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NOTE.—This book is made up of separate parts, or sections, as indicated by their titles, and the page numbers of each usually begin with 1. In this list of contents the titles of the parts are given in the order in which they appear in the book, and under each title is a full synopsis of the subjects treated.

LOCOMOTIVE BREAKDOWNS

LOCOMOTIVE APPLIANCES

LOCOMOTIVE BREAKDOWNS

Serial 2510 — Edition 1

PROCEDURE IN EVENT OF BREAKDOWNS

1. In the event of a breakdown on a busy line, the most important factor is to clear the track in the shortest possible time. The movement of traffic on a modern railroad is so closely coordinated that even a brief closing of the main track means the loss of many hundreds of dollars. Therefore, in the event of a breakdown employes are expected to make every effort to get the train into clear on a siding. Minor damage that may occur in moving the locomotive is not considered; the clearing of the track is considered of first importance. Of course, good judgment must be used and, if there is a strong possibility that further damage might occur and cause a total failure, the engine should not be moved. However, even with quite a serious breakdown, the locomotive, if moved slowly, can often be run to a siding with comparative safety.

Breakdowns can be largely prevented by an inspection at intermediate stops. Particular attention should be paid to the rods and brasses, especially the front-end main-rod brasses, because they are comparatively small and hence liable to break. The keyway in the piston rod at the crosshead, the tires, and in fact all moving parts, should be inspected as far as time will permit. Inspection is especially important when the speed at which modern locomotives are run is considered.

Modern locomotives are not equipped with tools that will permit of repairs in the event of a breakdown; usually the tool equipment comprises a wrench, a hammer, and a chisel.

2. If the breakdown is not too bad, men with the proper equipment are sent out from the terminal to make repairs; heavy breakdowns have to be handled by the tool car. In the latter class are such serious breakdowns as broken driving axles, engine-truck axles, trailing-truck axles, or tender-truck axles. Also, the tool car will have to be sent for in the event of such breakdowns, as broken crankpins, or failures involving heavy work such as the removal of some or all of the rods.

The fact that the locomotive is being put in a condition, by the crew of the tool car, to proceed under steam or to be towed, does not relieve the engineer, in the absence of the road foreman, of his responsibility for the care of the locomotive. Therefore, he should have a knowledge of the correct procedure to be followed in all cases either for his own guidance or for the tool-car foreman's and thus avoid censure for damage that might otherwise occur while the locomotive is being moved.

It is difficult to lay down the exact procedure to follow in many cases of locomotive breakdowns, because the extent of the damage that actually occurs varies and depends on the speed and other factors. The best that can be done in such cases is to outline the general principles that should be followed.

The instructions outlined in this text are considered good practice, but, regardless of this, the rules of the road concerning breakdowns must always be followed.

FAILURES THAT MAY OCCUR

BROKEN OR BURNED-OFF GRATE BARS

3. To avoid delaying the train when the grate bars are broken or burned off, provided only one or two of them are damaged, the opening should be covered, when possible, with fishplates or pieces of iron that will keep the live fire from falling into the ash-pan. If such are not available use the tank cover. If the fire must be cleaned before the terminal is reached, care must be taken not to disturb the plates over the hole. On arriving at the terminal, the disabled grate should be reported so that repairs can be made.

BURST TUBE

4. The Federal law prohibits the plugging of a burst tube unless a plug is applied at each end with a rod connecting the plugs so that they cannot be blown out. Therefore, when a tube bursts, nothing can be done, and the locomotive has to be towed in. Proper precautions should be taken in cold weather to drain all parts that contain water.

BROKEN CYLINDER HEAD

5. If the front cylinder head should break, disconnect the valve gear and secure the valve in mid-position. The main rod may be left up.

In the event of a broken back cylinder head, if the guides are not badly damaged, take down the main rod, block the crosshead all the way forwards, and secure the valve in mid-position. This procedure must also be followed, if, when the front cylinder head breaks, the cylinder is also damaged.

If the guides are badly damaged, the crosshead must be blocked securely in such a manner as to prevent it from moving in and striking the front crankpin or side rod.

BLOCKING OF VALVES

6. When necessary to block a valve, as in the event of a failure of the valve gear or some other cause, it is generally considered the best practice to secure the valve in mid-position or as nearly in mid-position as possible, instead of leaving one port open slightly for the entry of steam to lubricate the cylinder. With the port open slightly and the main rod up, the steam in the cylinder acts at times in opposition to the movement of the piston and sets up undesirable stresses; also, with the valve blocked to admit steam to one end of the cylinder, the other end is connected to the exhaust passage, from which smokebox gases will be drawn during the complete stroke. This action will probably neutralize whatever lubrication is obtained from the admission of steam. If the cylinders have been receiving proper lubrication the locomotive can be run a considerable

distance without damage to the cylinder, but if lubrication is necessary it can be applied through the indicator plug openings in the cylinders.

In the absence of a setscrew in the crosshead guide, the quickest way to secure the valve is to slacken off the nuts on the bolts of the outside guide, Fig. 1, then drive in a brake-shoe key or a thin wooden wedge between the guide and the crosshead,

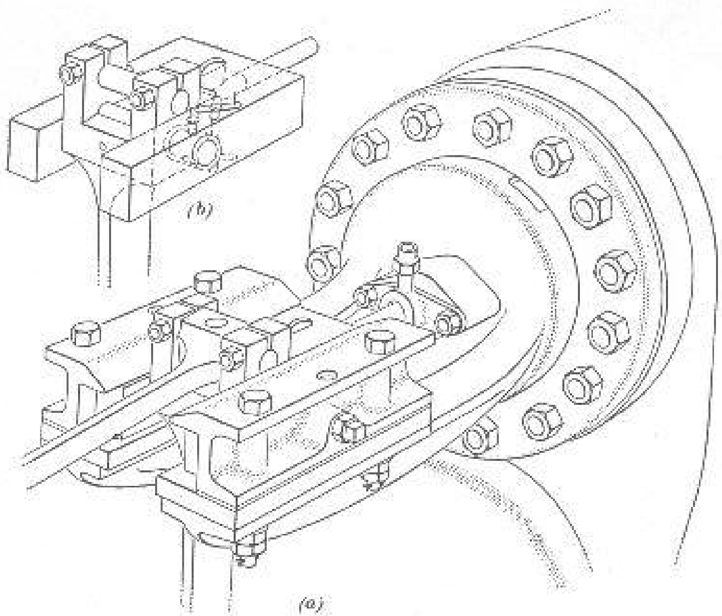


FIG. 1

and tighten the nuts. If enough side play exists between the guide and the crosshead, the key or wedge may be driven in between the two. If desired, the valve can also be secured by driving a wooden wedge between the valve stem and the gland.

The valve can be easily moved to its required position, after the eccentric rod has been removed, by moving the lower end of the link or the gear connecting-rod, or the valve may be moved by tapping the crosshead. It can be ascertained whether the valve has been blocked to exclude steam from the cylinder,

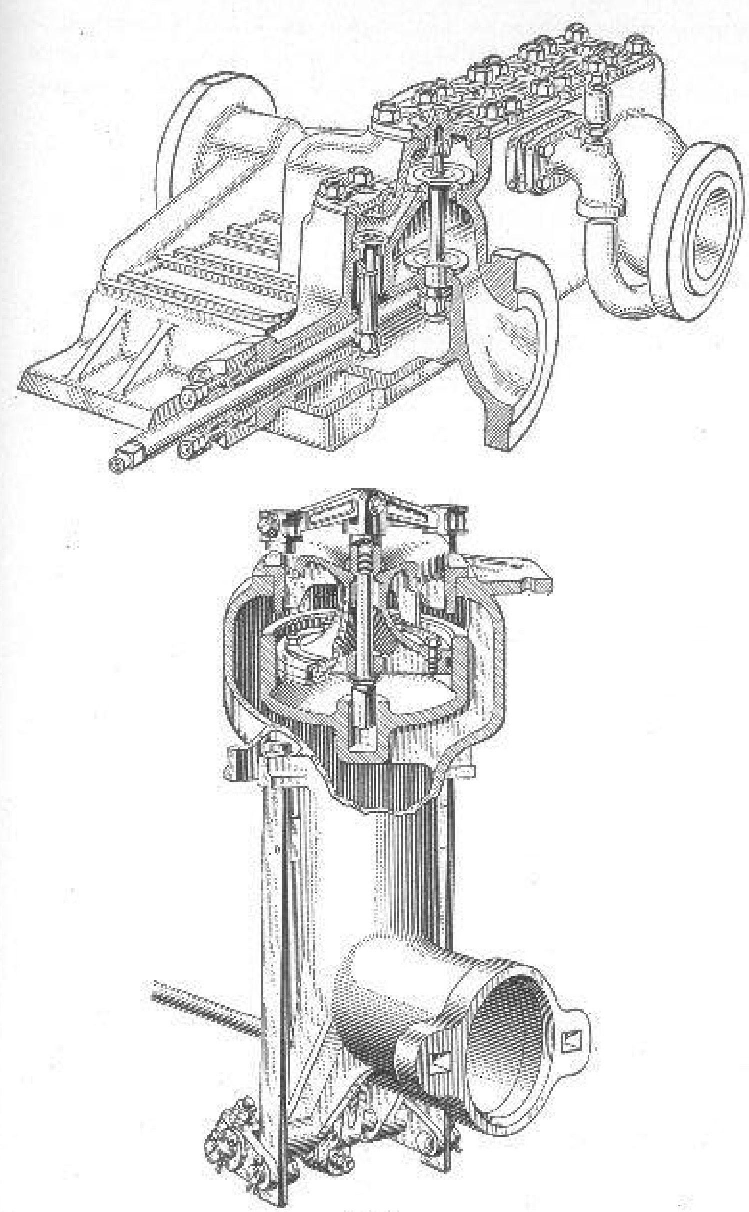
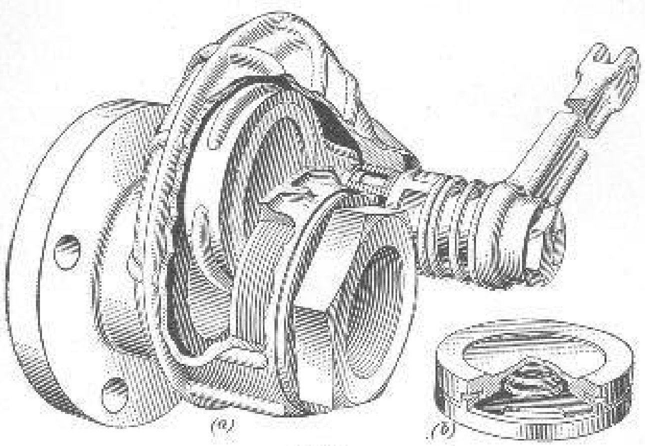


FIG. 2

by opening the cylinder cocks and giving the engine steam. The cylinder cocks should not be removed when the valve is blocked in mid-position, because this will increase the amount of dirt that will be drawn into the cylinder.

FAILURE OF THROTTLE TO CLOSE

7. A failure of the throttle to close is generally due to the binding of the parts of the throttle rigging. In such a case, the locomotive must be controlled by the reverse lever and the brake. Various types of throttle valves are shown in Fig. 2.



(a) (b)

FIG. 3

FAILURE OF BLOW-OFF COCK TO CLOSE

8. If the blow-off cock fails to close, the injectors must be started immediately and the fire dumped or deadened with wet coal by running the stoker. This must be done to protect the firebox sheets because the boiler will be quickly emptied of water. The proper officials should then be notified and the locomotive prepared to be towed in. The cylinders may be lubricated if necessary through the indicator plug openings.

In cold weather, the boiler, the tank, the lubricators, the siphon pipe to the steam gauge, the air compressor, the headlight, the feed-water pump, and all pipes and reservoirs that contain water must be drained. Also, the cylinder cocks and

the drain cocks in the exhaust passages in the cylinders should be opened. A type of blow-off cock in common use is shown in Fig. 3.

BROKEN FRAME

9. Two views of a built-up frame are shown in Fig. 4 (*a*). In a side frame, a break usually occurs either close to the cylinder or forward of the main driving box and is indicated by a severe pound, similar to that caused by a wedge being down. An inspection is necessary to determine the location. Regardless of where the failure occurs, the break will open and close when the locomotive is working, but this movement is more pronounced when the break is forward of the main driving wheel than when back of it.

A broken frame is liable to cause the back cylinder head to be broken with consequent damage to the guides, and a heavy strain is thrown on the knuckle-pin jaws; also, the frame on the other side is liable to be broken. The best procedure to follow is to reduce the tonnage to a point where the train can be handled with a comparatively light throttle. More tonnage can be handled with a break back of the main driving box than in front of it.

It is possible, with the frame broken back of the main driving box, to handle more of a train with the back section of the side rods down than up, because the break will not open and close as with the rods up. With the rods down, the only strain on the frame is due to the pull of the train.

A locomotive bed, Fig. 4 (*b*), has the side frames and cross-ties as well as the steam chests and cylinders cast in one piece; this arrangement is practically immune from the breakage that occurs with the built-up type of frame.

LOST FRAME KEY

10. The frame keys are used to relieve the cylinder bolts of a shearing stress caused by the thrust of the pistons. Modern frame keys vary from 1 to 2 inches in thickness and if lost it would be difficult to find a suitable substitute. In this event the locomotive should be worked as light as conditions will

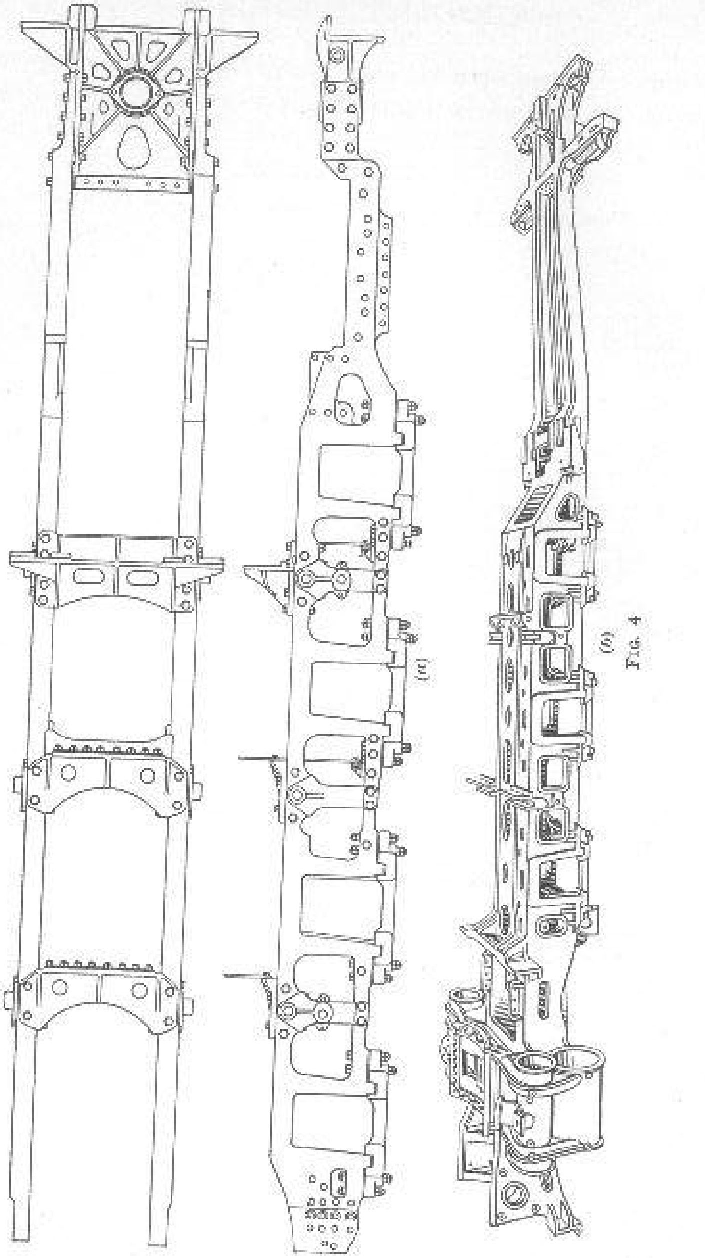


Fig. 4

permit. With modern locomotives the frame keys are usually welded to the frame and there is no possibility of their being lost. A frame key is indicated in Fig. 5 by the black rectangular part at the front of the cylinder.

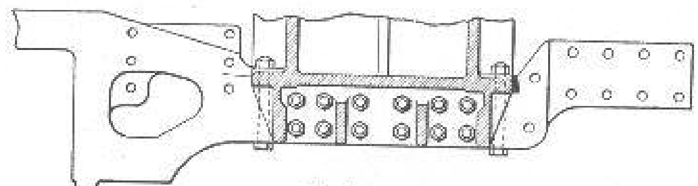


Fig. 5

BROKEN VALVE-STEM STUFFINGBOX STUD

11. When one of the studs that holds the valve-stem stuffing-box against the steam chest breaks, the valve-stem packing will not be held in position properly, and the steam will escape

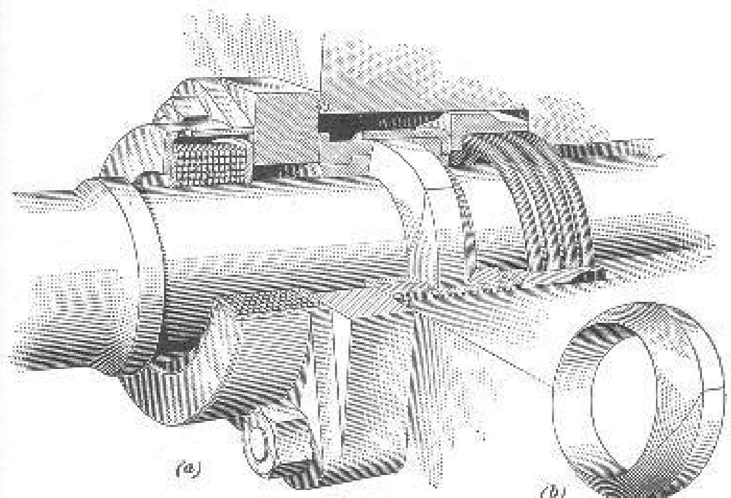
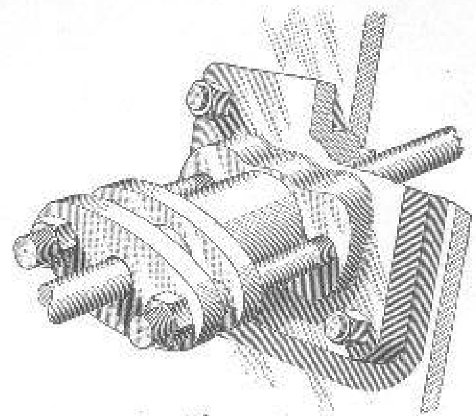


Fig. 6

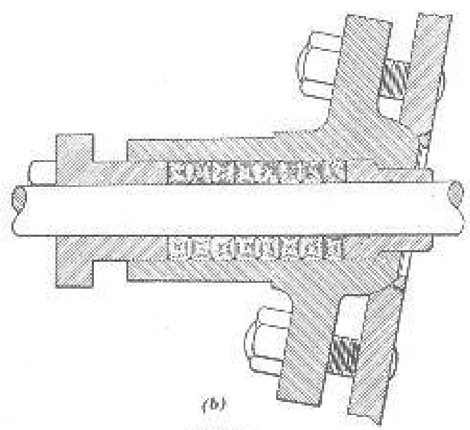
by the stem. However, as practically all piston valves are of the inside admission type, the steam that escapes is from the exhaust passages in the cylinder saddle, and the loss of steam is unimportant, except that it will obscure the vision in cold weather.

METALLIC PACKING BLOWN OUT

12. With the high temperature of superheated steam, no substitute can be used to repack when the metallic packing in the back cylinder head blows out. The locomotive must either



(a)



(b)

Fig. 7

be run light or with a very light train. Under some conditions a machinist may be sent out to apply new packing. A type of metallic packing in general use is shown in Fig. 6.

LEAKY THROTTLE PACKING

13. If the throttle packing, Fig. 7 (*a*) and (*b*), is not leaking too badly, tighten the gland nuts as much as possible. If this does not entirely stop the leak tie the curtain around it and proceed. The packing receives close inspection in the roundhouse and there is little liability of its blowing out entirely.

BROKEN VALVE YOKE

14. A valve yoke, Fig. 8, as used with the slide valves on the older types of locomotives, if broken, will be indicated by the engine going seriously lame. The break usually occurs where the valve stem is welded to the yoke.

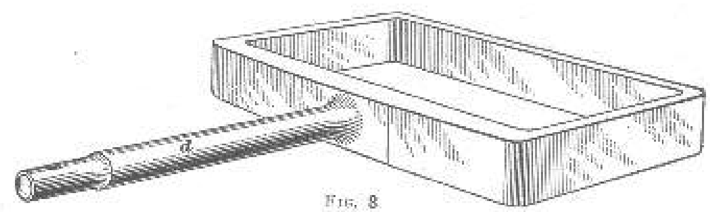


Fig. 8

If only one side of the yoke is broken, the valve will be moved properly when it is going forwards, but when the yoke is pulling the valve back, the crack will open up and the exhaust from the back end of the cylinder will be delayed as well as the admission at the front port. When the valve yoke breaks off entirely from the valve stem, the valve will be pushed ahead and will stay there, and the back steam port will be uncovered. In this event, the back end of the cylinder will always be full of steam that will exert a retarding effect on the piston when it is moving backwards and will at this time work in opposition to the steam that is forcing the piston in the other cylinder.

Normally, when the reverse lever is in the center of the quadrant, and the main crankpin is on or very near the back center, steam will discharge from the back cylinder cock. But a blow of steam at the back cylinder cock with the main crankpin in any other position will identify the side with the broken yoke.

Another test, provided the crankpin on the suspected side is near either quarter, is to move the reverse lever from one corner of the quadrant to the other and note whether steam comes out of one cylinder cock and then out of the other. If the steam continues to blow out of the back cock, the broken valve yoke is on this side.

15. If the valve yoke is not completely broken off, disconnect the valve rod and pull the valve back to cover the ports. The valve can be held in position by driving a wooden wedge between the valve stem and the gland.

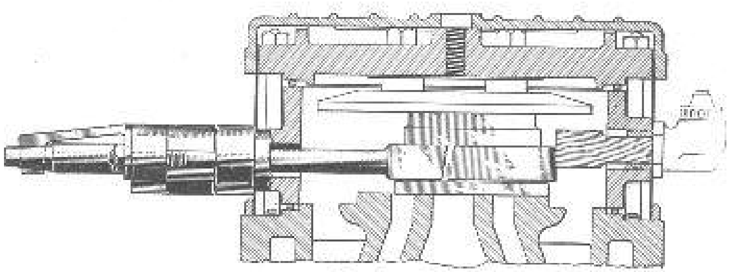


FIG. 9

If the valve yoke is completely broken off, the valve can be moved back by removing the relief valve, if there is one, and inserting a stick through the opening. The valve can be prevented from moving ahead by inserting two wooden blocks, Fig. 9, between the steam chest and the valve on each side of the relief-valve opening. The two blocks will keep the valve square over the ports. A clamp is shown applied to the valve-steam keyway to keep the valve from moving back but such clamps are seldom available. Instead the valve stem can be held by a wedge, as already explained.

