from the pipes and cylinders, and to open the cylinder cocks when the booster is not in operation.

Each operating cylinder is provided with a compact operating-rod arrangement for two cylinder cocks. The rear end of the piston rod is connected to a piston-rod block $d'$ which in turn connects to the operating rod $e'$. The two finger blocks $f'$ carry the operating fingers shown.

In allowing the cylinder cocks to close, the air enters through the pipe $y$ and forces the piston $z$ backwards until the bevel face of the piston makes a joint against its seat in the bushing. The operating fingers then release the ball valves and the steam pressure forces the balls to their seats in the cylinder-cock bushings.

In opening the cylinder cocks, the air is released from the cylinder, and this allows the spring to force the piston and the operating fingers forwards, thereby unseating the ball valves against the steam pressure and opening the cylinder cocks.
The forward movement of the piston continues until the integral valve on the rear finger seats against the seat on its cylinder cock. The valve on the front finger seats, owing to the pressure of the spring in the counterbored portion of the front finger block.

The operating cylinders are interchangeable to either side of the booster. The cylinder cocks are rights and lefts and are not interchangeable to opposite sides of the booster but are interchangeable to front and back on the same side.

OPERATING INSTRUCTIONS

27. Taking Over Engine.—The following instructions should be observed when the crew takes over an engine at a terminal: (a) Set the booster feed for at least two drops per minute to lubricate the cylinders and the valves. (b) Open the lubricator feed for about 2 minutes before cutting in the booster, and keep the feed open while the booster is in operation. (c) See that the preliminary shut-off valve at the steam turret is open wide. (d) See that the booster heater valve is open. This valve should be kept open constantly summer and winter to prevent condensation from forming in the pipes and cylinders and possibly freezing in extremely cold weather. The heater valve also makes prompt operation of the booster possible when it is cut in, as well as to assist in proper lubrication of the cylinders and valves. (e) See that the turret valve in the booster throttle valve is open. (f) See that the booster air line is open. (g) Idle the booster for 2 or 3 minutes before leaving the terminal.

28. Starting the Booster.—Before the booster latch can engage with the latch lever and start the booster, the reverse lever must be between a 66-per-cent. cut-off and the forward end of the quadrant. Then to start the booster, raise the booster latch until it engages the latch lever. Do not cut the booster in at speeds above 12 miles per hour or permit it to remain cut in at speeds greater than 21 miles per hour. Under no conditions is the booster to be used when backing up because the booster engine is designed to turn the trailing-truck wheels in the for-
ward direction only. Should the trailer wheels slip, knock down the booster latch and do not cut in again until the slipping has stopped.

29. Stopping the Booster.—To stop the booster, either draw the reverse lever back until the latch lever drops down, or if it is not desired to change the cut-off by moving the lever, knock the booster latch down. Always cut out the booster before coming to a stop so as to permit the gears to disengage. If the stop is made with the booster cut in, knock down the booster latch, then move the locomotive ahead a few feet and the gears will disengage.

30. Idling the Booster.—To idle the booster, that is, to cause the booster engine to work but not to be in gear with the trailing truck, turn the handle of the idling valve to idling position. The booster should be idled whenever possible before cutting it in.

31. Taking Slack.—When taking the slack with the booster cut in, the engineman should wait, after the reverse lever is moved back, until the hand on the booster steam gauge shows no pressure. The slack can then be taken in the usual way.

32. Cylinder Cocks.—If it is desired to have the cylinder cocks remain open for a longer time than the operation of the cylinder-cock control will permit, turn the handle of cock \( b' \), Fig. 10, to a vertical position.

33. Keeping Booster Engine Warmed Up.—To keep the booster engine warmed up when not in use, open the heater needle valve, Fig. 10.

34. Leaving Locomotive at Terminal.—When leaving the locomotive at a terminal, shut off the booster lubricator, and close the booster air-line valve in the main reservoir pipe.
35. Cutting In the Booster.—The passage of the compressed air and the operation of the various valves when cutting the booster into operation is as follows: With the cock in the main-reservoir pipe open, compressed air passes above the outside check-valve \( b \), Fig. 10, in the reverse-lever pilot valve. Raising the booster latch \( c \) depresses the spring cage \( d \) and results in the inside check-valve being closed and the outside check-valve \( b \) being opened. The compressed air then passes through the pipe \( f \) to the preliminary throttle valve, and also through the pipe \( g \) to the clutch cylinder. The admission of compressed air to the preliminary throttle valve moves its piston down and unseats the steam valve \( h \). Steam then passes from the steam-turret pipe to the pipe \( i \) and thence through the choke \( j \) to the pipe \( k \) and to the steam chests of the booster engine, which accordingly begins to turn over slowly. The passage of air to the clutch cylinder moves the piston \( l \) upwards, and causes the idler-gear rocker to turn on the pin \( a \) and bring the idler gear into mesh with the gear on the trailing-truck axle. However, there is not yet sufficient steam pressure in the cylinders to cause the booster engine to exert traction on the trailing-truck wheels, and the trailing-truck gear can be regarded at this time as driving the booster engine.