When the valve yoke is completely broken off, the valve will be pushed all the way forwards and the back steam port will be wide open. In this case, in the absence of a relief valve, the main rod will have to be taken down and the locomotive run in on one side because it is impossible to raise the steam chest and block the valve without the proper appliances. After the main rod is taken down, the crosshead must be moved forwards to

the front end of the cylinder and blocked there. Also, the front cylinder cock should be removed so as to prevent pressure from building up in front of the piston and moving it should the blocking drop out.

DEFECTIVE PISTON VALVE

16. About the only failure with a piston valve is in the packing rings, which break frequently owing to the constant springing action of the steam on the rings. The exhaust rings break much more frequently than the steam rings. With the rings gone on one or both ends, the escaping steam imposes a severe drain on the boiler, the result being a slower speed than otherwise. Parts of the broken rings will probably fall into the cylinder, but this very rarely results in any damage, as the rings usually break up into small pieces.

REMOVING SIDE RODS

17. Method of Removal.—The term side rod as here used refers to the combined sections on one side. This distinction is made because in some places one section alone is referred to as a side rod.

With modern locomotives, the outer portion of the crankpin is turned down to a smaller diameter than the part on which the side-rod brass wears. This portion of the crankpin is threaded, and the side rod is held on the pin by a nut, a washer, and a cotter key. However, this arrangement cannot be used at the crankpin on the forward driving wheel, owing to the lack of clearance between the end of the pin and the crosshead.

The front end of the forward section of side rod is held on the crankpin by a bolt that runs entirely through the pin with the outer end countersunk in a washer and with a nut on the inner end. The sections of a side rod are connected together by knuckle pins that are held in the rods by nuts, washers, and cotter keys. The side-rod brasses are solid and are pressed into the rods, so that keys are not used as when the brasses were made in two pieces. Therefore, to remove a section of a side rod, all that is necessary is to take out the cotter key and remove the nut and washer from the end of the crankpin and knuckle pin, then drive the pin out and work the rod outwards until it comes off the crankpin. However, the intermediate side rod cannot be removed until the main rod is taken off. The removal of the intermediate side rod, with four driving wheels connected, requires, on account of the location of the knuckle pins, the removal of the two other sections of the side rod. See Fig. 10.

18. With some types of locomotives the inside face of the crosshead or the guide bar is so close to the end of the crankpin on the forward driving wheel, that even with the pin on the bottom quarter, the front section of the side rod cannot be removed until the locomotive is raised high enough for the rod to be pulled off underneath the bottom guide However, if both side rods and the main rods have to be taken down, the crossheads will be blocked forwards; in this event the front sections of the side rods can be removed through the guides, with the crankpins near the back dead center.

Let it be assumed that the front section of the side rod, owing to a failure of the knuckle pin or the jaw, alone has to be removed. To raise the locomotive and thus get the bottom guide high enough to permit the removal of the front end of the rod, first block between the top of the driving box and the frame of the second driving wheel so that this wheel when raised will immediately begin to lift the frame. Next, jack or run this wheel up on a wedge, stopping with the front crankpin near the bottom quarter; this operation raises the frame, the cylinder, and the guide without lifting the front end of the rod. As explained later, the front side rod on the other side must also be removed.

However, with some locomotives there is so little clearance between the pedestal binders and the grease cellars that the front binder, as the frame is being raised by the second driving wheel, will strike its grease cellar and begin to raise the front driving box and wheel before the guide is raised high enough to permit the rod to be pulled off under it. In such an event, drop the binder at this wheel. If this cannot be conveniently done, spot the locomotive with the front crankpin near the back center,

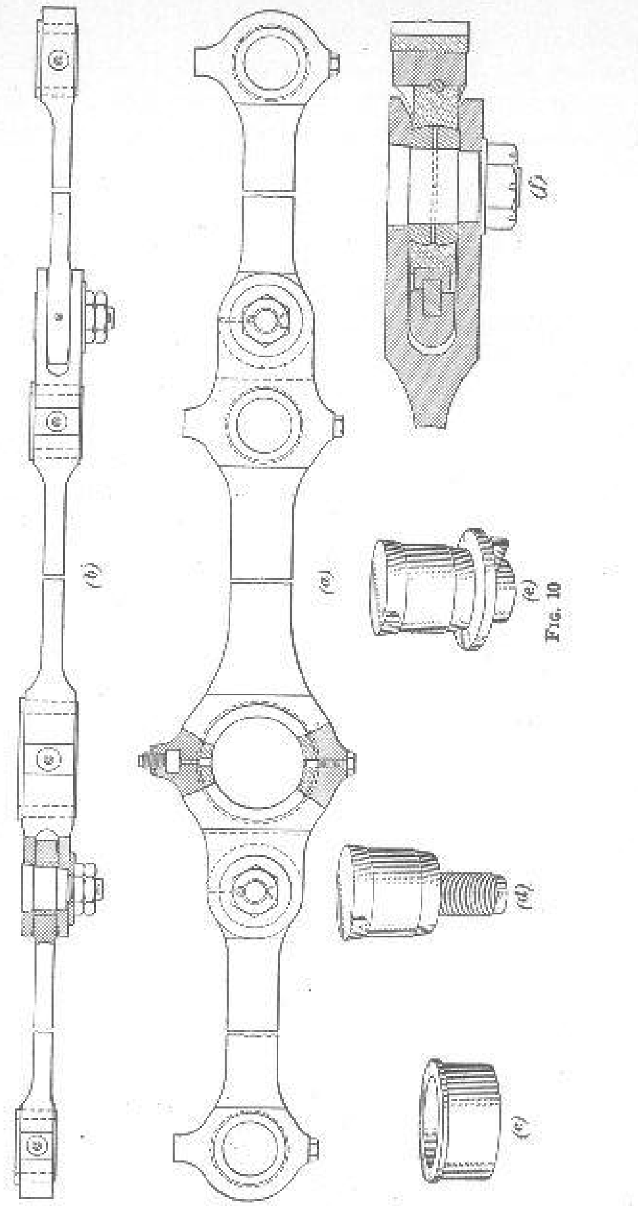


FIG. 10

then take out the wristpin and bar the crosshead forwards. The rod can then be removed through the opening made in the guides by moving the crosshead forwards. However, trouble may be experienced in removing the wristpin. In some cases the pin can be easily driven out with a light hammer; in other cases, a heavy sledge must be used.

Sometimes the wristpin can be loosened by first slacking off the nut on the key of the front-end brass, then giving the engine a little steam and moving the reverse lever forwards and backwards; this thumps the brass on the wristpin and loosens it.

19. Effect of Removing a Side Rod.—The side rods, in addition to distributing the thrust of the pistons equally to all crankpins, also perform the important function of keeping the crankpins in their proper relation to one another when either side is passing the dead centers.

To explain the foregoing, let it be assumed that the side rod and the main rod have been removed on one side, that the crankpins on the other side are passing their dead centers, and also that at this instant the main driving wheel slips ahead slightly. Now, owing to the flexible knuckle-pin joints at *a* and *b*, Fig. 11, it is possible for the main crankpin to slip from its dead center *c* to *d* or until the slack has been taken up without carrying the adjoining wheels with it. The side rod then buckles slightly at the knuckle joints, the result being that the sections of the side rod do not lie in a straight line but form an angle at these joints. Further buckling will occur as the crankpin is turned to *e*, with the result that the wheels will be turned in the direction of the arrows, provided the wheels do not lock on the centers.

If the crankpin *f* does not turn off the center, the middle section of the side rod will be bent or the pin will be broken off. In case the back crankpin locks, the back section of side rod will be stretched or the pin broken.

It will be noted that the section of the rod under compression or that is receiving a thrust, such as the section *g*, causes the second driver to be rotated in the reverse direction to the main driver. Also, as the section *h* of the side rod is under compres-

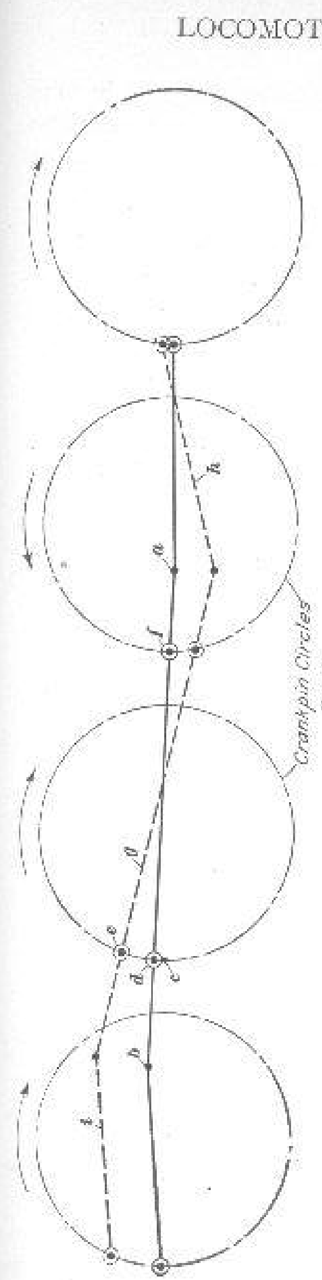


FIG. 11

sion, the first and second driving wheels will be turned in the reverse direction. A section of the rod under tension or that is subject to a pull, such as *i*, causes the fourth driving wheel to turn in the same direction as the main driving wheel.

The wheel in advance of the main driver rotates in the opposite direction because the main crankpin is above the other crankpin before the thrust is applied to it. The angle that the back section of side rod makes with the rear crankpin causes this pin to be pulled in the same direction as the main crankpin. The rod cannot buckle when passing the centers with the opposite side rod up, because the crankpins on this side are on the quarter and, irrespective of the knuckle joints, any rotation of one pin independent of another is impossible in this position. Therefore, the crankpins on the side passing the center are maintained in their proper relation to one another by the side rod that is on the quarter, and buckling cannot occur.

20. Although there is always the possibility of buckling with a side rod removed, yet the rules of some railroads permit locomotives to be run in this condition. The reason probably is that the possibility of slipping is remote because the only turning effort that would cause the crankpins to slip at the centers was removed when the opposite rod was taken down. Also, with all of the rods off on one side, the piston thrust is distributed to twice as many driving wheels; this lessens the tendency to slip except at the quarters, and such slipping will do no harm. However, if a slip starts when passing the quarter and is continued past the center, the rod will invariably buckle; hence care should always be taken to start without slipping.

Running a locomotive with only one section of a side rod removed is much more liable to cause buckling than if the whole side rod is taken down. With only one section removed, the piston thrust on this side is transmitted to three wheels instead of four if a Mikado type of locomotive is considered. Thus, the three wheels get more than their share of the thrust and are liable to slip. Should this happen, the mate of the section of the side rod that has been removed will buckle. Let it be assumed, for example, that the front section of the side rod on the left side has been removed. When the right side is approaching the front dead center, the left side is nearing the top quarter. If the three drivers on the left side now slip, the crankpin of the front driver on the right side in the absence of the section of side rod on the left side will not be compelled to pass its dead center at the same time as the others on the right side. This leaves the crankpins on the front drivers behind the others, and the front section of side rod will buckle with the result that it may be bent, stretched, or broken. Therefore whenever a section of a side rod is removed, the corresponding section on the opposite side must also be taken down.

The speed regulations of the road must be observed when a locomotive is towed without rods; if run too fast, the unbalanced driving wheels will bend the rails.

A heavy locomotive cannot be started with the side rods down and the main rods up, owing to the main driving wheels slipping when attempting to start. If another locomotive is used to start the disabled one, the latter can be kept going but it should not be stopped before the desired point is reached.

TAKING DOWN MAIN ROD

21. In the event of a failure that requires the main rod to be taken down, proceed as follows: Spot the locomotive on the disabled side in a position so that when removing the wristpin it does not come in contact with a spoke of a wheel; also, spot the locomotive so that the main crankpin on the other side is in a position that will permit the locomotive to be started after the rod has been taken down. This crankpin, if the locomotive is to be started forwards, should be somewhere between the

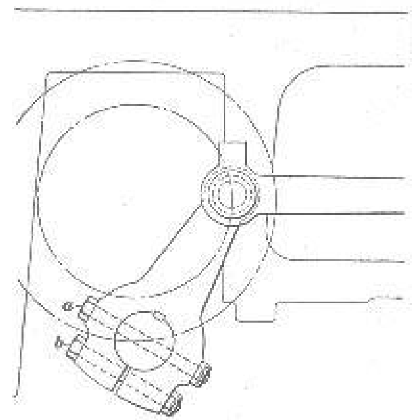


FIG. 12

front dead center and the bottom quarter or between the back dead center and the top quarter. Next, remove the split key and the nut or nuts from the wristpin, remove the union link, and drive the pin out, then pry the crosshead forwards away from the rod. The front portion of the rod, with an alligator type of crosshead, now rests on the bottom guide.

After the front end is disconnected, remove the eccentric rod and the eccentric crank that takes the place of washers and nuts used to hold the main rod on the crankpin with an outside valve gear. The back end of the main rod can then be pried off the crankpin, provided the front end is also pried outwards at the same time, thereby preventing the rod from binding on the pin. The locomotive should not be towed or run at too high a speed, owing to the liability of the rails being bent by the unbalanced main driving wheel.

Blocks should be wired on the crankpin to prevent the side rods from working out. When taking off the eccentric crank, remove the bolt *a*, Fig. 12, first. If the draw bolt *b* is removed first, the bolt *a* will bind and cannot be driven out.

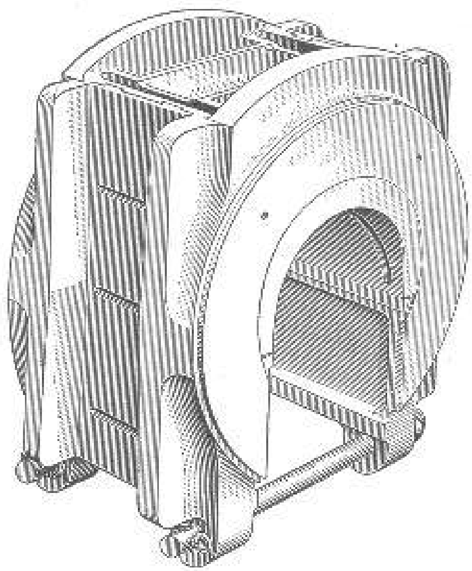


Fig. 13

BROKEN DRIVING-BOX BRASS

22. A broken driving-box brass, Fig. 13, will be generally indicated by the heating of the box, but the trip can be completed without much difficulty. With the exception of the front driving boxes, inspection can be made and the break noticed by looking at the box from the opposite side. Sometimes the brass will be lost; this is a serious breakdown even at moderate speeds. The driving box then settles on the journal, and the movement of the journal is almost sure to cause a derailment or to damage the rods, cylinder heads, and brake rigging. Sometimes, however, the box stays up.

The reason why a derailment is liable to occur is that the journal will move back and forth in the box and it and the wheel will not be square with the frame. The effect would be the same as if the shoe and the wedge were left out of the pedestal, thus giving a to-and-fro movement of the driving box.

With such a failure, remove the grease cellar and place wooden blocking between the bottom of the driving box and the binder. Next, jack up the frame; the driving box rises with the frame but the journal will remain stationary, thereby leaving the crown-brass space open. Apply hardwood blocking in place of the crown brass, leaving space for lubrication, and remove the weight from the driving box by blocking between the spring saddle and the frame. The only weight on the journal is now that of the driving box and as the blocking is so applied as to prevent movement of the journal the side rod may be left up. Sometimes a small brass is used instead of the blocking. The failure requires assistance to be sent for, and the workmen sent out to do the work are supplied with jacks and wedges.

BROKEN MAIN CRANKPIN

23. When a main crankpin breaks, remove the main rod and the side rod. In starting, use great caution to avoid slipping, otherwise the rods will invariably buckle. The rules of the road as to whether the side rod on the good side should be left up should be observed.

BENT OR BROKEN PISTON ROD

24. When the piston rod is bent, secure the valve in mid-position, take down the main rod, and block the crosshead. When the piston rod breaks, the front cylinder head is almost invariably knocked out. The rod generally breaks close to the crosshead, and all that has to be done is to disconnect the valve gear and secure the valve in mid-position so as to cover both steam ports to the cylinder; the main rod may be left up.

BLOCKING CROSSHEAD

25. With modern locomotives, the crosshead can be blocked at the end of its extreme travel in the guides, thereby bringing the piston to the rear end of the cylinder. There is no liability of the rings expanding into the counterbore; the piston can be pushed against either head without this happening.

The crosshead can be secured in position by placing a block of wood on the lower guide between the crosshead and the back cylinder head, and tying the block to the guide.

Fig. 14

RAISING A DRIVING WHEEL CLEAR OF RAIL

26. About the only breakdown that requires the driving wheel to be carried clear of the rail is a broken tire. A cast-iron wheel center will break down very rapidly if run on the rail; a cast-steel center can be run on the rail if the distance to clear the main track is not too far.

Breakdowns that require a driving wheel to be carried clear of the rail are handled, if serious enough, by the wrecking car, and if not, a machinist and a helper are sent out with the necessary tools, including jacks and wedges. The work can be done more quickly and satisfactorily with jacks; ordinarily a 10-ton and a 75-ton jack will take care of such breakdowns. A type of wedge is shown in Fig. 14.

When raising a driving wheel with a jack, the crankpin is placed on the top quarter, the jack is set under the rod at the pin, and the wheel is jacked up off the rail far enough to provide sufficient clearance between the tire and the rail. When the driving wheel is inside of the guides, as with a Mikado type locomotive, it is impossible, owing to the limited space, to apply the large jack under the crankpin. This jack is placed instead under the bumper bracket and the frame is raised, a beam being

first placed under the opposite side to prevent this side from settling as the other side is being raised. The small jack is then used to raise the driving wheel, which is now relieved of a greater portion of the weight.

It is possible in the absence of jacks and wedges to raise a driving wheel in the following manner: Obtain a good sound tie, lay it lengthwise just outside of the rail, and spike it solid. Then place a piece of rail on top of the tie if it can be obtained and place the engine in such a position that when moved the counterbalance on the wheel will mount the tie.

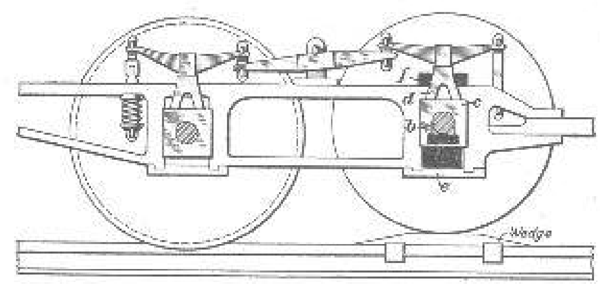


Fig. 15

CARRYING A WHEEL CLEAR OFF RAIL

27. The arrangement of the spring rigging of a locomotive is such that if necessary the entire weight that is carried by any certain driving box can be removed and transferred to the frame instead and thence distributed to the other driving boxes. This can be done by raising one of the driving wheels and placing blocking at the proper point.

28. In Fig. 15 is shown a part of the left side frame of a locomotive and the spring rigging as viewed from the right side. It is assumed that the tire on the middle driver is gone, thereby making it necessary to remove the weight from this driver and carry the wheel center clear of the rail. To do so the wheel center is first raised by either a wedge, as shown, or a jack; the journal *b*, as the wheel center rises, carries the driving box *c* and the driving-box saddle *d* upwards until finally the top of the box comes in contact with the frame as shown. This

is as high as the box can be raised without raising the engine. The driving box can be held in this position by removing the grease cellar and filling the space between the pedestal binder *e*, the driving box, and the journal, with blocking.

If the wheel were now run down off the wedge, the weight on the box would come on the pedestal binder *e*, the bolts of which might break and permit the wheel to come down on the rail. To prevent this it is necessary to transfer the weight from the box to the frame, and this can be done by fitting an iron block *f* tightly between the spring saddle and the frame while the wheel is still up. When the wheel is lowered, the driving box will recede slightly from the spring saddle, and the entire weight that was formerly on the box will come on the frame above the box. The pedestal binder carries only the weight of the wheel and the journal, and the binder and the binder bolts are sufficiently strong to bear this weight.

It is true that wooden blocking, with the journal turning, may soon wear out and permit the wheel to come down, but if properly lubricated the locomotive can be run for some distance. Iron blocking, even if it could be procured, would ruin the journal and a ruined journal would be expensive, especially if it had been recently turned up. If the journal cannot be run the desired distance on wooden blocking, and it is not permissible to use iron blocking, then the opposite wheel must be carried clear of the rail and a section of the side rods on each side should be removed to prevent the wheels from turning. It is not advisable to block under the driving box and rely upon the grease collar to hold the journal up when the wheel is not turning, because the cellar bolts will not stand the weight of the wheel.

BROKEN TIRES

29. When a tire breaks, it usually breaks up into several pieces and comes away from the wheel center entirely. A broken tire is usually caused by its being shrunk on the wheel center too tightly, thereby subjecting it to a greater strain than it is designed to bear or the shims may be placed too far apart. A tire failure requires workmen to be sent out with jacks, wedges, and blocking and whatever other material may be necessary to do the work. The wheel is then raised, the grease collar removed, and blocking applied between the driving box and the binder and between the spring saddle and the frame. Wooden blocking should be used under the journal; if the distance to go is too far for wooden blocking to stand, and the use of iron blocking is prohibited, then the opposite wheel must be swung and a section of side rods on each side should be removed to keep the wheels from turning. This is especially true with a tire broken on a front or a back driving wheel.

If a wedge is used its end should be forced under the wheel as far as possible so as to prevent tilting when the wheel starts. The engineer should be instructed to stop at the instant the wheel begins to mount the wedge, then by the time the locomotive is stopped it will stand on the level portion of the wedge.

30. With a rear driving wheel carried clear of the rail for a broken tire, the overhang will cause the rear of the locomotive to settle badly. This can be prevented to some extent by blocking between the box and the frame of the wheel ahead of the disabled one and between the trailing box and the frame on the opposite side.

With a loose tire, or with a tire that is broken in one place and is not clear of the rail, it will be necessary to send for workmen with the proper equipment to tighten it or cut it clear of the wheel. In this case the loose tire can usually be tightened by heating it with a torch and then applying shims in the usual way. With the tire partly off it is cut through with a burning torch so as to avoid the necessity of removing a side rod or all of the rods in order to get the tire clear. After this is done the wheel would have to be raised and carried clear of the rail as already described.

BROKEN AXLES

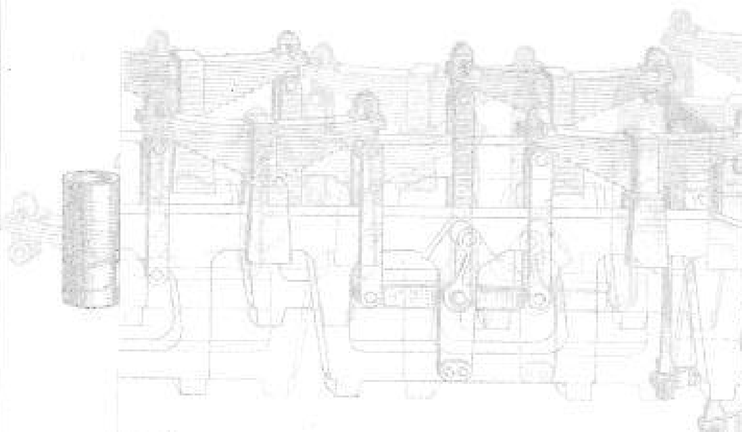
31. When an axle breaks on a modern locomotive, it is difficult to say just what damage may be done. This applies particularly to a broken journal on the leading driving wheel because this wheel is directly inside of the crosshead and the interference of the moving parts will result in serious damage even when the locomotive is moving slowly. The axle generally breaks through the journal at the hub of the wheel. Breakdowns of this nature are beyond the capacity of the engine crew to handle and assistance will have to be sent for.

With the journal of a main driving wheel broken, both main rods, both side rods, and the broken wheel will have to be cleared away. The broken end of the axle must be jacked up to normal position, the cellar removed, and blocking applied solidly between the pedestal binder and the axle. This blocking keeps the opposite wheel true on the rail and prevents derailment. Blocking must also be placed between the spring saddle and the frame, so as to transfer the weight from the driving box and the pedestal binder to the frame. The crossheads should be blocked securely. The locomotive is then ready to be pulled to the terminal.

If the front or back driving axles break, the same procedure as to blocking should be followed, but only the front or rear sections of side rods need to be removed. The locomotive can be run in if the crosshead and guides are not damaged.

DISABLED SPRING RIGGING

32. No repairs are ordinarily necessary when the spring rigging on one side of a locomotive fails because of a broken spring, spring hanger, or equalizer. The spring rigging is separated into sections as shown in Fig. 16 and, although a break in one section leaves the other sections unimpaired, yet the other sections cannot sustain the weight, hence the frame settles down close to or on top of the driving boxes. Theoretically, the frame could be raised and the spring rigging blocked in place by running a wheel up on a wedge and then prying up and blocking under an equalizer, but in practice this cannot be done. It should be noted, however, that none of the springs come in contact with a tire, as the heat resulting from the friction may loosen it. By running the wheel up on an angle bar, enough tension may be taken out of the rigging to permit the spring to be pushed out of the way. If the distance to be run is not too far, oil-saturated waste will keep the spring from cutting.



RUNNING ON ONE SIDE

33. A locomotive works very rough when run on one side. The power impulses are reduced by half and the pulling [illegible] is so jerky that it is questionable, owing to the damage to the draft rigging, whether it is advisable to attempt to haul any train at all, or at the most, a few cars. The locomotive has of necessity to be started in full gear with a wide-open throttle to avoid stopping on a dead center, and this is almost certain to break even a short train in two. Also, running a locomotive on one side throws severe stresses on the machinery and is likely to loosen the frame bolting. Some railroads require locomotives running on one side to be run light.

TWO-WHEEL ENGINE TRUCK

34. [illegible] a two wheel engine [illegible] shown in Fig. [illegible] damage that follows [illegible] engine truck depends [illegible] extent on the speed of the locomotive [illegible] of the front part of the locomotive is transferred [illegible] by the engine and truck equalizer [illegible] the front of the locomotive settles down [illegible] on the top of the forward [illegible] favorable conditions the truck [illegible] proper position. In order to get the locomotive [illegible] dition to run, a new pair of truck wheels [illegible] and this necessitates sending for the [illegible] that would be followed when [illegible] of the position of the truck [illegible] The pilot would be [illegible] be chained to the [illegible] removed. The front of the locomotive would [illegible] either by jacks or by the derrick [illegible] be placed over the [illegible] weight from being thrown on the springs [illegible] set while the front end is being raised.

With the tool car, a chain is placed [illegible] a large triangular piece of iron is placed under the [illegible] [illegible]

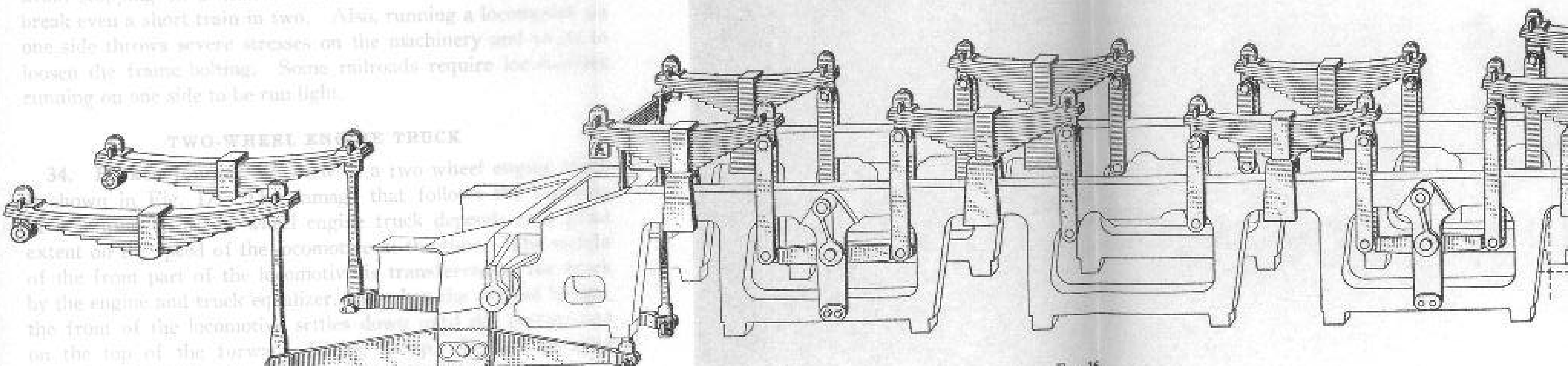


Fig. 16

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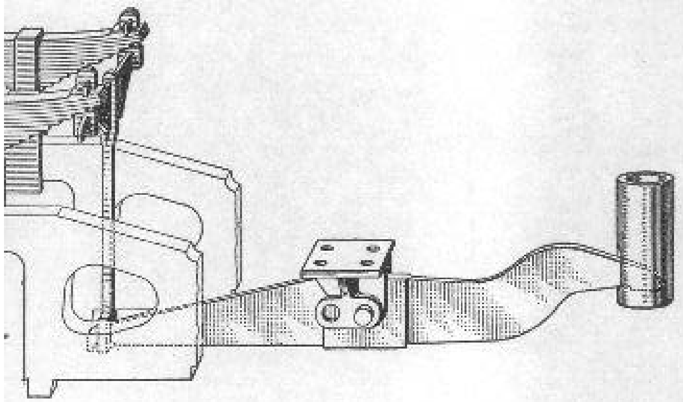
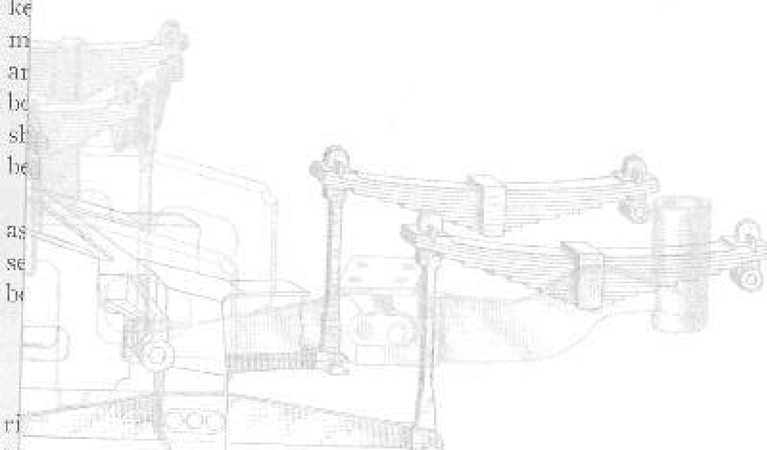




RUNNING ON ONE SIDE

33. A locomotive works very rough when run on one side. The power impulses are reduced by half and the pulling impulse is so jerky that it is questionable, owing to the damage to the draft rigging, whether it is advisable to attempt to handle any train at all, or at the most, a few cars. The locomotive has of necessity to be started in full gear with a wide-open throttle to avoid stopping on a dead center, and this is almost certain to break even a short train in two. Also, running a locomotive on one side throws severe stresses on the machinery and tends to loosen the frame bolting. Some railroads require locomotives running on one side to be run light.

TWO-WHEEL ENGINE TRUCK

34. Broken Journal.—A view of a two-wheel engine truck is shown in Fig. 17. The damage that follows the breaking of a journal on a two-wheel engine truck depends to a great extent on the speed of the locomotive at the time. The weight of the front part of the locomotive is transferred to the truck by the engine and truck equalizer, and when the journal breaks, the front of the locomotive settles down until the frames rest on the top of the forward driving boxes. Under the most favorable conditions the truck will be turned more or less out of its proper position. In order to put the locomotive in condition to run, a new pair of truck wheels will have to be applied and this necessitates sending for the tool car. The procedure that would be followed when the tool car arrives, regardless of the position of the truck on the rails, would be as follows: The pilot would be removed first, then the truck frame would be chained to the engine frame and the tie bars would be removed. The front of the locomotive would then be raised either by jacks or by the derrick car, but first blocking should be placed over the rear driving boxes so as to prevent additional weight from being thrown on the springs and spoiling their set, while the front end is being raised.

With the tool car, a chain is placed around the smokebox or a large triangular piece of iron is placed under the buffer beam.

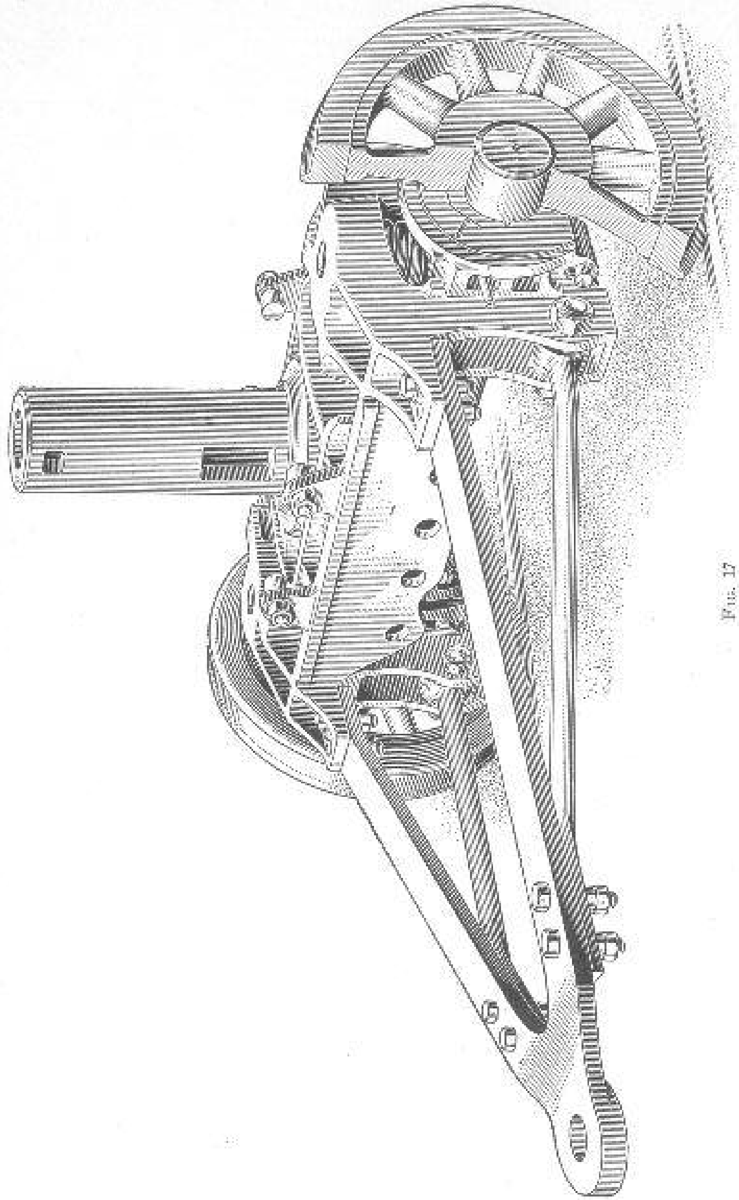


Fig. 17

With the pedestals cast integral with the truck, a lift of about $1\frac{1}{2}$ feet is required before the pedestals will clear the boxes and permit the wheels and the boxes to be removed from the truck. When the pedestals are bolted to the truck frame, the locomo-

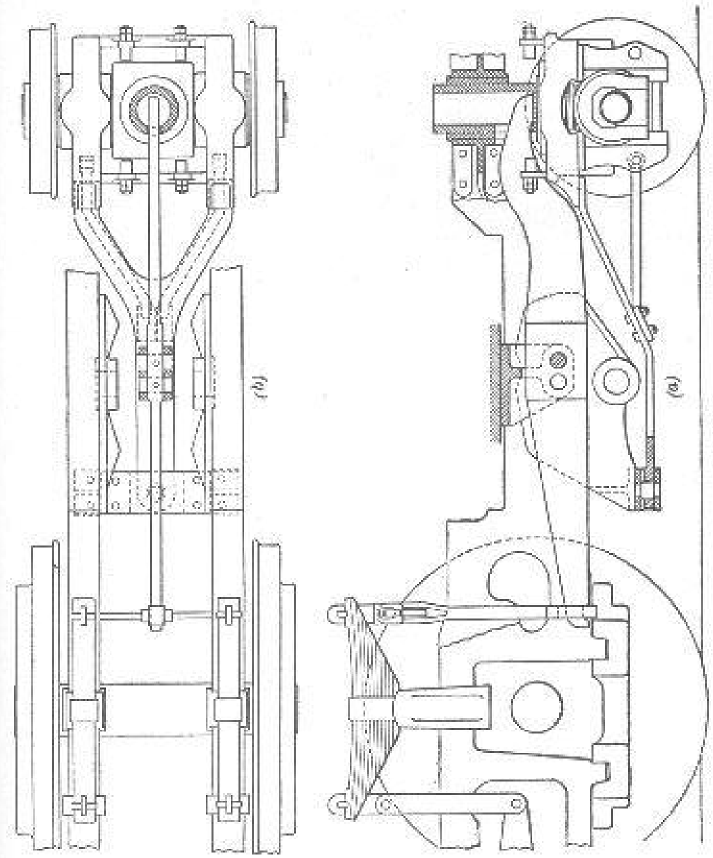


Fig. 18

tive has only to be lifted high enough to bring the top of the boxes in line with the top of the pedestals. By removing the front pedestal braces the wheels can be rolled out; then the boxes are applied to the new pair of wheels, and the locomotive is lowered, thereby lowering the truck frame on to the wheels.

The front end of the long truck equalizer, Fig. 18, must be chained up to the engine frame so that both will rise together when the locomotive is being raised.

FOUR-WHEEL ENGINE TRUCK

35. Broken Journal.—The procedure to be followed when a journal breaks on a four-wheel engine truck, Fig. 19, does not differ essentially from that with a similar breakdown with a two-wheel truck. The front of the locomotive is raised by

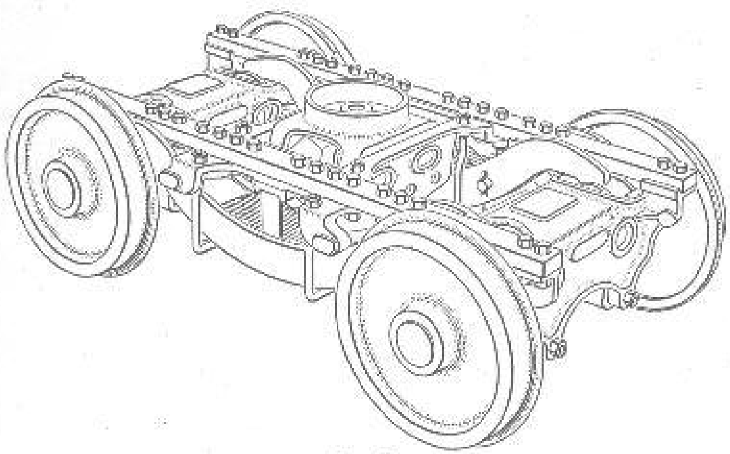


Fig. 19

the derrick car, the truck is run out, and a new pair of wheels is applied, or it frequently happens that the auxiliary carries a spare truck, which is substituted for the disabled one.

BROKEN TRUCK SPRING OR HANGER

36. If an engine truck spring or hanger that serves to connect the end of a truck spring to the equalizers, Fig. 19, breaks, the truck frame will settle down somewhat but the safety hangers if used will prevent the frame from settling down on top of the boxes. If the springs do not interfere with the truck, the engine can be run in but no doubt the truck journals will run hot. It may be possible, should the springs interfere, to relieve some of the weight on the truck by raising the second

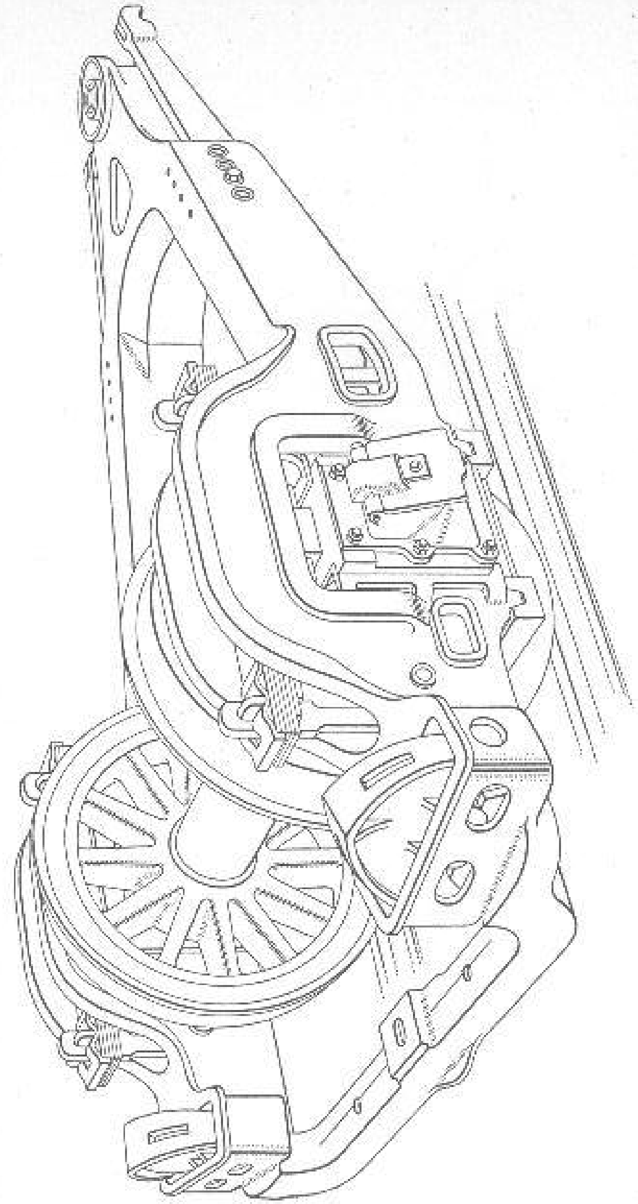


Fig. 20

driving wheel on the disabled side first, blocking over this driving box, and then blocking over the front driving box. This will permit the spring to be pulled out of the way and will also prevent overheating.

When a truck equalizer breaks, the truck frame will drop down on the boxes. The truck loses some of its flexibility, hence the locomotive should be run carefully, especially over frogs and around curves.

TYPES OF TRAILING TRUCKS

37. A perspective view of a Commonwealth trailing truck is shown in Fig. 20, and in Fig. 21 is shown an Alco truck manufactured by the American Locomotive Company. These trucks are shown applied to locomotives in Figs. 22 and 23.

The principal difference between the Alco and Commonwealth trucks is that with the former none of the weight is carried by the truck frame, whereas with the latter the truck frame bears a portion of the weight of the boiler and frame. Another difference is that the design of the Commonwealth truck permits of a vertical movement of the truck boxes independent of the truck frame, whereas the truck boxes are a part of the truck frame with the Alco truck and both are subject to the stresses of rough track.

The frame of the Alco truck can be made light because it serves merely to retain the wheels and the boxes in their correct positions; the weight carried by the frame of the Commonwealth truck requires it to be made heavier.

The weight with an Alco truck is applied directly to the truck boxes; its connection to the main frame supports no weight, but is merely a swiveling point. The spring rigging, which is connected to the locomotive cradle and not to the truck frame, apportions the proper share of the load to the journals.

38. With the Commonwealth truck, the weight of the rear end of the boiler and the frame is supported by the truck frame at three points, none of which are rigid. The rockers *a*, Fig. 22, one on each side, constitute the two rear points of support. The front end of the truck frame is connected flexibly to a pocket in

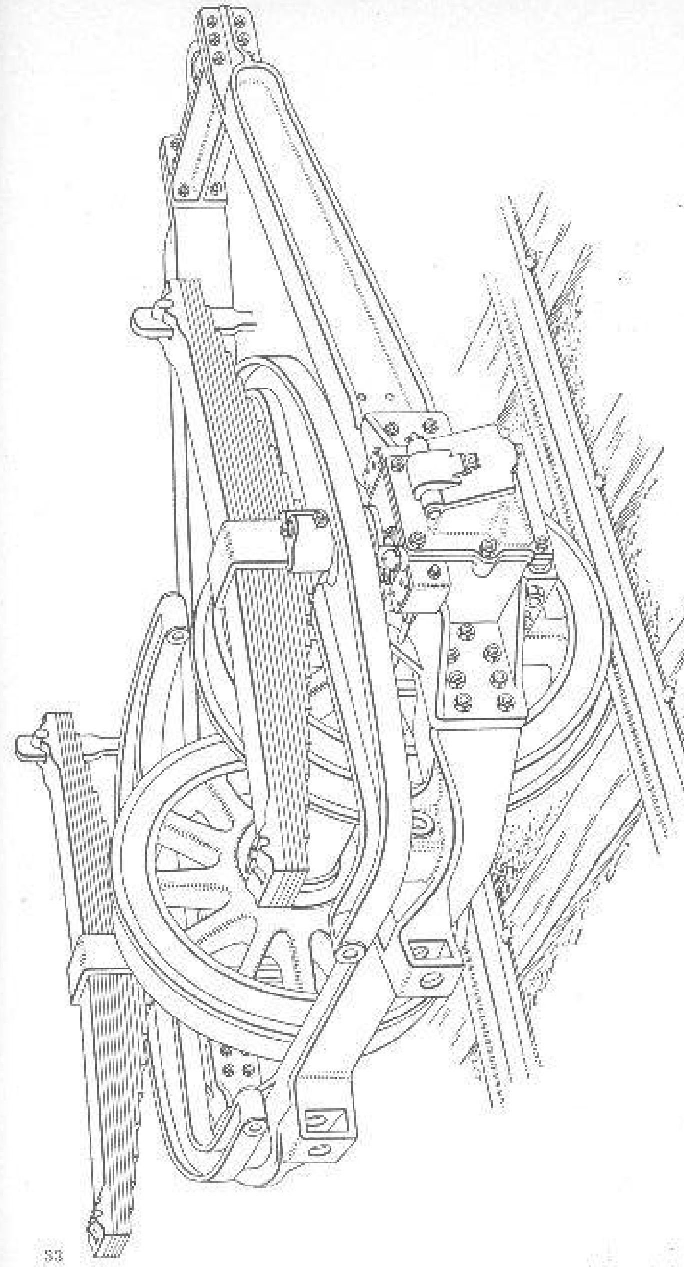


Fig. 21

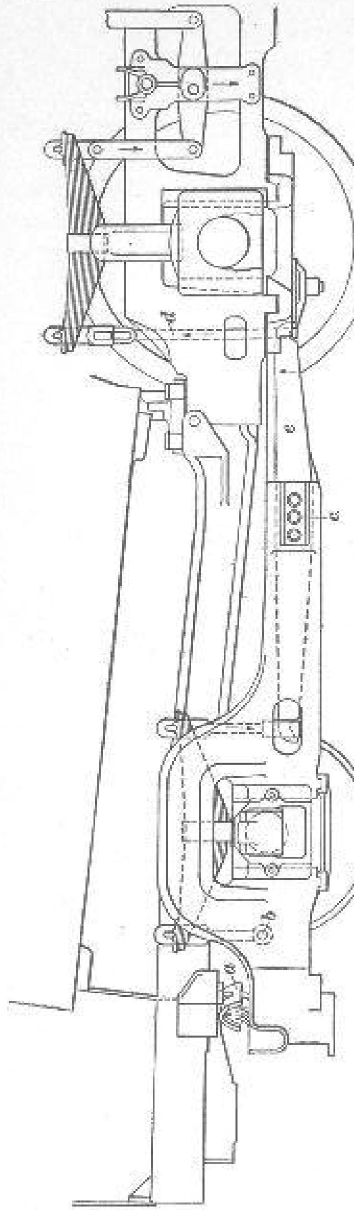


Fig. 22

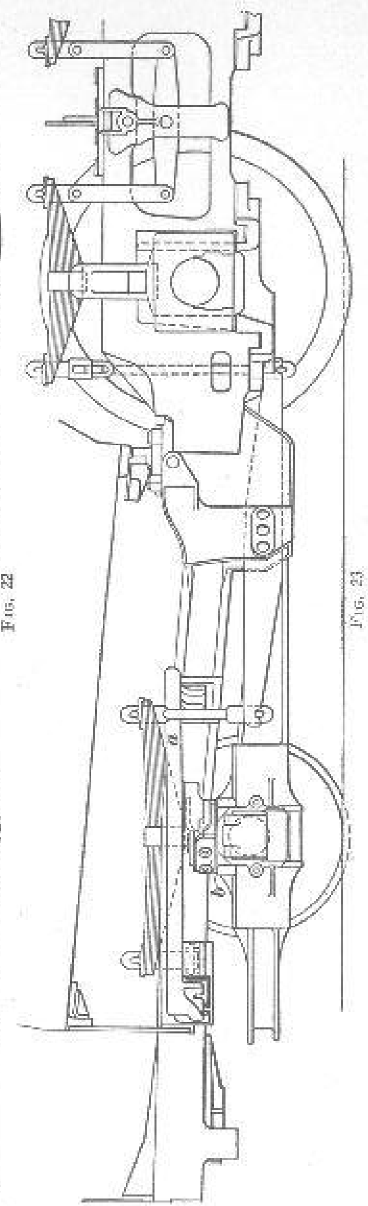


Fig. 23

the locomotive cradle at a point between the ends of the frame and forms the third point of support for the rear of the boiler.