36. The upward movement of the piston in addition to raising the idler-gear rocker, also opens port \( m \), Fig. 10, and permits the compressed air to flow through pipe \( n \) and pipe \( p \) through the dome pilot valve and through pipe \( o \) to the throttle operating cylinder. The admission of air to the throttle operating cylinder depresses the piston \( r \) and opens the main booster throttle \( s \). The steam then passes through the steam pipe \( k \) to the steam chests of the booster engine, which accordingly begins to transmit a turning impulse to the trailing-truck gear and to the trailing-truck wheels.

The cylinder cocks of the booster engine, which up to this time have been open, are now caused to close in the following manner: As soon as the steam pressure in the steam pipe \( b \)
becomes high enough to compress the piston spring \( t \), in the dome pilot valve, the piston in the dome pilot valve lifts, and the inside check-valve \( v \) seats, and thereby unseats the outside check-valve \( q \). This permits the air to pass through the \( \frac{1}{2} \) inch drilled hole in the bushing to pipe \( w \), the timing reservoir, and thence through the pipes \( x \) and \( y \) to the cylinder-cock operating cylinders. The piston \( z \) moves backwards and draws the operating fingers away from the balls \( a' \), which accordingly seat and stop the discharge of steam from the cylinders. The fact that the air passes through a small port in the outside check-valve \( q \) as well as through the timing reservoir, delays the building up of sufficient pressure to allow the cylinder cocks to close until a certain elapsed period of time.

If desired, the closing of the cylinder cocks can be delayed for any length of time by turning the handle \( b' \) of the three-way cock vertical. This permits the air that ordinarily would pass to the cylinder cock operating cylinder to pass instead to the atmosphere and the cylinder cocks will not close until the handle is turned back to its original position.

37. Cutting Out the Booster. The discharge of air from the piping and the action of the various valves when cutting out the booster are as follows: When the booster latch \( c \), Fig. 10, drops or is knocked down, the spring cage \( d \) returns to its normal position, thereby causing the inside check-valve to unseat and the outside check-valve \( b \) to seat. The air in the pipe \( g \) and in the clutch cylinder escapes to the atmosphere through the port marked *atmosphere* in the reverse-lever pilot valve, the clutch spring then depresses the idler-gear rocker, and the idler gear is pulled out of contact with the trailing-truck axle gear. With the piston back in its normal position, the air in the pipes \( n, o \), and \( p \) exhausts to the atmosphere around the lifting post \( c' \), and this causes the spring to move the piston \( r \) in the throttle operating cylinder back to normal position, thereby closing the main booster throttle. The decrease in steam pressure in the steam pipe \( k \) when the main booster throttle closes, causes the piston \( u \) in the dome pilot valve to return to normal position, thereby opening the inside check-valve...
valve $v$ and closing the outside check-valve $q$. The air in the cylinder cock piping then passes by the unseated inside check-valve $v$ to the atmosphere and the spring in the cylinder-cock operating cylinder moves the piston $z$ forwards, thereby opening the cylinder cocks.

38. Idling the Booster.—To idle the booster, thereby warming it up preliminary to cutting it in, the handle of the idling valve is turned to idling position. In this position, the passage from the main reservoir pipe connects to the pipe that leads to the preliminary throttle valve, Fig. 10. Compressed air then opens the preliminary throttle valve, and allows steam from the steam turret to idle the booster.

With the plug cock in idling position, air is admitted through passage $h$, Fig. 18, behind the piston $i$, which moves forwards and prevents the spring cage $a$ from being depressed by the booster latch. This indicates that the idling valve handle must be returned to running position before the booster can be cut in.

THE TENDER BOOSTER

39. The tender booster is designed to utilize the adhesion of a pair of the tender-truck wheels, for traction, when the locomotive has no trailing truck. The booster engine, which is of the same type as already described, is mounted on a front tender truck of special design, and is geared to the rear axle of this truck.