The action of the spring rigging, which is anchored to the truck frame at the points *b*, causes the front end of the truck frame to be thrust upwards in its pocket in the main frame; similarly the rear end of the truck frame is thrust up against the rockers. In this manner the truck frame, through these three points of support, is made to carry a portion of the weight of the rear end of the boiler and main frame. Calculations show that the thrust at the front of the frame exceeds the thrust at the rockers. It is to be understood that an upward thrust always supports an equal downward weight.

The spring rigging apportions, according to the location of the points *c*, the proper share of the load on the three points of support to the trailing-truck journals and passes the remainder on to the driving-wheel journals. The load on the truck journals is always less than that on the truck frame.

39. The truck box of an Alco truck, when curving, moves laterally with respect to the spring seat *b*, Fig. 23, any movement of the seat being prevented by the yoke *a* that ties it to the frame. As all of the spring rigging is connected to the locomotive frame only, the trailing-truck spring remains in line with the other springs when curving.

The spring rigging of the Commonwealth truck is housed in the truck frame and is pulled out of line with the other springs when curving. However, sufficient play is provided in the hangers *d*, Fig. 22, for the ends of the equalizers *e* to swivel freely when curving without affecting the back driving springs to any extent. The equalizers cannot move sidewise in the truck frame, therefore the trailing-truck springs always remain in correct alinement when curving.

LOOSE TRAILING-WHEEL TIRE

40. If the tire becomes loose on the wheel center, it will be safe to proceed with caution, provided the tire is held on by retaining rings and bolts. However, both the preliminary steam valve and the main steam valve to the booster must be shut tight.

In the absence of retaining rings, assistance will have to be sent for because, to tighten the tire, it will have to be heated so that new shims can be applied. With facilities at hand to do this work, jacks should be placed at the front corners of the firebox, and the rear of the locomotive raised.

The trailing wheel can be raised by blocking inside of the box between the bottom and the journal and then placing a journal jack under the box.

With a broken tire on a cast-steel trailing-wheel center, the engine can be run in slowly.

BROKEN TRAILING-TRUCK SPRING OR HANGER

41. When a trailing-truck spring or hanger breaks, the rear of the locomotive will usually settle down enough for the trailing wheel to cut into the ash-pan. Often the ash-pan is made with a depression to prevent damage in cases of this kind.

When a spring, a spring hanger or an equalizer breaks on a trailing truck with outside journals, the truck will be tilted up on the broken side on account of the frame on this side settling on top of the driving boxes and thus relieving the weight on one side of the truck; the weight on the other side then tilts the truck. The truck will invariably derail if run backwards, especially through a curve.

If desired, the trailing wheel may be held solid on the rail by running up the back driving wheel on the broken side and blocking between the radius bar of the trailing truck and the main frame.

BROKEN TRAILING-TRUCK WHEEL, AXLE, OR TIRE

42. It will be necessary to send for assistance in order to have the necessary repairs made when a trailing-truck wheel or axle breaks. While waiting for help the steam pipes and the air pipes to the booster engine should be disconnected because they are liable to be broken when the truck is being raised. Briefly, this breakdown is handled by raising the main frame of the locomotive and blocking it at such a height that the trailing truck when chained to it will be clear of the rails. The procedure when assistance arrives is usually as follows: The rear end

of the engine is jacked up, blocking being first placed over the forward driving boxes to prevent the frame from lowering at the front while it is being raised at the rear. The frame can be raised until its top strikes the spring saddles or the pedestal binders strike the grease cellars, depending on where the clearance is the least. The latter ordinarily occurs first. After the frame has been jacked up high enough to insure that the trailing truck when chained to it will have its wheels clear of the rails, blocking is placed between the front portion of the truck equalizers and the frame to take the tension of the spring rigging off the chains after the truck has been chained up; also, blocking is placed over the top of the back driving boxes to prevent the possibility of the engine settling. Next, the trailing truck is jacked up and chained directly to the engine frame, although in some cases a piece of rail will have to be placed across the frame to chain the truck to. The slack is taken out of the chains by driving in wedges.

43. In some cases the brasses of the trailing truck will have to be removed before the truck wheels can be raised high enough to clear the rails. The trailing truck is jacked up high enough to permit the removal of the brasses, and the frame is lowered down to permit of the maximum application of blocking under the journal; the truck frame is then jacked up as before. The journals of the back driving wheels will probably heat, owing to the extra weight that has been thrown on them; also, the additional weight may loosen the tires on these drivers.

With a Commonwealth truck, the truck equalizers are in the truck frame; this makes it impossible to remove the tension of the spring rigging from the truck. Hence, when the truck is chained up, the chains not only have to bear the weight of the truck but the tension of the spring rigging as well. Blocking is placed over the back drivers, as before, to prevent settling.

It may be possible, with a partly broken wheel, to open the main track by sliding the wheel to the nearest siding. This can be done either by wedging a cross-tie against the broken part of the wheel, thereby keeping it from turning, or by passing a short piece of rail, if available, through the spokes of the wheel.

BREAKDOWNS OF FOUR-WHEEL TRAILING TRUCK

44. The fireboxes of modern locomotive boilers are so large that their weight if carried on a two-wheel trailing truck would result in excessive journal loads; the four-wheel truck, Fig. 24, was introduced to lessen the load by distributing it to a greater number of journals. The load is carried on the frame of a four-wheel truck as with a Commonwealth two-wheel truck. A portion of the load is carried at the front end where the truck is pivoted to a cross brace at the rear of the main frame, the balance of the load is transferred to the rear of the truck frame through a pair of heart-shaped rockers interposed between the rear of the cradle and the frame. The weight that is on the truck frame is transferred through the spring arrangement, here shown by dash lines, to the truck boxes and thence to the journals.

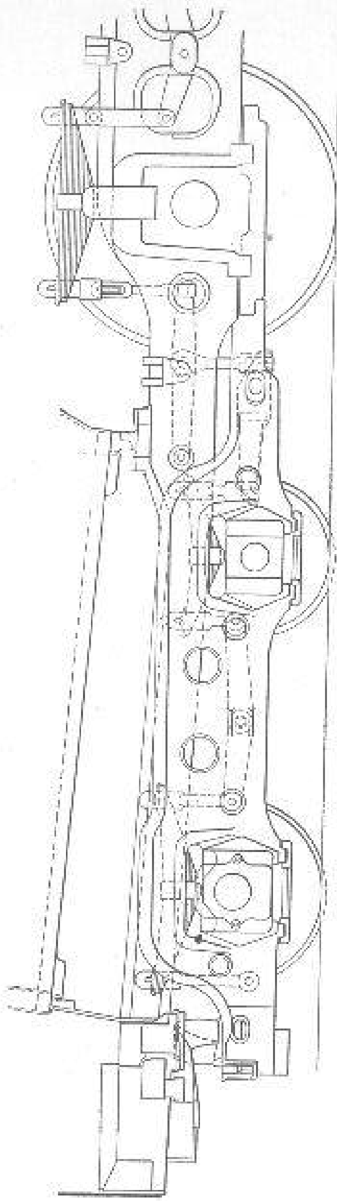


Fig. 24

BROKEN TIRE, JOURNAL, OR WHEEL

45. The weight of locomotives with four-wheel trailing trucks is such that breakdowns affecting the trucks can only be handled successfully by work-

men supplied with the proper equipment such as jacks, blocking, etc.

A truck wheel with an outside journal is liable to derail if its mate is carried clear of the rail. Therefore it is generally advisable to carry a pair of wheels clear of the rails for breakdowns that involve only one wheel. The first step when proceeding to do this work such as in the case of a broken tire, is to jack up the rear end of the locomotive taking care before doing so to block over the forward driving boxes to prevent the frame from settling at the front while it is being raised at the rear. A heavy jack should be placed on each side under the corner of the cradle. The truck is relieved of a greater portion of its weight as the frame is jacked up, also some of the tension is taken out of the spring rigging. Smaller jacks can then be used to raise the truck wheels and by blocking between the binders and the boxes the wheels can be carried clear of the rail. Blocking should also be placed under the back ends of the truck equalizers, Fig. 25, so as to take the weight off the truck boxes, as well as over the back driving boxes to prevent the rear end of the locomotive from sagging down and causing the truck wheel to come down on the rail when the heavy jacks are removed. The blocking under the equalizers can be inserted through the opening shown that is provided for this purpose in the bottom of the truck frame. If more convenient, the ends of the equalizers can be supported by a long pin placed in the two holes in each side frame.

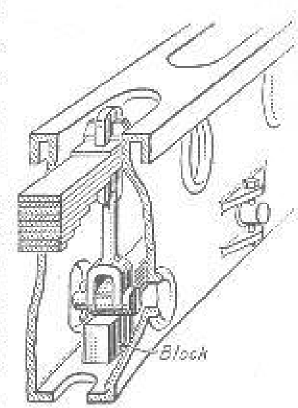


Fig. 25

The procedure for a broken tire on a front wheel is similar except that blocking should be placed under the ends of the equalizers on each side of the wheel.

46. A broken wheel can be similarly handled; a broken journal requires the same treatment except that the end of the axle next to the broken journal will have to be chained up to the cradle, the other wheel being carried by blocks over the binder as before described. If the rear of the truck frame has a tendency to sag, it will have to be chained up to the cradle but this will be seldom necessary if the rear ends of the equalizers are blocked high enough. Blocking should also be placed over the back driving boxes to relieve some of the overhanging weight from the truck.

BROKEN TRUCK SPRING

47. A broken truck spring will cause the truck to derail for the same reason that a derailment occurs with a two-wheel trailing truck for a similar breakdown. The journals are on the outside of the wheels, and when a spring breaks the locomotive frame on that side settles down on the driving boxes and relieves the truck wheels on this side of their weight. The overhanging weight on the journals on the other side then tilts the wheels on the side with the broken spring. These wheels can be held on the rail by jacking up the rear end of the locomotive as already explained and blocking over the tops of the truck boxes.

TENDER BREAKDOWNS

48. When a tender-truck axle breaks, assistance will have to be asked for, and a new truck applied. If a tender-truck spring or equalizer breaks, the tender will list over on that side, and care should be taken to see that it has enough clearance. The speed should be reduced with such a failure. When the tender drawbar or pin fails, the tank hose will be ruptured; the fire will then have to be drawn and the locomotive drawn in.

LOCOMOTIVE APPLIANCES

Serial 2512 Edition 1

GAUGES AND SAFETY VALVES

WATER GAUGES

1. Water-Registering Devices.—With no means of ascertaining the water level in the boiler, it would be impossible to know whether there is sufficient water in the boiler to protect the crown sheet or whether the water is so high as to be carried to the cylinders. The crown sheet is the highest sheet in the firebox and is therefore the first one to be uncovered when the water becomes too low. With no water on the crown sheet, it will overheat quickly and the result will be either a boiler explosion or a badly damaged crown sheet that will have to be renewed.

The importance of always being able to determine the water level makes it unsafe to rely wholly on one device for registering the height of the water, hence two are used so that one may serve as a check on the other. One device is known as a water gauge, often referred to as the water glass, and the other device is called the gauge-cock, three of which are commonly used. However, the modern practice is to use a water column, which is a water gauge and gauge-cocks combined in one device.

The water gauge, when working properly, shows the exact water level in the boiler, whereas the gauge-cocks indicate only the approximate level.

2. Types of Water Gauges.—Water gauges are of two types. One type consists of a straight tubular glass connected to brackets on the back boiler head that are tapped through the sheet into the water space. With the other type, the water in the boiler is connected to a metal compartment in which a strip of glass is placed so that the water level can be readily observed. This latter type of water gauge is known as a reflex gauge, because the glass strip reflects the light in such a way as to make the water appear black and the steam white.

3. Ordinary Water Gauge.—A water gauge of the ordinary kind that employs a straight tubular glass to indicate the water level is shown connected to the back boiler head in Fig. 1 (*a*). The gauge consists of two brackets, or fittings, *a* and *b*, screwed into the boiler and connected by the water glass *c*, and the piping shown. The steam from the boiler enters the top of the glass through the opening in the bracket *b* and the water enters the bottom of the glass through a similar opening in the lower bracket *a*. Therefore, practically the same pressure is exerted on the top of the gauge as at the bottom and the weight of the water will cause it to assume the same level in the glass as in the boiler as shown by the shaded portion in each. The bracket *a* extends a short distance through the back sheet so that the solid water will enter the glass instead of a mixture of steam bubbles and water as would be the case were the brackets flush with the inside of the sheet. The spindles *d* and *e* in the top and the bottom brackets are used to shut off the discharge of steam and water into the cab should the water glass break, when a new glass is being applied or when the accuracy of the water gauge is being tested. Under all other conditions, the spindles should be kept wide open as shown.

4. All water gauges are enclosed by a water-gauge protector, or shield, that will permit the water level to be observed and at the same time will prevent injury to the enginemen by flying glass should the tube break. A modern protector, shown in section in view (*b*), usually consists of a round metal shield *a* screwed on to the top and bottom brackets, in which two or three observation slides *b* and a perforated release plate *c* are set. Should the water glass break, the small perforations in the release plate permit the steam to escape and relieve the protector of pressure, and the shield and the slides retain the broken

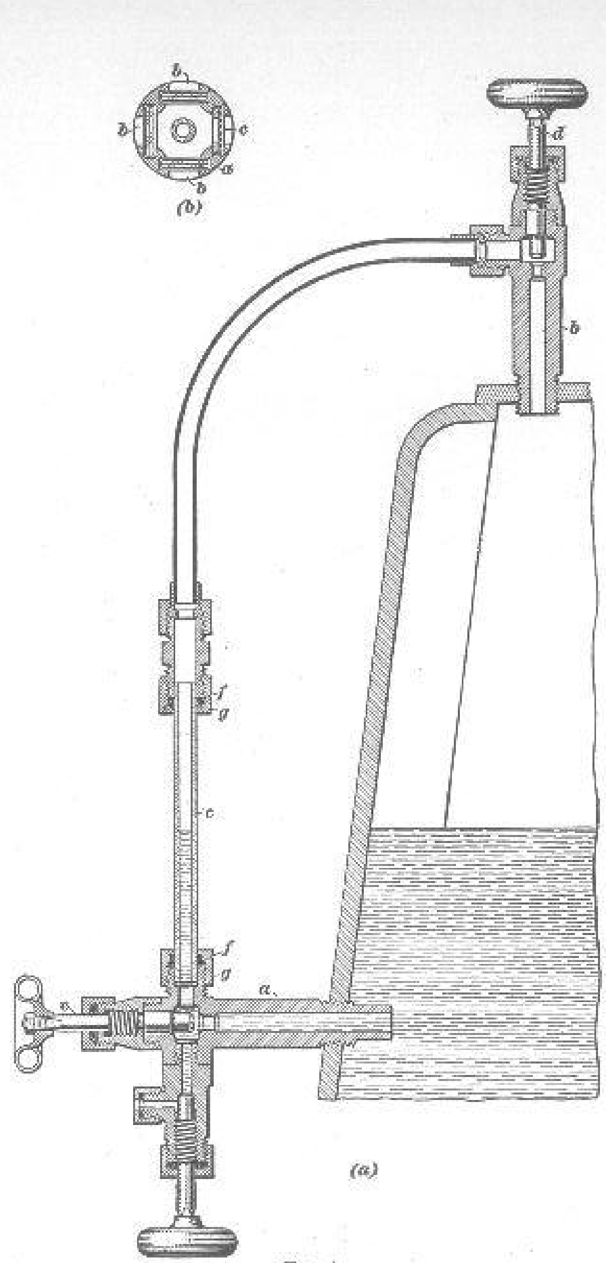


Fig. 1

particles of the glass. The glass can be blown out and cleaned, when its interior becomes dirty and discolored, by opening the drain cock below the bottom bracket, and then closing the valve *c*. The steam blows through the upper bracket, down through the glass, and out of the drain cock.

The lower bracket *a* is tapped into the boiler at such a point that, with the water at the lowest visible part of the glass, there will be from 3 to 6 inches of water over the crown sheet, the actual depth depending on the railroad company's standard. According to the Federal law, the depth of water over the highest part of the crown sheet with the water just showing in the water glass must not be less than 3 inches. The gaskets *f*, that are squeezed lightly against the water glass *c* by the packing nuts *g*, make a steam-tight or water-tight joint where the glass enters the brackets.

5. Reflex Water Gauge.—The tubular type of water gauge has several disadvantages. The glass is liable to break, and it is difficult to see the water level in poor light on account of the similarity in color of the water and the glass. When the tubular glass is partly filled, the movement of the water will ordinarily indicate the level, but with the glass filled completely, it is not altogether evident whether the glass is full or empty unless the gauge-cocks are tested. The appearance of the flame of a lighted match when held on the opposite side of the water glass will show whether or not the glass contains water, because the flame will look blurred when viewed through water.

6. With the reflex type of gauge, two views of which are shown in Fig. 2, there is no difficulty in observing the water level for the reason that the water appears black as shown in view (*a*), whereas the steam space above the water is light. The construction of this type of gauge is shown by the cross-sectional view in Fig. 3. The gauge consists of a hollow metal body *a* with the water space *b* closed in front by a thick glass *c* that sets in the glass seat *d*. Gaskets *e* are placed between the glass seat and the glass, and between the glass and the body. The studs *f* cause the glass seat *d* to draw the glass *c* up steam-tight against the body *a*. The face, or the front, of the glass is

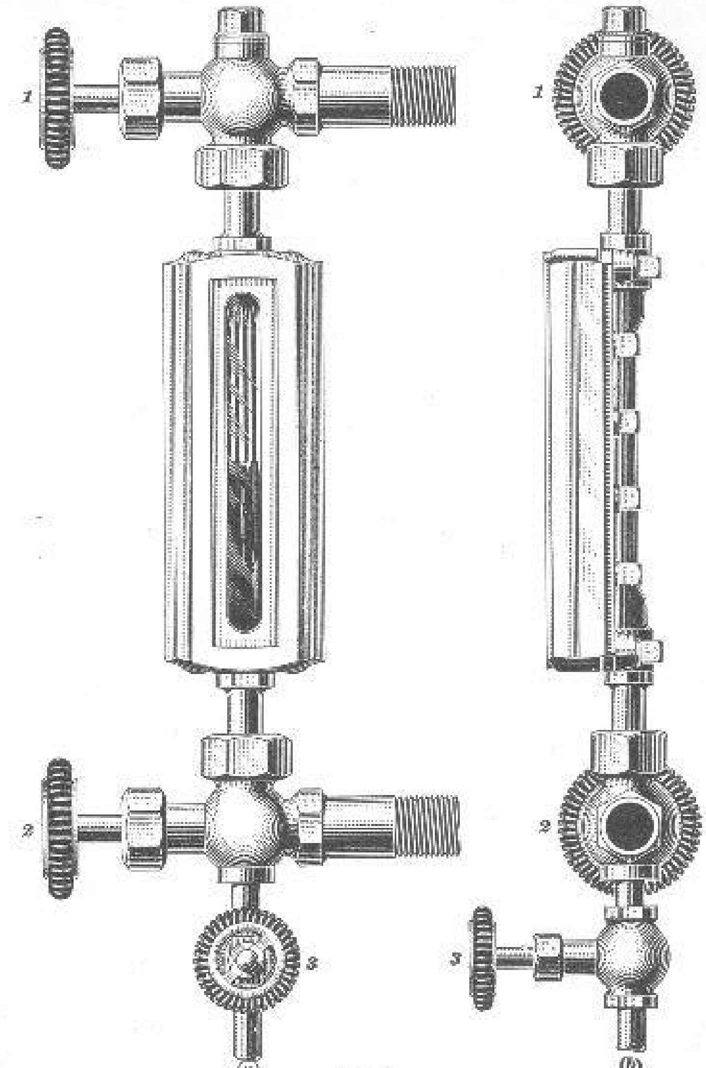


Fig. 2

smooth, and the back, or the water side, of the glass is fluted or corrugated as shown. These corrugations reflect the light in such a manner that the portion of the gauge filled with water will appear black, and the part filled with steam will appear colorless. The glass is made very thick and there is very little danger of breakage. However, the steam, in following the movement of the water in the gauge, gradually wears away the corrugations, especially at the upper end. When this occurs, the glass no longer reflects the light properly, and is liable to be misleading because the part of the glass that contains steam will begin to darken and will cause the steam to show dark like the water. The glass should then be turned end for end or a new one should be applied. This type of glass is also liable to leak in time at the gaskets.

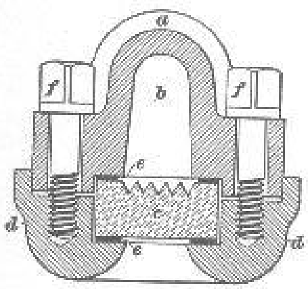


FIG. 3

With the exception of the water glass, the arrangement of the reflex water gauge is the same as in Fig. 1. The top or the bottom of the glass can be connected to or shut off from the boiler by turning the valve handles *1* or *2* of the spindles in the proper direction. The valve handle *3* is used to open and close the drain valve.

7. Disorders of Water Gauges.—When the water gauge is in good order, the water will rise and fall freely in the glass with the movement of the water in the boiler when the locomotive is in motion. A sluggish movement of the water indicates that the steam or the water has not free access to the gauge glass, and the gauge indication must not be regarded as reliable. It should be remembered that disorders in the water gauge always cause the water level to appear higher, and not lower than the water level in the boiler.

The water gauge must be in the following condition before it will register the water level correctly: Both the spindles *d* and *e*, Fig. 1, must be opened fully, the openings in the brackets *a* and *b* must be clear, and the top and the bottom of the glass must be unobstructed. If the top spindle is closed and the bottom one open, the water glass will always show full of water as long as the water in the boiler is up to the level of the lower bracket *a*. In this case there would be no pressure on the top of the water in the glass, and the pressure in the boiler, acting through the lower bracket, would force the water upwards. With the top spindle partly closed, the pressure of the steam on the top of the water in the glass will be less than normal and the water level will be higher than in the boiler. If the spindle *e* in the bottom bracket *a* is closed and the top spindle *d* is open, the glass will fill with condensed water through the bracket *b*.

8. Any obstruction in the opening through the water-gauge brackets *a* and *b* is almost invariably caused by mud or scale. The lower bracket, as it is always in communication with the water, is the one that generally becomes obstructed.

The Federal regulations require the spindles of water gauges and gauge-cocks to be removed and the cocks thoroughly cleaned of scale and sediment at least once each month.

The water-gauge brackets as well as the gauge-cocks should have a straight opening through them so that they can be easily bored out when necessary to clean out the scale.

An obstruction at the top or at the bottom of the gauge glass that restricts the passage of steam or water to the glass is generally caused by the gaskets. Cases have been found in which the water glass when applied was so short that the rubber gasket partly covered the end of the glass.

9. Testing Water Gauges.—It should always be ascertained whether the water gauge is in good order before leaving the terminal, and in making the test each end of the gauge should be tested separately. It can be determined whether the opening in the top bracket *b*, Fig. 1, or whether the top or the bottom of the water glass is obstructed by closing the bottom spindle *e* and then opening the drain cock. Steam should then blow freely through the glass and the drain cock; if not, the upper bracket and the ends of the glass should be examined.

The bottom bracket *a* can be tested by closing the top spindle *d* and opening the bottom spindle *e* and the drain cock. The water should then escape freely; also after the drain cock is closed and the spindle *e* is opened, the water should return to its former level in the glass instantly. A slow return of the water is positive evidence that the opening through the bracket is obstructed.

After making the test, the drain cock should be closed, and both of the valves *d* and *e* should be opened an equal amount. It is important that these valves be examined as soon as the engineman gets on the engine at a terminal, because they are often closed while the locomotive is in the roundhouse.

Sometimes the water gauge is tested by merely opening the drain cock, but such a test is unreliable, because a good flow of steam or water could still be obtained with one of the spindles wholly or partly stopped up. The reflex type of water gauge is tested in the same way as the tubular type.

10. Broken Water-Gauge Glass.—The spindles *d* and *e*, Fig. 1, in the top and the bottom brackets should be closed at once, when the gauge glass breaks, to prevent the escape of water and steam into the cab. In applying a new tubular glass, the glass should be just long enough to extend through both the top and the bottom gaskets, in which event the gaskets cannot squeeze out over the end of the glass and stop it up. With the glass in position, the packing nuts at first should be screwed up very moderately by hand so as to allow the gaskets to soften with the heat and also to give the glass a chance to expand. When the glass breaks during application, it is generally due to the fact that the packing nut is too tight to permit the glass to expand when heated. The spindles *d* and *e* should then be opened slightly and, if the gaskets leak, the packing nuts should be tightened up a little at a time until the leak stops. The packing nut at the steam end of the glass should be a little slacker than at the water end because the glass is hotter at the top and the expansion is greater. It should be possible to move the glass vertically with the finger and the thumb after the packing nuts are screwed up enough to stop leaks. If the packing nuts are

screwed up tight with a wrench at first, the glass will almost invariably break when the steam is turned on, because the glass cannot expand. A wrench should be used carefully and only when the packing nuts cannot be tightened enough by hand. However, if the threads on the packing nuts as well as the threads on the brackets are thoroughly cleaned and oiled slightly, the nuts can be screwed up by hand without difficulty. With the ordinary arrangement of glass, the gasket turns with the packing nut. To permit the gasket to turn freely and not crowd against the glass, the inside of the nut should be well cleaned and a little oil should be applied.

11. Repair parts are seldom available when the glass of a reflex gauge breaks, but the run can be completed by depending on the gauge-cocks.

The glass or the gasket of this type of gauge is renewed as follows: The gauge is first removed from the brackets by unscrewing the packing nuts, shown in Fig. 2. The glass seat *d*, Fig. 3, and the glass *c* are next disconnected from the body *a* by unscrewing the studs *f*. All of the old gaskets should be removed and the parts of the body and the glass seat with which the gaskets are in contact should be thoroughly cleaned. When assembling the gauge after the defective parts have been renewed, the studs *f* should all be tightened uniformly. After the gauge is applied and becomes heated, the studs should again be tightened up so as to take up any slack caused by expansion. A gasket should always be renewed with this type of water gauge as soon as a leak starts.

GAUGE-COCKS

12. Description.—The damage that results when the water in the boiler becomes too low is so serious that it is not safe to rely wholly on one device like the water gauge to determine the water level. Therefore, gauge-cocks are also applied to the back boiler head for the purpose of testing the water level in the boiler as well as for checking the accuracy of the water gauge. At least three gauge-cocks are used, which are placed one above the other on the back boiler head an equal distance or about

3 inches apart. The gauge-cocks are placed on a slant so that they can drain more conveniently than otherwise into the gauge-cock dripper, which is a receptacle for catching and carrying the water from the cocks to a waste pipe. The exact water level cannot be determined by the gauge-cocks. For example, if the bottom gauge-cock blows water, and the next one steam, there is more than one gauge of water and less than two gauges, but the amount in excess of one cannot be determined. The water level between the gauge-cocks can be told only by the water gauge.

According to the Federal law, the bottom gauge-cock must not be less than 3 inches above the highest part of the crown sheet. The same applies to the lowest visible part of the glass in the water gauge; therefore, the bottom of the glass in the water gauge and the center of the bottom gauge-cock are in line.

13. A sectional view of the ordinary type of gauge-cock is shown in Fig. 4. The front part of the cock is threaded and is screwed into the back boiler head. The opening *a* is normally closed by the spindle *b*, which can be turned by the handle

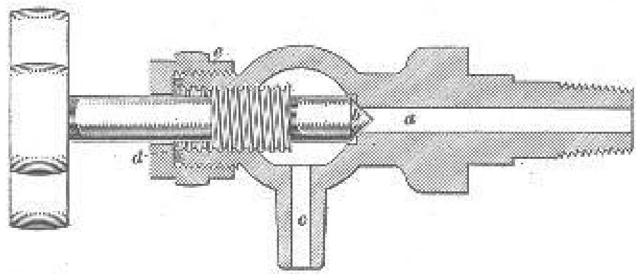


FIG. 4

shown. When the valve is opened, the steam or the water discharges through the nipple *c*. The steam is prevented from escaping along the valve stem with the spindle open by the packing *d* and the packing nut *e*.

The frequent opening and closing of the gauge-cock causes the end of the spindle and the valve seat to wear until finally the spindle is no longer steam-tight. The spindle cannot be reground to a steam-tight fit with pressure in the boiler, because

there is no way to shut off the steam when the spindle is removed.

14. The gauge-cock shown in section in Fig. 5 is designed so that it can be repaired with pressure in the boiler; therefore, the pressure does not have to be blown down or the repairs to the cock delayed until the boiler is without pressure as with the ordinary type of cock. The end *a* of the spindle does not come

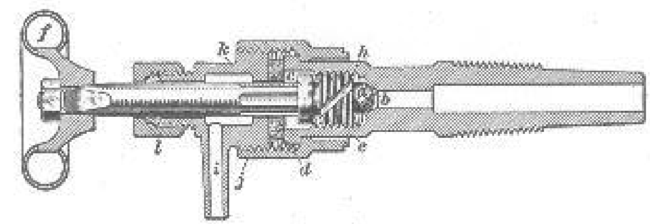


FIG. 5

in contact with its seat *b*, when the valve is opened and closed, but the joint at this time is made instead by the collar *c* and the renewable composition disk *d*. Therefore, there is no wear on the end *a* because this part is never used except when the disk *d* is to be renewed, in which event the end *a* is screwed to its seat as shown. The thread at *e* is cut left-handed in order to make the movement of the valve handle *f* correspond with the ordinary gauge-cock when the valve is opened and closed. That is, a movement of the spindle handle to the right draws the collar *c* back against the disk *d* and closes the gauge-cock, whereas a movement to the left carries the collar away from the disk and opens the cock as shown. In open position, the steam or the water from the boiler passes through the slots *h*, one shown, milled across the threads on the stem, then past the collar *c* and the disk *d*, and along the fluted stem to the nipple *i*.

15. To renew the disk when it leaks, the spindle handle is turned to the left as far as possible, thereby moving the collar *c* away from the disk *d* and bringing the end *a* of the stem in contact with its seat *b*, as shown. The discharge of steam through the nipple *i* then stops. The coupling nut *j* is next turned off the bonnet *k*, the packing nut *l* is unloosened and the handle *f* is removed. The packing nut, the bonnet, and the disk are then slipped off the stem, a new disk is applied, and the parts are connected up again. The spindle handle should then be turned to the right as far as possible, which brings the collar *c* in contact with the disk *d*. It should be noted that, if the spindle handle is turned too far to the left when trying the water level, the end *a* seats and shuts off the discharge of water or steam. Therefore the handle should be turned only enough to cause a good flow. One and one-quarter turns of the handle brings the end *a* against its seat.

16. Disorders of Gauge-Cocks.—Gauge-cocks are subject to practically no disorders if they are properly applied and kept clear.

Sometimes a gauge-cock, when opened, will blow steam while the one above it will discharge water. Such a condition is brought about because the gauge-cock does not project far enough into the boiler. On modern locomotives, the water next to the back head, especially near an arch tube and beneath a boiler bracket, is not solid and may be largely steam bubbles. Unless the gauge-cock projects through this film of steam, steam will discharge when the cock is opened.

17. Number and Location of Water Glass and Gauge-Cocks.—The Federal regulations prescribe that every boiler shall be equipped with at least one water glass and three gauge-cocks. The lowest gauge-cock and the lowest reading of the water glass shall not be less than 3 inches above the highest part of the crown sheet. According to another rule, all tubular water glasses and lubricator glasses must be equipped with a safe and suitable shield, which will prevent the glass from flying in case of breakage, and such shield shall be properly maintained.

WATER COLUMNS

18. Water Level in Modern Boilers.—With the earlier types of boilers, and the locomotive working, the gauge-cocks indicated the same water level as the water gauge, or the readings of the two corresponded. For example, with the water

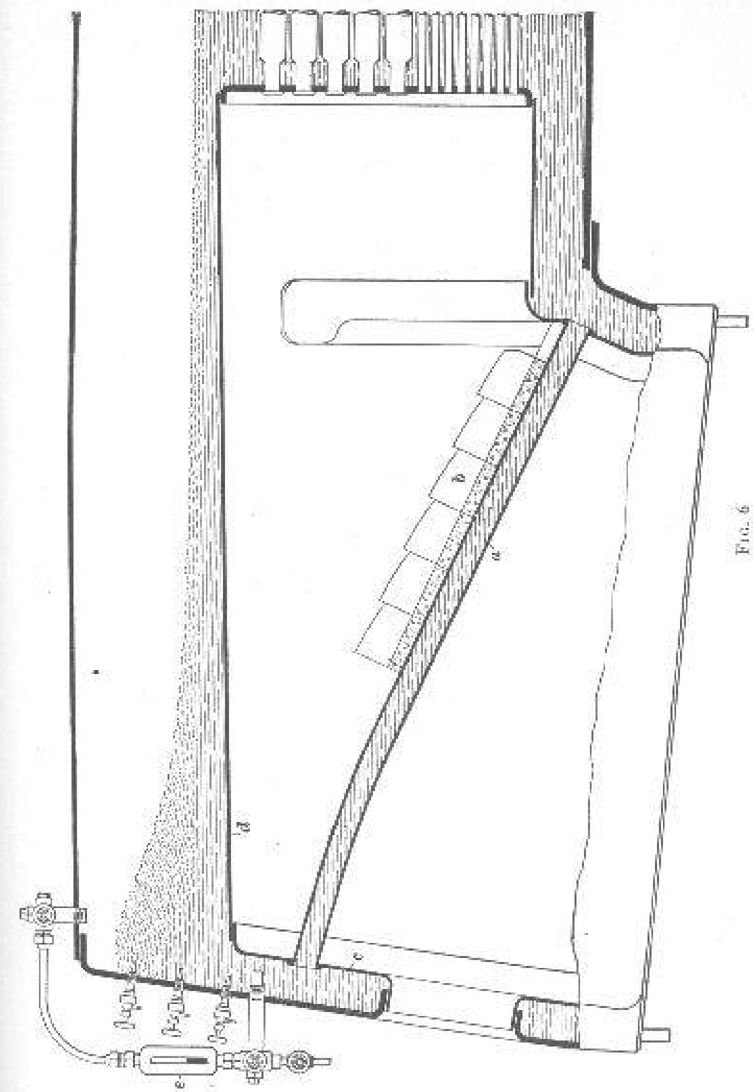


Fig. 6

level just reaching the middle gauge-cock, an equal height of water would be shown by the water gauge. With a modern boiler, unless the locomotive is at rest, a considerable variation exists between the water level as shown by the water gauge, and the gauge-cocks, if these devices are applied in the ordinary manner. Therefore, either the water gauge or the gauge-cocks are registering incorrectly, and serious consequences will result if reliance is placed on the one that is wrong. The conditions that cause the gauge-cocks and the water gauge to indicate differently are as follows: The modern boiler has a sloping back head as shown in Fig. 6, so as to make more room in the cab, and the firebox is equipped with arch tubes *a*, one shown, and a brick arch *b*. The brick arch causes the heat of the fire to impinge on the arch tubes, the door sheet *c*, and the back end of the crown sheet *d*, and this results in a severe agitation of the water and a rapid circulation through the arch tubes and up the door sheet.

19. The sloping back head and the door sheet *c*, in combination with the rapid circulation, lift the water at the back of the crown sheet from 4 to 6 inches higher than in any other part of the boiler, as shown, when the locomotive is working hard. The water gauge *e* shows that the water is about 6 inches deep on the crown sheet, while the top gauge-cock, if opened, would indicate a depth of water equal to about three gauges. The gauge-cock at the top therefore will show about 3 inches more water in the boiler than will the water gauge. The water level in the water gauge is not affected to any great extent when the water is lifted at the back of the boiler. The water is forced into the water gauge by its weight, and the weight of the water in the boiler at the normal level is so much in excess of its weight at the higher level that this latter level does not raise perceptibly the water in the gauge.

The following will also explain why the higher water level is not shown by the water gauge: With the water higher in one part of the boiler than in the other, the water gauge will indicate the average height of the water in the boiler. The higher water level is only a small part of the total level, hence the aver-

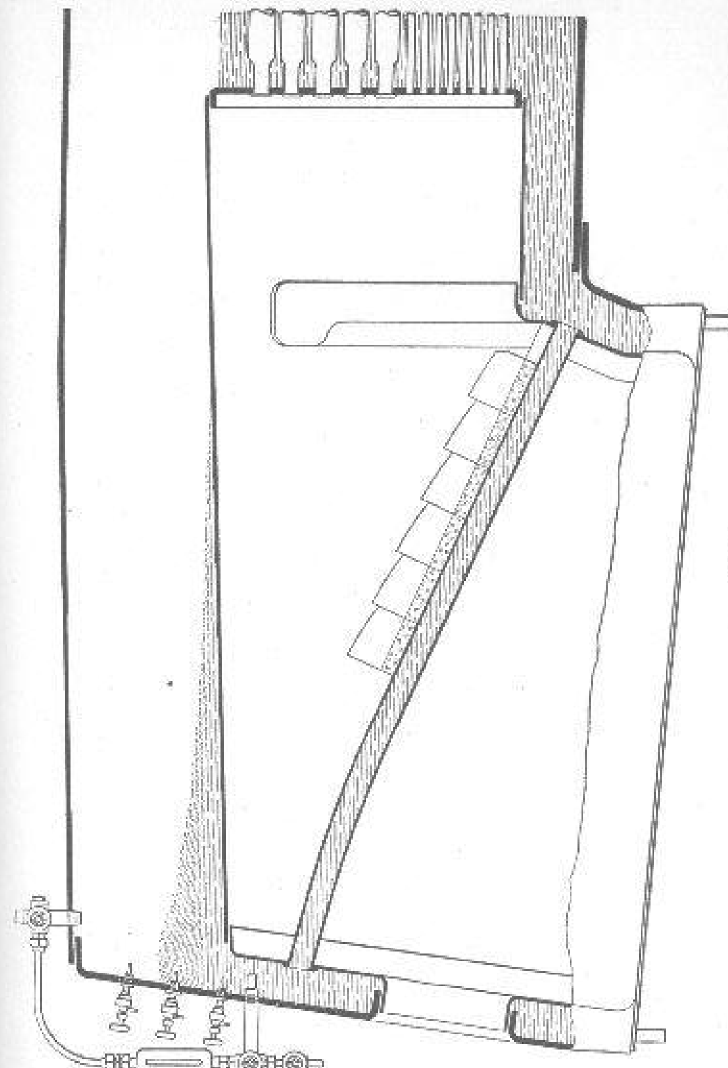


Fig. 7

age water level as indicated by the water gauge will be very slightly more than the normal level.

However, if the rear of the boiler could be walled off from the remainder of the boiler, the high water level at the rear would then be indicated by the water gauge.

20. The gauge-cocks only indicate the water level at the point where they are tapped into the boiler, and they therefore show a greater depth of water than really exists when the water is higher at the back. As shown in Fig. 7, the front of the crown sheet is unprotected, whereas the two lower gauge-cocks show water. The water-gauge glass in this case shows no water. The crown sheet slopes to the rear; there is less liability then for it uncovering when descending grades when the rear would be the high point, if level. When ascending a grade, the front is the high point but being nearer the center of the boiler the water is not lowered as much as at the front tube sheet. This construction reduces the damage with low water as but a small area of the sheet is uncovered.

The common understanding has always been that the true water level can only be determined by the gauge-cocks, because they are tapped directly into the boiler, and that the water level as indicated by the water gauge is unreliable on account of the disorders to which it is liable. However, when the water lifts at the back end, the correct water level is indicated more accurately by the water gauge. The fact that the gauge-cocks have been relied upon instead of the water gauge has resulted in damaged crown sheets.

21. Purpose of Water Column.—The purpose of the water column is to prevent the high water level in the back of the boiler from being indicated by the gauge-cocks, or the water column serves to give a correct gauge-cock reading.

An exterior view of a water column is given in Fig. 8, which in this case consists of a hollow metal body *a*, $4\frac{1}{2}$ inches in diameter, with a water gauge *b* and gauge-cocks *c* connected to it. In reality a water column is a special form of water gauge, with gauge-cocks attached to it. The water gauge shows the exact water level in the interior of the body *a*, and hence in the boiler,

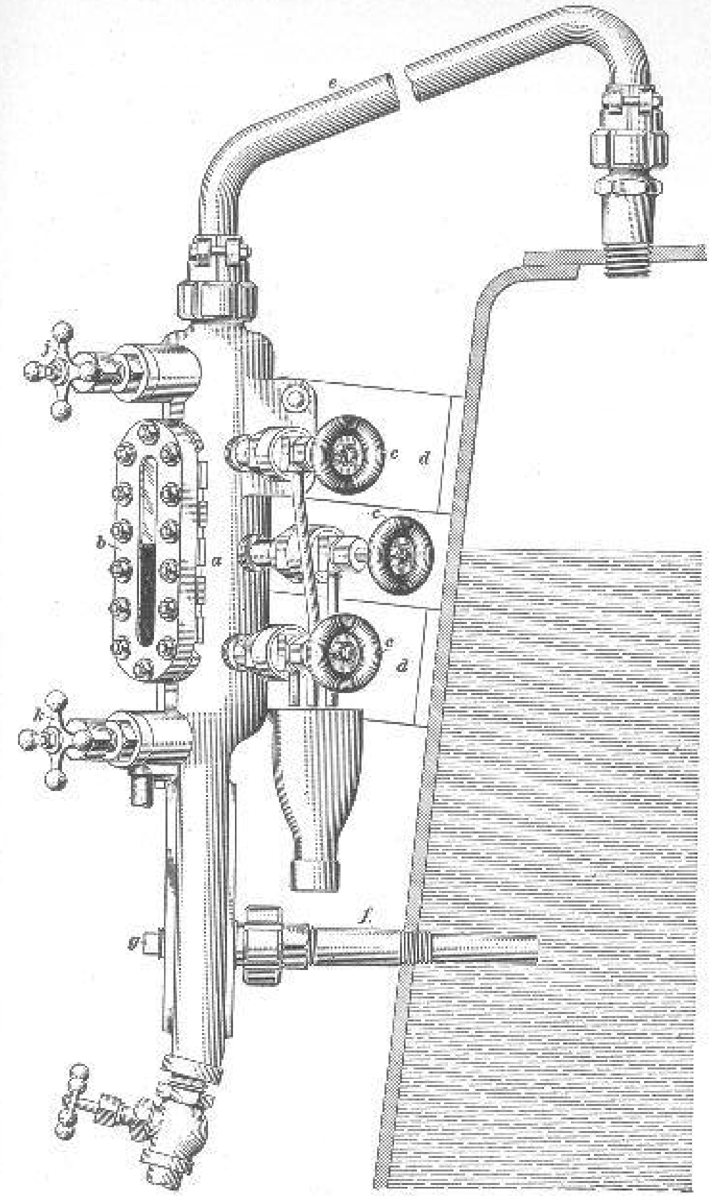


FIG. 8

and the gauge-cocks check the accuracy of the water level as indicated by the water gauge, also to indicate the water level should the valves *j* have to be closed owing to failure of the glass.

22. The water column is connected to brackets *d* on the back boiler head and is placed, if possible, midway between two arch tubes. The top of the column is connected to the roof sheet by the copper pipe *e* and the bottom is in communication with the interior of the boiler through the pipe *f*. This pipe enters far enough into the water space to extend beyond a crow-foot or boiler-brace foot that may be above it, thereby insuring, as far as possible, that water and not a mixture of water and steam enters the pipe and the water column. The pipe, or extension, *f* can be bored out by removing the plug *g*. No valve is placed in the pipe *e*, because if one were used, there would be the possibility sometimes of its being closed.