As there is not sufficient weight on the wheels of the ordinary tender truck to prevent slipping when the booster is cut in, the equalizers on the forward truck are arranged so that a greater portion of the weight is carried on the rear wheels and less on the front wheels. As an added precaution against slipping, the back truck wheels are connected to the front truck wheels by side rods. Therefore any tendency for the rear wheels to slip will be prevented by the resistance offered by the front wheels.
40. Air Leaks in Piping.—The air piping should be maintained perfectly tight. Air leaks, if bad enough, will prevent the booster from being cut in; slight leaks will interfere with cutting in the booster properly, but such leaks will assist in the cutting-out of the booster.

41. Gauge Shows Pressure After Cutting Out.—If considerable pressure still shows on the booster gauge after the booster latch has been knocked down, the main booster throttle is partly open or leaking badly. It is not advisable to operate the booster with this disorder, and the turret valves in the steam pipe to the preliminary throttle valve and to the main booster throttle should be closed.

42. Booster Does Not Start.—If the booster does not start when the latch is raised, the turret valves at the main booster throttle valve may be closed, or the preliminary throttle shut-off valve or the valve in the air line may be closed. A bad leak by the packing ring of the piston in the operating cylinder may also prevent the throttle from opening.

43. Gears Do Not Disengage.—If the gears do not disengage when the booster latch is knocked down, with the locomotive in motion, and with little or no pressure on the gauge, either the preliminary throttle valve or the main booster throttle valve is leaking. If in doubt, close the turret valve at both throttles and do not attempt to use the booster until repairs have been made. With the gears engaged, and the booster engine working owing to a leaky throttle, the pressure on the gears is sufficient to hold them in mesh even with no air in the clutch cylinder.

44. Hobnobbing of Gears.—If a continuous hobnobbing of the gears occurs when the locomotive is moving, the spring seat of the clutch cylinder or the spring is probably broken, and the booster should not be cut in until repairs have been made.

45. Booster Idles at High Speed.—If the booster idles at high speed when the locomotive throttle is opened and the
booster latch is down, the trouble is due to the main booster throttle valve not seating properly. The booster should not be used until repairs have been made.

46. Cylinder Cocks Will Not Close.—A failure of the cylinder cocks to close may be due to any of the following reasons: The small hole drilled through the bushing in the dome pilot valve may be closed by dirt or scale, there may be leakage in the air lines to the cylinder-cock operating cylinders, or there may be a bad leak in some part of the control system, some part of the cylinder-cock operating rigging may be binding, or the cylinder-cock cut-out cock may not be closed to the atmosphere.

47. Pistons Stuck.—With the locomotive tied up for some time, as when in the back shop, the pistons of the booster engine are liable to stick in the cylinders, owing to rust, and the booster may be damaged when cut in. A liberal quantity of oil should be introduced into the cylinders whenever there is any likelihood of the booster being out of service for any length of time.

48. Blow at Reverse Lever Pilot Valve.—A blow at the exhaust port of the reverse-lever pilot valve, with the booster cut out is an indication that the outside check-valve is leaking. A blow when the booster is cut in indicates that the inside check-valve leaks.

49. Blow at Dome Pilot Valve.—A blow of air at the dome pilot valve for a brief interval before the booster starts to operate indicates leakage by the outside check-valve. A blow at this port with the booster in operation indicates leakage by the inside check-valve. A leak of steam indicates that the packing ring on the steam piston is leaking or that the piston is not steam-tight on its seat.
EXAMINATION QUESTIONS

Notice to Students.—Study the Instruction Paper thoroughly before you attempt to answer these questions. Read each question carefully and be sure you understand it; then write the best answer you can. When your answers are completed, examine them closely, correct all the errors you can find, and see that every question is answered; then mail your work to us.

(1) Name the valves used with the booster.

(2) What is the purpose of the idler-gear rocker?

(3) What is the purpose of the booster?

(4) On what part of the engine bed are the oil-filling plugs located?

(5) How is the height at which the oil is to be maintained, indicated?

(6) What is the purpose of the booster control system?

(7) Should the booster be used when backing up?

(8) Name the positions of the idling-valve handle, and give the purpose of each position.

(9) What is the purpose of the preliminary throttle valve?

(10) Explain how to start the booster.

(11) Explain how to stop the booster.

(12) What instructions should be observed with regard to the booster when taking an engine over at the terminal?
(13) Where should the trouble be looked for if the booster will not start?

(14) What should be done if the gears do not disengage?

(15) What should be done if the gauge shows pressure after the booster is cut out?

(16) What is the cause of the hobnobbing of the gears?

(17) What is wrong when the booster idles at high speed?

(18) What must be done in order to have the cylinder cocks remain open?

(19) Explain how to take the slack with the booster cut in.

(20) What booster valves should be closed when leaving the engine at the terminal?

Mail your work on this lesson as soon as you have finished it and looked it over carefully. DO NOT HOLD IT until another lesson is ready.