The water-gauge compartment *b*, as shown by the part-sectional view of the water column in Fig. 9 (*a*), is connected with the interior of the column through the openings *g*, the communication through which is controlled by the valves *h* and *i* on the spindles *j* and *k*. Unless each valve is open fully as shown, steam or water will pass by the part *l* of the spindle and escape at a warning port *m*, thereby indicating that a valve is partly closed. Of course, if both valves are closed tight, no blow will occur at either warning port. The water compartment can be blown out by removing the plug *n*; and the water column, by opening the valve *o*. The openings *p* are provided for the gauge-cocks. A sectional view of the water column is shown in (*b*).

23. Disorders of Water Columns.—The water-gauge portion of the water column shown in Fig. 9 is subject to practically no disorders, provided the openings *g* are kept clear. Some types of water columns have the water gauge connected to them by piping instead of the gauge being a part of the column as shown in Fig. 9. With such a type of column, unless the piping and brackets are arranged so that they can drain into the column, water pockets will form in them and interfere with the reading of the water gauge. Sometimes the opening through the water-gauge brackets, Fig. 10, is not bored exactly through

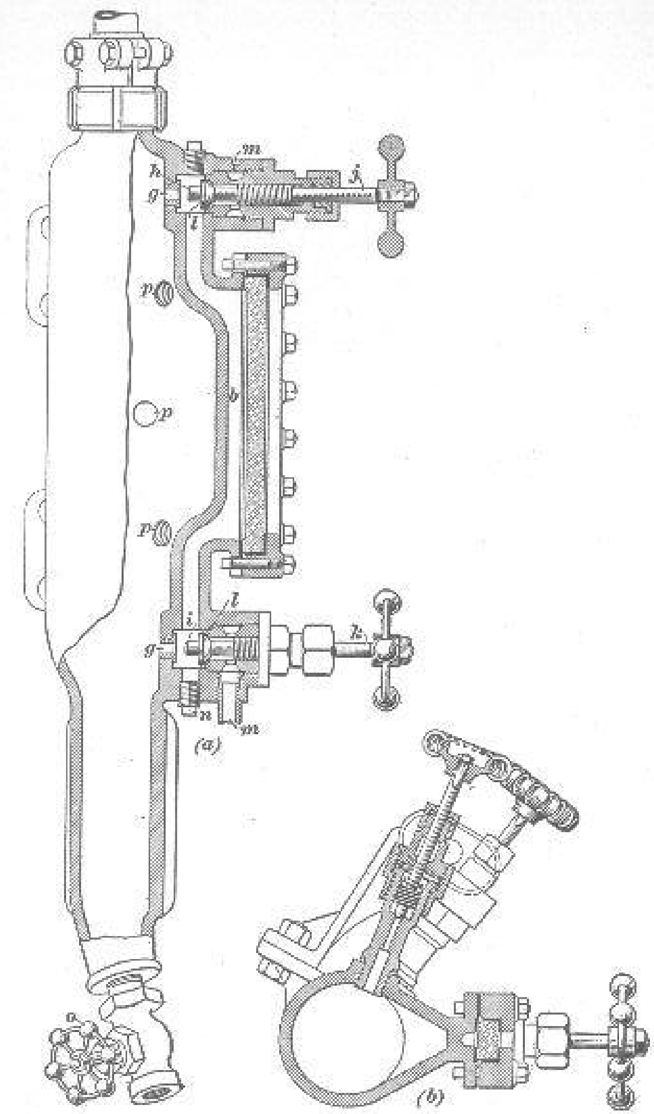


Fig. 9

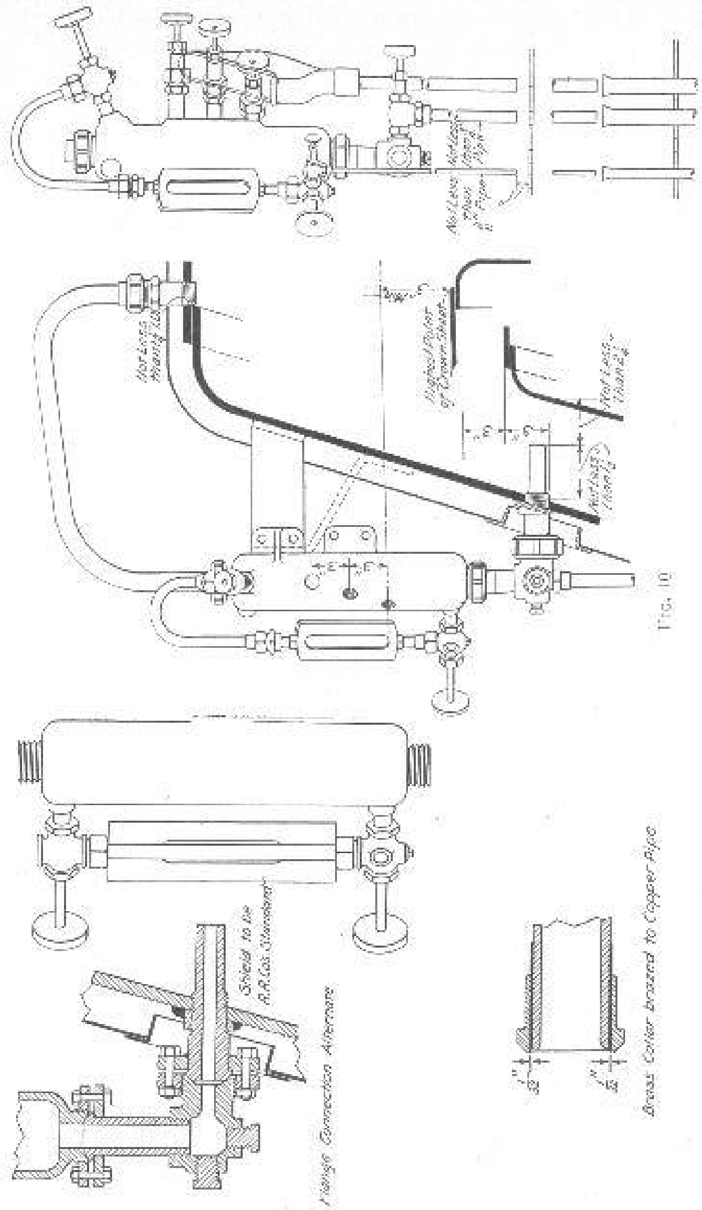


Fig. 10

their center, and this will cause condensation to be retained, even with the bracket inclined. A very small pocket of water in the piping or brackets will seriously affect the operation of the water gauge, as it prevents the gauge from receiving full steam pressure, with the result that a higher water level will be indicated than exists in the boiler.

24. A. R. A. Recommended Practice.—The recommended practice of the American Railway Association with respect to the application of water columns is shown in Fig. 10. The water column is to be located well toward the center of the boiler to afford protection and to avoid violent fluctuation of the water while rounding curves. The top of the water column is to be connected to the boiler on the top center or in a location not farther to the side than 9 inches and not nearer to the back head than the back-head seam. The drain pipes may either be extended to within 1 inch of the cab floor or deck and discharge through holes slightly larger than the diameter of the pipes or they may be arranged to discharge into pipes with funnel-shaped tops as shown. The inner end of the bottom spud must not be closer than 2¼ inches to the firebox-door sheet; if nearer than this the gauge indication will be affected by the rapid boiling of the water next to the sheet and a too high water level will be indicated. This spud must not be located in the radius or knuckle of the back-head flange or immediately above the arch-tube opening and must extend not less than 1½ inches through the back head and beyond any attachment to avoid location within an eddy or pocket where water may dam up. Also, this spud must be located in a vertical range between 3 inches below and 3 inches above the back end of the firebox crown sheet.

Sometimes it may be found that a water gauge and a water column do not register alike; this may be due to their spuds not extending through the back sheet the same amount or to the boiler not being level on its springs.

The pipe from top of water column to boiler must be of copper not less than 1¼ inches inside diameter. The bottom spud should have a ¾-inch straight bored port. The steam pipe to the water glass is to be not less than ½ inch outside diameter.

STEAM WHISTLE

25. Purpose and Description.—The purpose of the whistle is to give the signals required by the rules. A sectional view of a whistle is given in Fig. 11. The bowl *a* is screwed into the steam dome and the bell *b* is connected to it by the center bolt *d* and the top nut *c*. The washer *f* completely closes the top of the bowl with the exception of the circular slot *g*. The valve *h*, which is opened by the lever *i*, serves to admit steam to the bell of the whistle through the opening *g*. The lever *i* is connected by a rod to the whistle lever in the cab.

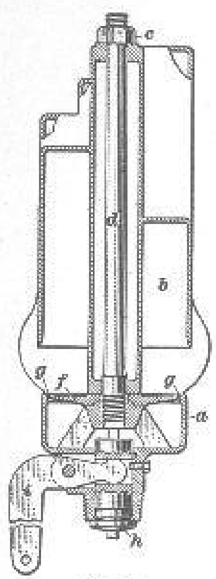


FIG. 11

26. Operation.—The lever *i*, Fig. 11, is pinned to the whistle body, therefore the lever will unseat the valve *h* when the lower end is drawn back. The steam in discharging through the opening *g* against the edge of the bell *b* causes it to vibrate, with the result that the bell will also vibrate and produce a sound. The valve *h* is seated by the steam pressure when the end of the lever *i* is released.

Whistles are of two types, the common, or ordinary, type and the chime type, shown in Fig. 11. The bell of the ordinary type of whistle consists of one chamber, whereas the bell of the chime whistle has several chambers of different lengths. In this case, each chamber emits a different tone, and the sound is more agreeable than that produced by the whistle of the ordinary type.

STEAM GAUGE

27. Purpose and Description.—The steam gauge is a device that shows the pressure that the steam exerts on each square inch of the interior of the boiler. Various types of steam gauges are used but they all operate on the same principle. An exterior view of a steam gauge is shown in Fig. 12 (*a*).

The gauge is connected to the boiler by a pipe that is coupled at *a*. The dial *b*, which is connected by screws to the case *c*, is graduated from 0 to 300 pounds. The gauge hand *d* is pivoted in the middle to the interior mechanism of the gauge and moves around the dial in accordance with the pressure in the boiler. The dial is white, and the gauge hand and the figures are black in order to facilitate reading. The dial and the gauge hand are protected by a glass held in a ring *e* that screws on to the case *c* and makes a dust-proof joint.

28. The dial, the glass, and the ring are shown removed in Fig. 12 (*b*) in order that the interior parts of the gauge can be seen. The gauge tube *f* is closed at the upper ends and is of elliptical section as shown by the full lines in view (*c*). The

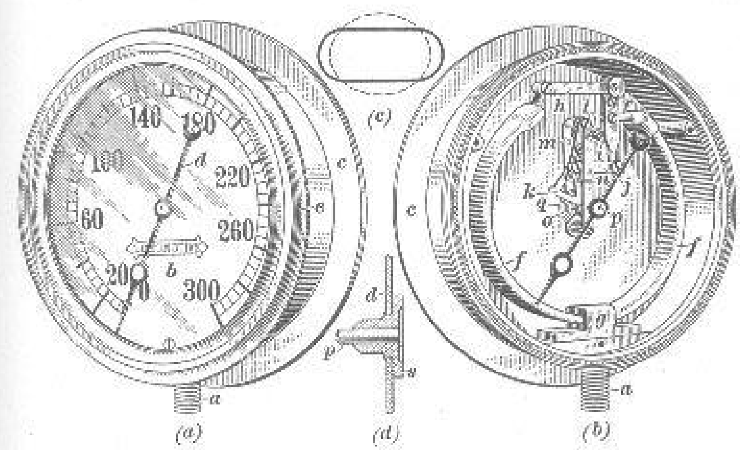


FIG. 12

tube is made in two parts, with the lower ends brazed to a socket *g*, view (*b*), that is secured by two screws to the case *c*. A part *a* of the socket extends through the case as shown, and it is to this part that the steam pipe from the boiler is attached. The interior of the tube is connected to the steam pipe through a passage in the socket. The left end of the tube is flexibly connected by a screw to the link *h* and the other end is flexibly connected by a screw to the link *i*.

The link j is flexibly connected by a screw to a slotted adjusting slide, which is secured to the toothed section k by the two lock screws shown. The purpose of the slide is to permit the inner end of the link j to be moved to another position on the toothed sector when the gauge is being adjusted. The sector k is secured to a spindle l the ends of which are free to rotate in the inside movement plate m and the outside movement plate n. The two movement plates are connected at the required distance apart by two movement posts and the complete movement is connected to the gauge case by screws in the inside movement plate.

The pinion o that meshes with the teeth in the sector k is also carried on a spindle p, the ends of which turn in the movement plates. The gauge hand is set on the outer end of the spindle. One end of the pinion hair spring q is connected to the movement post and the other end is connected to the spindle o. The spring resists slightly the action of the sector in turning the pinion; therefore, the spring keeps the pinion in contact with the teeth in the sector and thereby prevents the pinion from turning back and forth on the sector and causing wear. In the absence of the spring, the movement of the engine would cause the pinion to move on the sector and the gauge hand would vibrate.

The link h is connected by a screw to an eccentric r so that the link can be lengthened or shortened when adjusting the gauge by turning the eccentric. The eccentric is clamped in position by the screw shown beneath it. The gauge hand d, view (d), is connected to a stud s that in turn is pressed on to the end of the spindle p.

29. Operation.—The operation of the steam gauge is due to the effect of pressure on the interior of a tube of elliptical cross-section, as shown by the solid line in Fig. 12 (c), which is bent in the form of a circle. Pressure when applied to the inside of such a tube tends to make its cross-section round, as shown by the dotted line. But if the tube is bent into the arc of a circle its cross-section cannot become round until the tube is straightened out; hence pressure applied to the inside of the tube causes its free ends to move outwards. If the tube were circular in section

instead of elliptical, the application of interior pressure would cause no movement of the ends of the tube. Therefore, in view (b), both ends of the tube f, which is of elliptical cross-section, will move outwards when pressure is exerted on the interior through the passage in the socket a. The effect of the movement of the ends of the tube is to move the lower end of the link i and of the link j to the right, thereby causing the toothed sector k, which is pivoted on the spindle l, to move across the pinion o. The turning movement imparted by the sector to the pinion turns the spindle p, and thereby causes the gauge hand

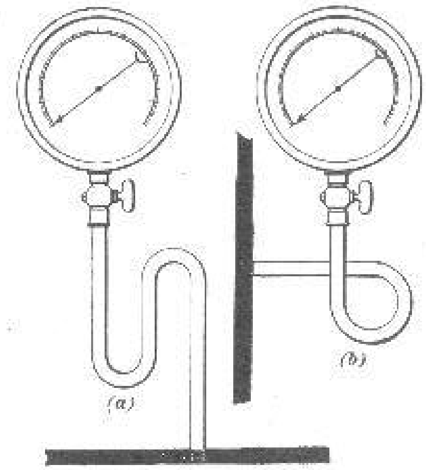


FIG. 13

to move forwards on the dial. When the pressure decreases in the interior of the gauge tube, the ends of the tube move inwards, and the sector and the pinion are moved in the reverse direction. The gauge hand then moves backwards in accordance with the change in pressure. The scale on the dial of the gauge is graduated so that the position of the gauge hand will indicate the pressure that acts on the tube in the gauge.

30. Gauge Pipe.—In order to operate properly, the expansion of the gauge tube should be accomplished by pressure only, and the shape of the tube should not be influenced by changes in temperature. Therefore, the pipe between the boiler connection and the gauge must be so arranged that steam will never get into the gauge tube and cause it to expand. The entry of hot steam to the tube is prevented by bending the gauge pipe somewhat as shown in Fig. 13. The bent portion of the pipe as well as the tube in the gauge fills with water that is condensed from the steam. Therefore, the gauge tube is operated by the pressure that the steam exerts on a column of water in the gauge pipe and in the gauge tube.

The pipe connection at the gauge must be maintained tight, otherwise the water will leak out, and the accuracy of the gauge will be impaired by the steam that enters the tube. The gauge should also be placed in a reasonably cool part of the cab so that the accuracy of the gauge will not be affected by the heat. The Federal law requires steam gauges to be tested every 3 months and also when any irregularity is reported.

SAFETY VALVES

31. Purpose.—The purpose of the safety valve is to prevent the steam pressure in the boiler to which it is attached from rising above a definite point called the working pressure. Locomotives are provided with two or three safety valves set to open at slightly different pressures. Two safety valves are required by law for the reason that should one valve fail to operate, the other will open and relieve the pressure. The safety valves are connected to the interior of the main steam dome or auxiliary steam dome by means of a piece of pipe called a safety-valve extension. One end of the extension is screwed into the dome, and the other end is screwed into the safety valve.

Safety valves are either of the open-pop or muffled-pop type. A muffled-pop safety valve is merely an open-pop safety valve enclosed within a perforated plate called a muffler, which lessens the noise of the steam when the valve opens.

32. General Design of Safety Valves.—Safety valves are designed to avoid certain objectionable features in operation which will be more clearly understood by considering Fig. 14 and the explanation that follows. The valve *a*, which will be assumed to be held to its seat by a spring with a tension of

100 pounds, has an area that exceeds only slightly the area of the opening through the pipe. When the pressure rises to 100 pounds the valve will unseat, but very slowly, because the area exposed to the pressure when the valve opens is very little more than when the valve is closed. Also, the valve will seat immediately when the pressure reduces slightly, and will open again at once when the pressure rises a little. A valve that opens and closes with a slight difference in pressure will seat and unseat very rapidly as the pressure keeps increasing and the relief of pressure will be accompanied by a chattering or hammering action that will quickly wear out the valve and its seat. Therefore, it is evident that such a type of valve would be altogether unsuited for the purpose of relieving pressure.

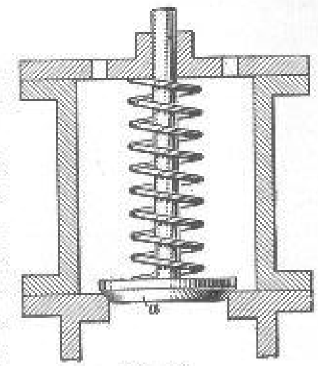


FIG. 14

33. Locomotive safety valves are designed to overcome the objectionable features of the valve shown in Fig. 14. The design of these valves is such as to cause them to open quickly and remain open until the pressure reduces to whatever extent may be desired, when they close quickly. In other words, the design is such as to prevent the slow opening of the valve and its rapid seating and unseating, or chattering action, just considered.

Safety valves that operate quickly during the opening and the closing movement are said to have a pop action, hence, valves of this type, which are universally used on locomotives, are referred to as pop safety valves.

The difference between the pressure when a safety valve opens and when it closes is called the blow-down. For example, if the valve opens at 200 pounds and closes at 197 pounds, the blow-down is 3 pounds. All locomotive safety valves are designed so that the blow-down can be changed to any amount desired.

ASHTON SAFETY VALVES

34. Description.—A sectional view of an Ashton open-pop safety valve in open position is shown in Fig. 15. The base ring *a* is screwed on to the bottom, or base, *b*, which is threaded as shown for the safety-valve connection in the boiler. The

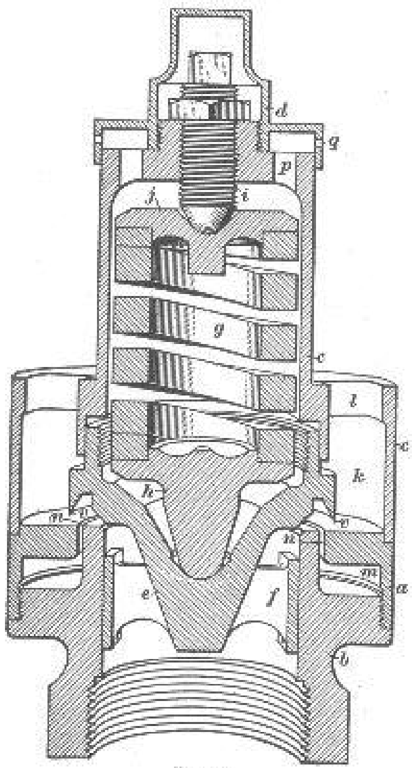


FIG. 15

head *c* is secured to the base ring by head bolts, not shown, and the cap *d* is screwed on to the top of the head. The valve *e* with guiding wings *f* can only move upwards and open against the resistance of the spring *g*. The pressure of the spring is transmitted to the valve through the lower disk *h* and the proper tension is placed on the spring by the pressure screw *i* and the

upper disk *j*. The chamber *k* extends entirely around the valve, and communicates with the atmosphere through the openings *l*, two shown. Chamber *k* is in communication with chamber *m*, which also extends entirely around the valve, through the narrow slot *n* between the base and the base ring.

As shown in Fig. 16, the steam that enters chamber *m* through the slot *n* passes by the two pop regulators *o* to chamber *k*, which, as already stated, is open to the atmosphere through the openings *l*, Fig. 15. The extent of the opening between the two chambers can be varied by turning the pop regulators *o*,

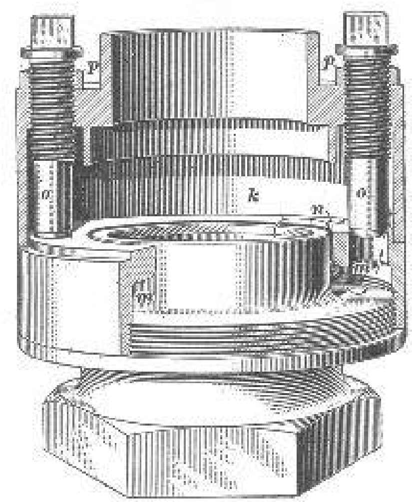


FIG. 16

Fig. 16, which are held in any desired position by the check-nuts *p*. The spring chamber is connected to the atmosphere through the openings *p*, Fig. 15, in the body, and a series of ports *q* in the cap. Any steam that enters the spring chamber will therefore not impose additional weight on the valve.

The safety valve is about 12 inches high, and has a diameter of about 6 inches. The valve *e* has a diameter of 2½, 3, 3½, and 4 inches, depending on the size of the safety valve.

35. Muffled Type.—As shown in Fig. 17, the muffled type of the Ashton pop safety valve consists merely of the open-pop type enclosed by a dome top *s*, with two muffler plates *t* within it. The dome top is held in place by the cap *d* and the pop regulators *o*, which are lengthened so as to bring their upper ends at the top of the valve. The other parts of the valve are lettered as in Fig. 15. A perspective view of one of the perforated muffler plates is shown in Fig. 18. The openings *l*, in the head *c*,

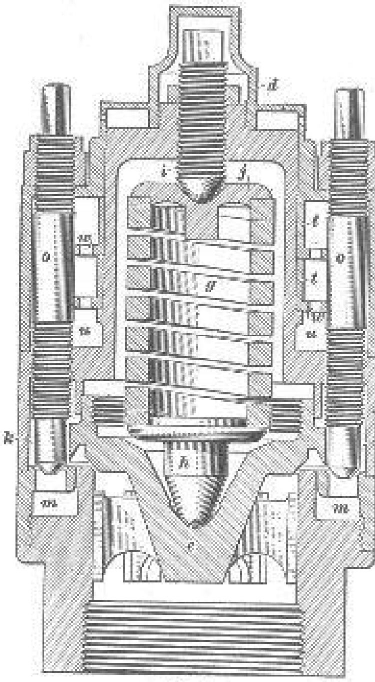


FIG. 17

Fig. 15, cannot be seen in Fig. 17, as two of them lie behind the pop regulators *o*. After the steam passes through these openings and enters the chamber *u*, it passes through the perforations *w* in the muffler plates and through openings, not shown, in the dome top *s* to the atmosphere. The steam is divided into small streams and escapes with little noise.

36. Operation.—The operation of a pop safety valve may be divided conveniently into four phases; namely, the opening

of the valve, the holding of the valve open, the closing of the valve, and the varying of the time the valve is held open, or the blow-down.

Opening of Valve.—When the upward pressure of the steam under the valve *e*, Fig. 15, increases beyond the downward pressure exerted by the spring *g*, the valve moves upwards and opens as shown. When the valve begins to open, it exposes a greater area to the steam, hence the pressure under the valve increases with the result that it moves up quickly. The increase in the effective area of the valve also causes it to move upwards farther than otherwise and the steam passes up by the valve into chamber *k* and from thence through the openings *l* to the atmosphere. A part of the steam that is passing under the lip *v* on the valve is deflected downwards through the slot *n* to chamber *m*, from which it passes by the pop regulators *o*, Fig. 16, into chamber *k* and to the atmosphere through the openings *l*, Fig. 15.

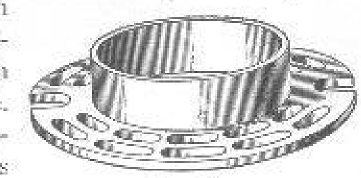


FIG. 18

Holding the Valve Open.—The valve does not seat and unseat as the pressure reduces but remains open until the pressure reduces to a certain amount that can be varied as desired. That the valve remains open is due mainly to two reasons; namely, a greater area is exposed to the pressure of the steam when the valve is open than when it is closed, also the lip of the valve restricts the free passage of the steam from under it. Besides, as will be explained farther on, the steam that passes through the slot *n* to chamber *m* acts to keep the valve unseated to a degree determined by the opening by the pop regulators. The result is that for a time the upward pressure exerted on the valve by the steam exceeds the downward pressure exerted by the spring, hence the valve will open wide and will remain open until the pressure decreases to such an extent as to cause it to remain closed, when it will finally seat.

Closing of Valve.—As the pressure of the steam beneath the valve begins to decrease, it will begin to move downwards. However, the downward movement is not uniform but increases as the valve approaches closer to its seat. The reason for this is that the opening between the valve and its seat lessens as the valve moves downwards, hence less steam escapes, and the pressure of the steam against the area of the valve outside of its seat begins to decrease. The decrease in the pressure against this part of the valve finally becomes so pronounced that the valve seats quickly with a pop action.

Therefore, while an increase in the effective area causes the valve to open quickly, the reverse, or a decrease, in the effective area causes it to close quickly.

Varying the Blow-Down.—The blow-down or the extent that the pressure reduces before the valve seats can be varied by turning the pop regulators so as to decrease or increase the outlet from chamber *m*, Fig. 16. The blow-down is increased when the pop regulators are turned down and the escape of steam from chamber *m* is reduced, because more steam has now to pass under the valve *e*, Fig. 15, and the steam will not escape with the same freedom as before. The steam will therefore exert a greater pressure under the valve and the boiler pressure will accordingly reduce more or the blow-down will increase before the valve will seat.

An opposite effect occurs when the pop regulators are screwed up and the outlet from chamber *m* is increased. In this event more of the steam will be diverted to the slot *n* and a corresponding lesser quantity of steam will pass under the valve *e*. With the steam escaping with more freedom, less pressure will be maintained under the valve and it will seat with a less reduction in pressure. The length of time the valve remains open during the blow-down depends on how rapidly the water is being evaporated, but the extent of the blow-down depends on the adjustment of the pop regulators.

The chamber *m* or a similar chamber in other types of pop safety valves is commonly known as a *huddling* chamber, from which the escape of the steam can be varied at will.

CONSOLIDATED SAFETY VALVE

37. Description.—A sectional view of a Consolidated open-pop safety valve is given in Fig. 19. The case *a* is screwed on to the base *b*, which is threaded as shown for the safety-valve connection. The downward pressure of the spring *c* is transmitted to the valve, or feather, *d* through the lower spring

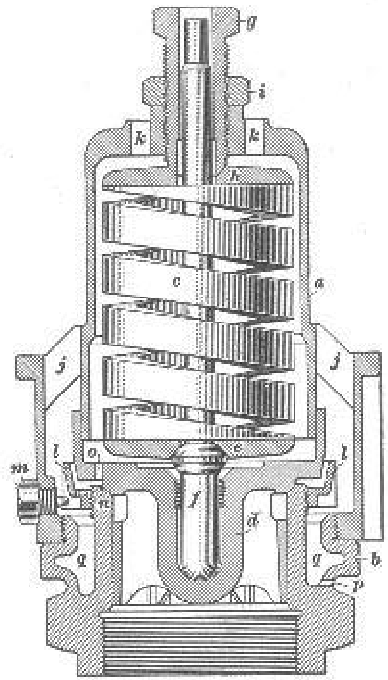


Fig. 19

washer *e* and the spindle *f* and the required tension is placed on the spring by the compression screw *g*, which bears against the upper spring washer *h*. The locknut *i* prevents the compression screw from moving after it has been adjusted. When the valve *d* lifts, the steam escapes to the atmosphere through the openings *j* in the case. The openings *k* in the top of the case, of which there are ten, permit any steam that enters around the spring to escape. The adjusting ring *l*, which is used to regulate the blow-down, is threaded on to the base *b* and is held from turning by the ring pin *m*. A series of slots are cut around the ring, and the ring pin, when screwed in all the way, fits into one of these slots. A hole *n* is drilled through the adjusting ring and a hole *o* is drilled through the valve. These holes prevent water from collecting and freezing in severe weather when the

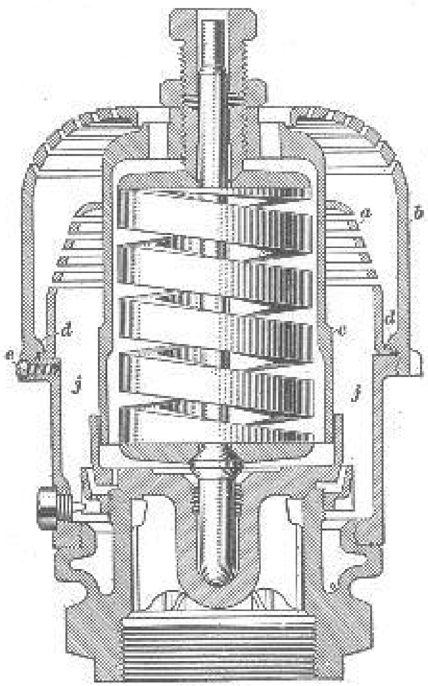


Fig. 20

boiler is cold. A drip hole *p* is also drilled from the outside of the valve into chamber *q*. The valve is threaded as shown so that should the valve stick when necessary to remove it for repairs, a stud can be screwed in and the valve lifted out.

38. Muffled-Pop Safety Valve.—A sectional view of the Consolidated muffler-pop safety valve is shown in Fig. 20. The only difference between the open-pop and the muffled-pop type is the addition to the latter of an inside muffler shell *a* and an

outside muffler shell *b*. The inside muffler shell is placed around the case *c* and is held in position by a lip *d* on the outside shell *b* when it is screwed on to the case. The outside muffler is further secured to the case by the locking screw *e*.

The steam instead of discharging through the openings *j* to the atmosphere, as with the open-pop valve, passes through the series of narrow slots shown in the inside and outside mufflers to the atmosphere. The slots divide the steam into fine streams and thereby deaden the noise. In all other respects, the operation of the muffled-pop type of safety valve is similar to the open-pop type.

39. Operation.—When the pressure of the steam under the valve *d*, Fig. 19, exceeds the tension of the spring *e*, the valve lifts and the steam escapes into the adjusting ring *l* and thence through the openings *j* to the atmosphere. A greater area is exposed to the action of the steam when the valve begins to rise, hence it will lift quickly. When the pressure reduces, the valve moves downwards, and as the pressure on the outer edge of the valve reduces as the opening between the valve and the seat lessens, the valve will seat quickly with a pop action. The wings on the valve cause it to move upwards vertically and they also serve to guide the valve to a true seat.

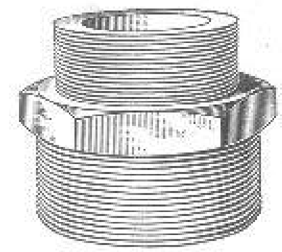


Fig. 21

40. Varying the Blow-Down.—The blow-down can be varied by removing the ring pin *m*, Fig. 19, and turning the adjusting ring *l* with a pointed tool. The thread on the ring is right-handed and the blow-down is decreased by turning the adjusting ring downwards on its base and increased by turning the ring upwards. The ring should be moved only four or five notches at a time. The reason why the blow-down is decreased by turning the adjusting ring down is that the steam can then escape more freely from under the valve. The outer portion of the valve will then be subjected to less pressure, and the valve will seat when the pressure is reduced to a lesser degree.

When the ring is turned upwards, the passage of steam by the edge of the valve is restricted and a higher pressure is maintained under the valve. Accordingly, the valve does not seat until the pressure has blown down to a greater extent than when the ring was lower.

41. Safety-Valve Extension.—A perspective view of a safety-valve extension is shown in Fig. 21. The lower end of the extension is screwed into the boiler and the safety valve is screwed on to the upper end.

CAPACITY OF SAFETY VALVE

42. Definition.—The capacity of a safety valve is the number of pounds of steam that it will discharge in one hour, and this depends on the area of the discharge opening, the steam pressure, and the lift of the valve. At 200 pounds gauge pressure a safety valve with a valve 3½ inches in diameter will discharge about 12,000 pounds of steam per hour.

It requires 1 pound of water to make 1 pound of steam, hence the discharge of steam at the safety valves may be considered in pounds of water instead of pounds of steam, if desired.

43. Capacity and Boiler Evaporation.—The Federal regulations require that every boiler shall be equipped with at least two safety valves, the capacity of which shall be sufficient to prevent, under any conditions of service, an accumulation of pressure of more than 5 per cent. above the allowed steam pressure.

The foregoing shows that the capacity of the safety valves must be such as to discharge the steam faster than it is being evaporated. A locomotive boiler will evaporate from 8 to 12 pounds of water per hour for each square foot of heating surface. A modern locomotive has ordinarily about 4,000 square feet of heating surface, hence the evaporation will be 4,000×8, or 32,000 pounds of water, if 8 pounds is assumed to be evaporated for each square foot per hour. Three 3½-inch safety valves with a combined capacity of 36,000 pounds of steam per hour will easily keep the boiler pressure within the limit prescribed by law.

44. Setting Safety Valves.—The Federal regulations prescribe that safety valves shall be set to pop at pressures not exceeding 6 pounds above the working steam pressure and also that the water level in the boiler shall not be above the highest gauge-cock when setting the valves. The steam pressure the boiler is designed to carry is indicated on a metal badge plate attached to the boiler head.

With a locomotive equipped with three safety valves and a boiler pressure of 200 pounds, the valves are usually set as follows: The third valve is set for 205 pounds, with a pop, or blow-back, of 5 pounds before it seats; the second valve is set for 202 pounds with a blow-back of 4 pounds; and the first valve is set for 200 pounds with a blow back of 3 pounds.

45. Waste at Safety Valves.—When the capacity of a safety valve is known, it is a simple matter to calculate the amount of coal that is wasted for each minute that the valve is open. A 3½-inch safety valve has a capacity of 12,000 pounds of steam per hour, or 200 pounds per minute. One pound of coal will evaporate about 7 pounds of water and it therefore requires nearly 30 pounds of coal to evaporate 200 pounds of water, or the amount that is escaping through the safety valve each minute.

BLOW-OFF VALVES

46. Purpose.—Boilers are provided with blow-off valves for the purpose of cleaning out the mud and the scale that settles in the water legs, and they are located just above the mud-ring in the water legs of the boiler. Generally, there is a blow-off valve on each side of the boiler and also one in the throat sheet at the front of the firebox. A surface blow-off valve is one that opens into the boiler at about the level of the top gauge-cock. Its purpose is to skim off the scum from the surface of the water in cases of foaming. Blow-off valves are usually of the gate type, that is, when the main valve is opened there is an unobstructed passage for the discharge of the water. Blow-off valves of the globe type are no longer in general use because their design is such that the water cannot blow straight through them. Therefore, this type of valve would check the flow of muddy water with the liability of foreign material accumulating near the valve and under the valve seat.

47. Description.—An exterior view of the Okadee blow-off valve, which is of the gate type, is shown in Fig. 22 (*a*), and in view (*b*) is shown how the valve is connected to the

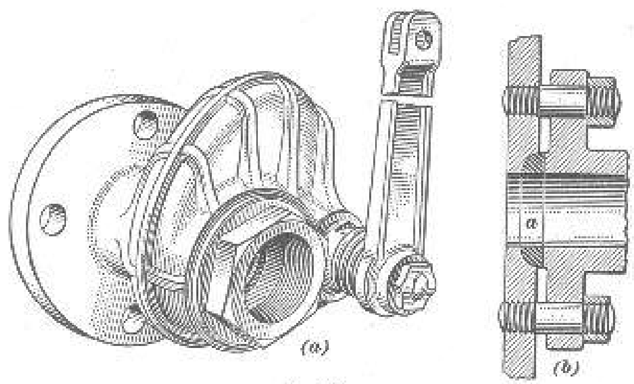


FIG. 22

boiler. The valve is connected to the boiler sheet by studs that pass through a flange on the valve, and a steam-tight joint between the valve and the sheet is made by the ball-faced bronze ring *a*.

The blow-off valve with a part of the body broken away and with the disk valve *a* partly open is shown in Fig. 23 (*a*). The disk valve is shown removed in view (*b*). In view (*a*), the stem *b* is carried within the stem bushing *c*, which is screwed into the body *d*. A ring gasket *e* prevents leakage of steam along the stem.

A spring *f* placed between the collar on the bushing and the operating handle *g* pulls the stem outwards and keeps the ring gasket against its seat at all times. The disk carrier *h*, in which the bronze disk valve *a* is inserted, is placed on the inner end

of the stem *b* and is operated by it. The disk valve seats against the inner end of the hexagon nut *i*, which is screwed into the body *d*. In order to make the joint absolutely steam-tight the disk valve is ground into its seat on the nut.

The disk valve, view (*b*), is made in two parts and the spring *j* keeps each part against its seat when the valve is assembled in the disk carrier. The opening *k* permits a balance of pressure on the inner disk, and also assists the spring to hold the outer, or top, disk to its seat.

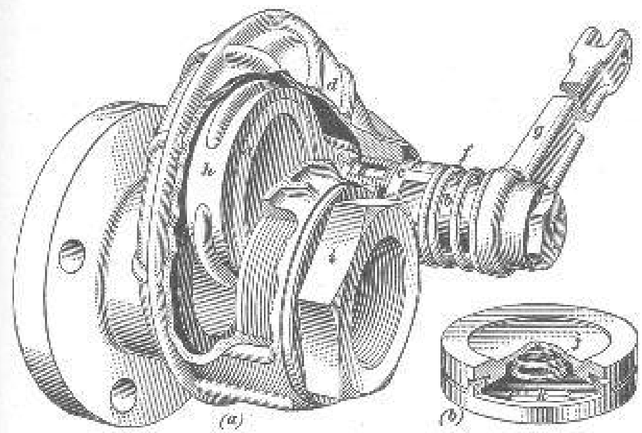


FIG. 23

48. Operation.—When the shaft *b*, Fig. 23 (*a*), is turned by the operating handle *g*, the disk carrier *h* lifts the disk *a* away from its seat and permits the water in the interior of the body and in the boiler to discharge to the atmosphere through the opening in the hexagon nut *i*. This opening is threaded so that a pipe can be coupled to it if desired. The top of the body is shaped so as to accommodate the disk carrier when it is moved upwards. The valve can be removed for grinding into its seat on the hexagon nut by removing this nut. After the stem bushing has been removed, the disk carrier can be lifted out through the opening made by the removal of the hexagon nut.

PRESSURE IN PIPES

49. The internal pressure in a pipe is obtained by multiplying its inside area in square inches by the pressure in pounds per square inch. The pressure in pounds per square inch in a pipe is found by dividing the internal pressure in the pipe in pounds by the number of square inches in the interior of the pipe.

With a pipe $\frac{1}{4}$ inch in diameter and another 1 inch in diameter, both connected to a boiler carrying a pressure of 200 pounds to the square inch, the pressure in the small pipe in pounds per square inch will be exactly the same as in the large one. The internal area of the small pipe may be only $\frac{1}{2}$ square inch so that the pressure in it will be 100 pounds, but this pressure acting on an area of $\frac{1}{2}$ square inch is exactly the same as a pressure of 200 pounds exerted on 1 square inch.

The calculated internal pressure in a pipe does not correspond to the pressure that tends to burst the pipe. The pressure that tends to burst a pipe is found by multiplying the diameter of the pipe in inches by its length in inches and by the pressure in pounds per square inch. For example, the pressure that acts to burst a pipe 1 inch in diameter and 1 inch long connected to a boiler carrying a pressure of 200 pounds is 200 pounds, whereas a pipe of a diameter of $\frac{1}{4}$ inch, and a length of 1 inch under the same boiler pressure has a pressure that acts to burst it of 50 pounds. This is why the wall of a small pipe can be made thinner than the wall of a larger pipe as well as why a small pipe made of material of the same thickness as a large pipe can withstand a much higher pressure. The foregoing explains why the copper pipe to the steam gauge as well as the water-gauge glass, on account of their small diameter, can safely withstand high boiler pressure.

LOCOMOTIVE AIR WHISTLES

50. It takes about 1,200 pounds of coal to produce the steam required for the operation of the steam whistle for one hour; the air consumption of a quadruplex type of air whistle

for the same time requires only about 185 pounds of coal. Therefore, the air whistle is the more economical; also, it has a much more agreeable tone than the steam whistle.

The air whistle as used in steam-railroad service is usually made up of four units of the shape shown in Fig. 24, two of these being curved projectors that point ahead and two straight projectors that point to the rear. A sectional view of one unit is given in Fig. 25; it comprises a body *2* with a horn, a cover *5*, and a diaphragm *3* with a pear-shaped portion riveted to it.

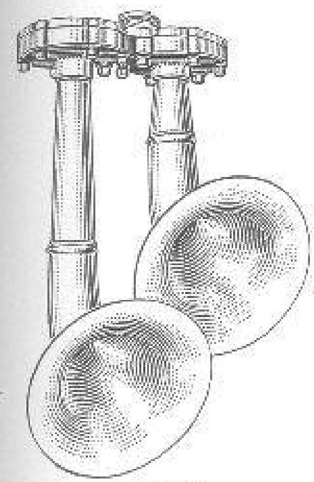


Fig. 24

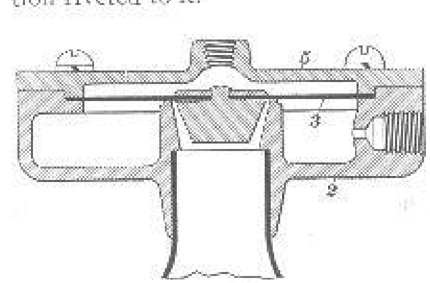


Fig. 25

Air enters the unit at the point shown, deflects the diaphragm, and permits air to pass out through the horn. The escape of air increases with the deflection of the diaphragm until finally the air is discharging faster than it is entering; the diaphragm then moves in the opposite direction and the discharge of air stops. The pressure on the diaphragm immediately builds up again and the diaphragm is again deflected. The foregoing actions occur so rapidly that the column of air confined within the horn is set in vibration that is communicated to the surrounding air and produces sound. The bell-shaped ends of the horns serve to magnify the sound produced.

FIRE-DOORS

FRANKLIN AUTOMATIC FIRE-DOOR

51. Advantages of Automatic Fire-Doors.—The automatic fire-door has several advantages over the hand-operated door. It not only relieves the fireman from the labor of swinging a hand-operated door, but, owing to its more rapid action, the admission of cold air through the door is decreased, resulting in a more nearly uniform firebox temperature and less fluctuation in steam pressure, and preventing damage to sheets and flues. It is estimated that an automatic fire-door is open only one-third as long as a hand-operated door when the engine is operating. As the automatic door cannot be blown open, possible injury to the crew is prevented in the event of a burst flue or a crown-sheet failure.

52. Principal Parts.—A front view of the Franklin No. 8 automatic fire-door is shown in Fig. 26. The operating cylinder *a* is bolted to the top of the door frame *b* and furnishes the power by which the left-hand and right-hand door plates *c* and c_1 are swung outwards and upwards, away from each other, to open the fire-door. An adjustable foot pedal *d* transmits the pressure of the foot to an operating valve *e* by which air is admitted to the operating cylinder *a* to cause the door to open. A lever *f* and a rocker arm *j* are provided to open the door by hand. The door may be held open to the extent desired by hooking the lever *f* in one of the notches in the latch *g*. The door plates swing on the fulcrum pins *h* and are protected from the heat of the furnace by inside baffle plates that are held in position by bolts and nuts *i*.

OPERATION OF FIRE-DOOR

53. Automatic Operation.—The operation of the fire-door will be considered in connection with Fig. 27. Air is admitted through the strainer valve e_4, needle valve e_8, and pipe e_1 to the chamber e_2. When the foot of the operator presses on the

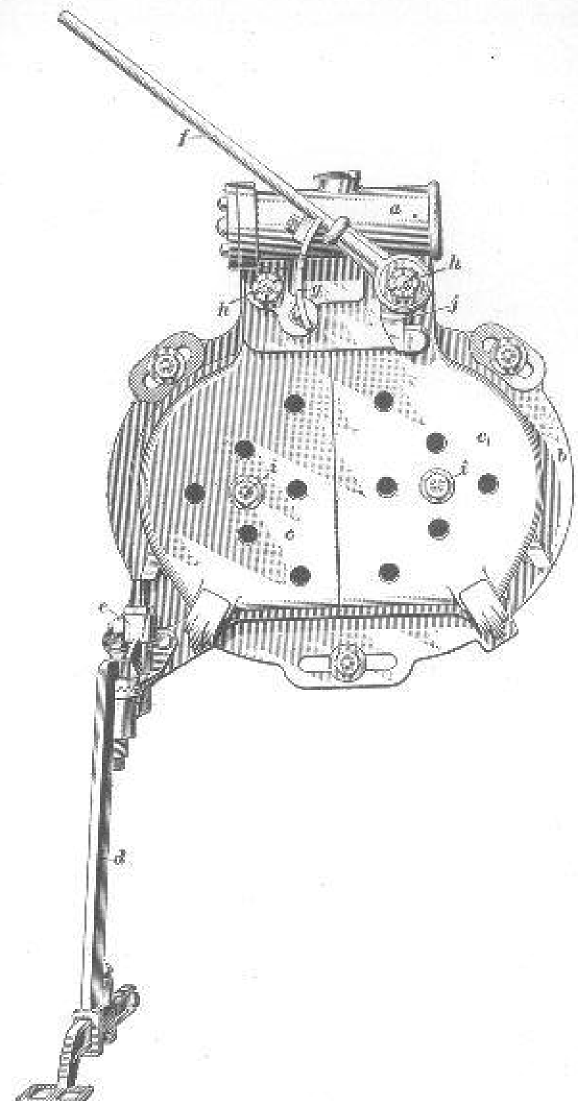


Fig. 26

tread d_3, the arm d_3 rises and unseats the valve e_9. As the lower part of the valve stem is a snug fit in its guide, the connection between the exhaust ports e_{10}, view (*a*), and the port e_8, view (*b*), is closed when the valve moves upwards. Air then passes through the passage e_8 and the pipe e_6 to the operating cylinder. The piston a_1 in the operating cylinder is forced outwards by the air pressure, and its movement is communicated to the link a_4, which is attached to the left-hand door plate. As the piston continues to move forwards, the door plates, connected by intermeshing gear-teeth, rotate on the fulcrum pins until they have uncovered the opening in the door frame.

54. When the doors are fully opened, the link a_4, Fig. 27 (*c*), forms a straight line between the piston pin a_2 and the link bolt c_1. Thus, the pull exerted by the piston has its greatest effect at the beginning of motion and rapidly decreases as the doors open, eliminating all possibility of slam or shock. Should the momentum of the door plates be such as to carry the doors beyond the full-open position, the piston would be pulled back against the air pressure in the cylinder. This would act as a cushion and bring the doors to rest without any jar or noise. When the foot of the operator is removed from the tread, the valve e_9 is seated by the spring just above it, thus cutting off admission of air to the cylinder through the pipe e_6. The upper part of the valve, which is smaller than its guide, then connects the passage e_8 with the exhaust ports e_{10}, and the air in the cylinder escapes to the exhaust. The weight of the doors immediately causes them to close, at the same time returning the piston to its starting position at the left-hand end of the cylinder. The door is cushioned when closing, owing to the fact that, in the closed position, the door plates are nearly balanced and, as the door plates close very rapidly near this position, there is sufficient pressure remaining in the cylinder (the exhaust from which is restricted) to slow up the movement and allow the door plates to come together without slamming.

55. Manual Operation.—The door is operated by hand by means of the operating lever *f* and the rocker-arm *j*, Fig. 27. These parts do not move while the door is being operated by

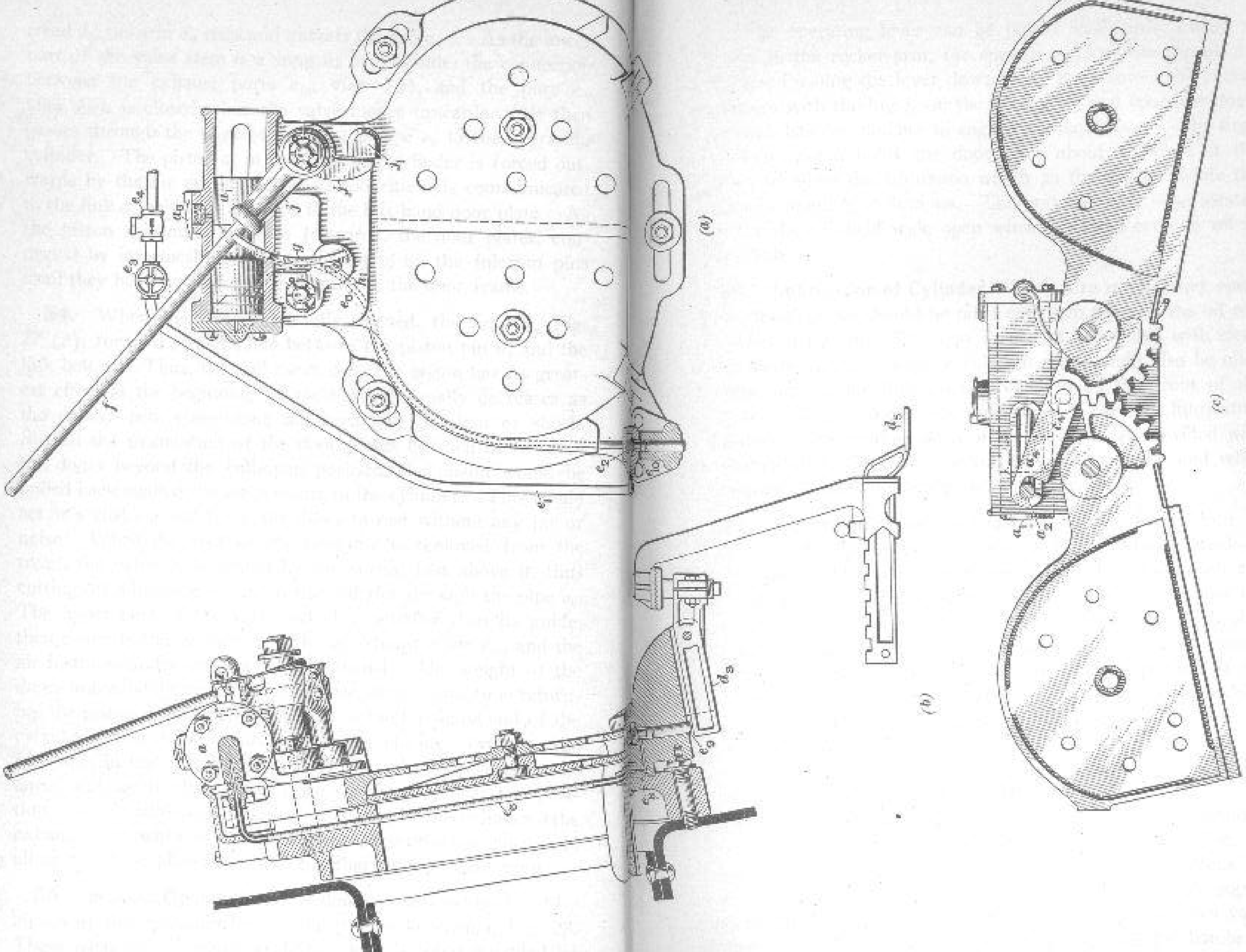


Fig. 27

air. The operating lever can be pulled backwards, owing to the slot in the rocker-arm, far enough to clear the top of the latch g. Pushing the lever downwards then causes the rocker to engage with the lug j_1 on the door plate and open the door. The latch has two notches to engage the hand lever. The first, or smoke, notch holds the door open about 8 inches at the bottom to allow the admission of air to the firebox while the engine is standing at stations. The bottom notch is so located that the door is held wide open when the hand lever is set in that notch.

56. Lubrication of Cylinder.—To insure satisfactory operation, the cylinder should be oiled each trip through the oil cup provided at the top. The cup should be kept filled with clean wool waste. The door-plate fulcrum pins should also be oiled at least once a day through the oil holes on the front of the cylinder. Engine or car oil should never be used for lubricating cylinders. The strainer valve in the pipe line is provided with a cleaner plug. It should be inspected occasionally and when necessary cleaned and refilled with new mattress hair.

57. Failure of Door to Close.—Failure of the door to close is probably due to the valve e_9, Fig. 27, being stuck or held open by dirt on the valve seat. A little kerosene oil run through the valve will generally clean the seat and allow the door to open freely. If this does not overcome the difficulty, the valve should be removed and cleaned. A slow movement of the door plates with a blow of air at the open end of the operating cylinder is an indication of leakage of the packing rings on the piston in the operating cylinder.

SHOEMAKER FIRE-DOOR

58. Opening Door.—A perspective view of the Shoemaker fire-door is shown in Fig. 28 and a sectional view in Fig. 29. The operation of the door in opening is as follows: When the valve a, Fig. 29, is opened, air from the source of air supply passes through the pipe b to the chamber c in the foot-valve above the foot-valve stem. The air also passes to chamber d

between the two pistons *e* and *f* by way of pipe *g*, the check-valve *h*, which opens upwards, and passage *i*. A constant pres-

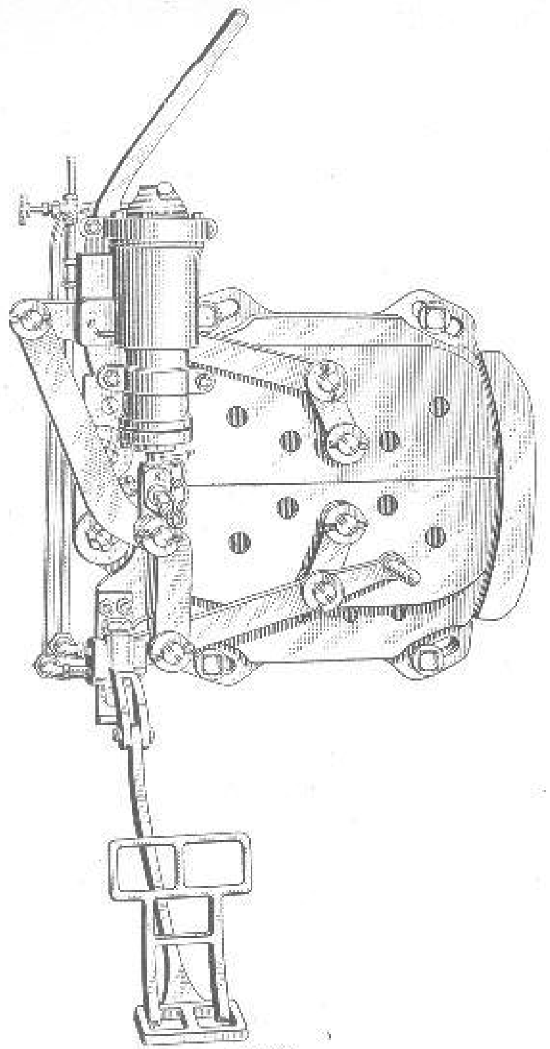


Fig. 28

sure is maintained in chambers *c* and *d* as long as the valve *a* is open.

The foot-lever *j* is pivoted to the foot-valve at *k* so that when the pedal step is depressed the other end of the lever moves

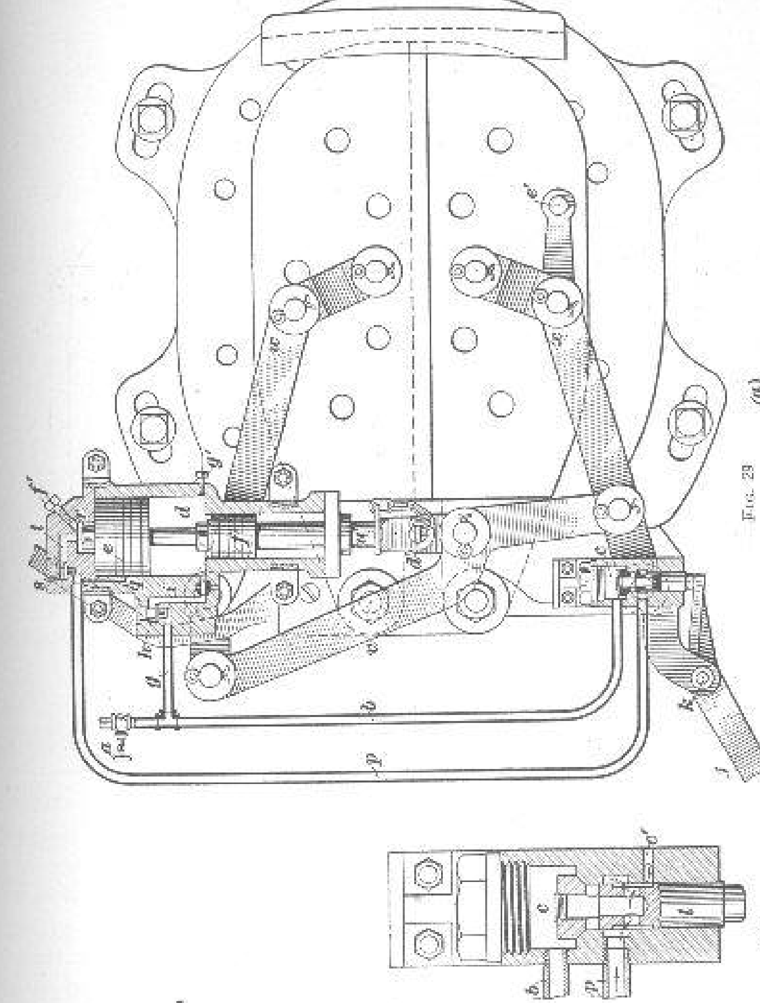


Fig. 29 (a) (b)

upwards and unseats the foot-valve stem *l*, as shown in Fig. 30. The compressed air in chamber *c* then passes through the ports *m* in the foot-valve stem into the interior passage *n*, thence out through the ports *o* into the pipe *p*. The air unseats the check-valve *s* and enters chamber *r* and when the piston *e* has been moved down far enough the air also passes through pas-

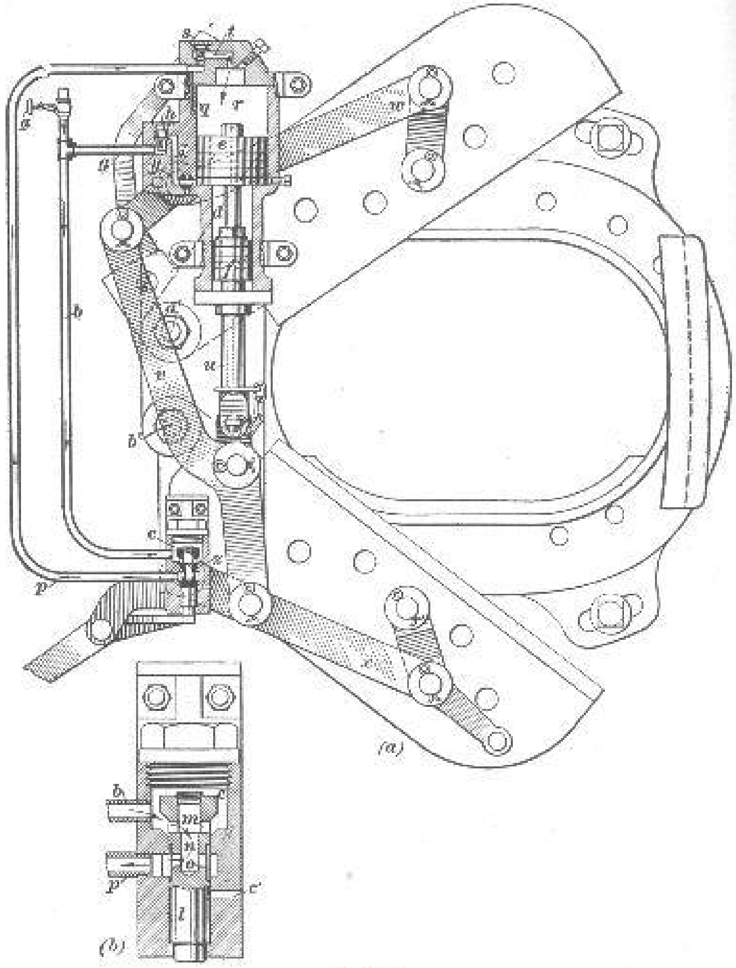


FIG. 30

sage *q* into chamber *r*. The reason why the pistons move down is as follows: The air in chambers *r* and *d* exerts a downward pressure on the pistons *e* and *f* and the air in chamber *d* also

exerts an upward pressure on piston *e*. However, the combined area of the pistons exposed to the downward pressure of air exceeds the area of the piston exposed to the upward pressure with the result that both of the pistons and the piston rod *u* are forced downwards. The downward thrust of the piston rod is transmitted through the connecting lever *v* to the levers *w* and *x*, which are pivoted at *y* and *z*, and the doors turn on their pivot points *a′* and *b′* and open as shown.

59. The doors are prevented from banging during the latter part of the opening movement by an air cushion in chamber *d*, Fig. 29, that acts to arrest gradually the downward movement of the pistons. As the piston *e* moves down, the air in the large chamber under the piston is gradually compressed into the small chamber *d*, until with the large piston at the end of its stroke, the entire volume of air in the large chamber under piston *e* has been compressed into the small chamber *d*.

Owing to the increase in the volume of the air, and also to the fact that the check-valve *h* seats and traps the air in chamber *d*, the pressure between the two pistons increases, and their downward movement and also the opening movement of the doors are arrested gradually and with an absence of shock.

60. Closing Door.—As soon as the pedal step is released, the pressure in chamber *c*, Fig. 29, forces the foot-valve stem downwards to closed position. The air now escapes from chamber *r*, through passage *q*, the pipe *p*, and around and through the foot-valve stem *l*, as shown by the arrows to the exhaust ports *c′* in the foot-valve. The pressure in chamber *d* against the larger area of piston *e* forces both pistons *e* and *f* upwards, and the movement transmitted by the piston rod *u* through the connecting lever *v* to the levers *w* and *x* causes the doors to close. The piston when moving upwards finally closes port *q* and the air that remains in chamber *r* escapes slowly through a small hole drilled vertically through the check-valve *s*, which is now seated. The gradual increase in pressure in chamber *r* cushions the upward movement of the piston and prevents the slamming of the doors when closing.

When the doors are not being operated, the area of piston *e* in chamber *d* is so much greater than the area of piston *f* that the doors are positively held in closed position.

61. Cracking Fire-Door.—It is frequently necessary to partly open, or crack, the fire-door at terminals to reduce smoke

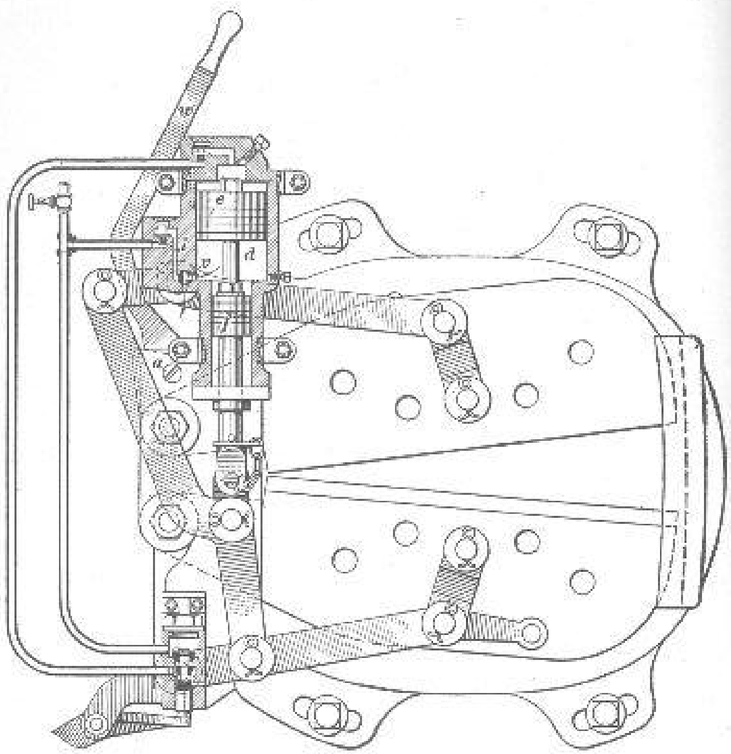


FIG. 31

as well as to prevent the locomotive from popping. The doors can be held open by turning the petcock *v*, Fig. 28, one-quarter turn to the right and then pulling the cracker lever *w*, Fig. 31, to the left until the doors are opened the required amount.

The petcock when turned prevents the air in passage *i* from entering chamber *d* and permits the air in this chamber to exhaust through the petcock to the atmosphere, as shown by

the arrows. Therefore, there is then no pressure in chamber *d* to force the pistons *e* and *f* upwards and close the doors.

The lower end of the cracker lever sets in a recess in the upper fire-door and is held in position by a screw *a* that passes through the cover-plate and the cracker lever into the door ring. The recess in the door and the end of the cracker lever are so shaped that while the door can be opened and closed during normal operation without moving the lever, yet a movement of the lever to the left will open the door.

The doors when cracked are about balanced and there is no tendency for them to open wider or to close. It is only necessary to turn the petcock one-quarter turn to the left, when it is desired to close the door.

62. Manual Operation.—It will be necessary to operate the door by hand in the absence of air pressure or in the event of any of the pipes breaking off. To do so, disconnect the piston rod *u*, Fig. 29, from the connecting lever *v* by removing the pin *d'*, so that the pistons will not be removed when operating the doors by the handle *e'*.

DISORDERS AND MAINTENANCE

63. Failure to Close Fully.—If the doors do not close fully, the trouble is due to the hole through the check-valve *s*, Fig. 29, being closed by dirt, thereby trapping the air in chamber *r* and preventing the piston *e* from completing its up stroke, or the cylinder end of port *i* is stopped up. The check-valve can be taken out by removing its valve cap.

64. Slamming When Opening and Closing.—If the door slams when opening, the trouble is due to dirt on the seat of the check-valve *h*, Fig. 29, or the cup leathers on the pistons may be leaking. The check-valve can be taken out by removing the valve cap above it. If the door slams when closing, the check-valve *s* is either held off its seat by dirt, the valve cap leaks, or the check-valve has been lost. When removing the valve caps, the lead gaskets under them should be reapplied and the caps should be drawn down air-tight.

65. Blow at Exhaust Ports.—A constant blow at the exhaust ports *c'*, Fig. 29, when the door is not being operated indicates that the foot-valve stem is held from its seat by dirt. The valve can be taken out by removing the cap nut above it.

66. Oiling.—The air cylinder should be oiled each trip by removing the oil plugs *f'* and *g'*, Fig. 28, and pouring in a moderate amount of light valve oil. The air cylinder should also be flushed occasionally with signal oil. All working joints of the door mechanism should be oiled when necessary.

GOLLMAR LOCOMOTIVE BELL RINGER

67. Purpose.—A bell ringer is a device that is attached to the bell for the purpose of ringing it. Bell ringers are operated by air pressure and are wholly automatic in operation when once started. They not only relieve the enginemen of the duty of ringing the bell by means of a bell rope, but they also insure that the bell is rung continuously when necessary.

68. Operation.—In Fig. 32 is shown the bell ringer *a* bolted at the lower end to a pad cast on the bell frame and connected at the upper end to the crank *b* of the bell. The bell ringer is started and stopped by turning the air supply on or off by means of a valve in the cab. With the parts of the ringer at the lower end of their stroke as shown in Fig. 33, the air enters the interior of the hollow valve *c* through the ports *s* and *t*, and then passes through the openings *u* in the valve against the lower end of the piston *d*. The piston and the parts connected to it are forced upwards, and as the crank *n* begins to move upwards in an arc the ball-shaped end of the connecting-rod *i* turns in the end of the piston *d*, and the rod finally assumes the position shown in view (*b*). The upward movement of the piston *d* and the valve stem *e* does not at first move the valve *c*, which therefore remains in the position shown in (*a*) and permits the air to enter the cylinder of the bell ringer. However, as the piston and the valve stem continue to move upwards, the head of the stem finally comes in contact with the valve, which

is accordingly pulled upwards into the position shown in view (*b*). This position of the valve blanks port *s* and opens port *v*, thereby shutting off the air from the cylinder and allowing the air in it to escape through the exhaust port *r*. The weight of the bell now returns the parts to the positions shown in view (*a*). The foregoing shows that the pressure of the air causes the ringer to make an upward stroke, and the weight of the bell causes it to make a downward stroke.

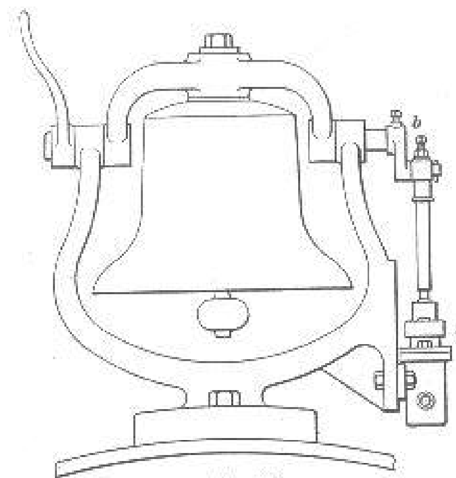
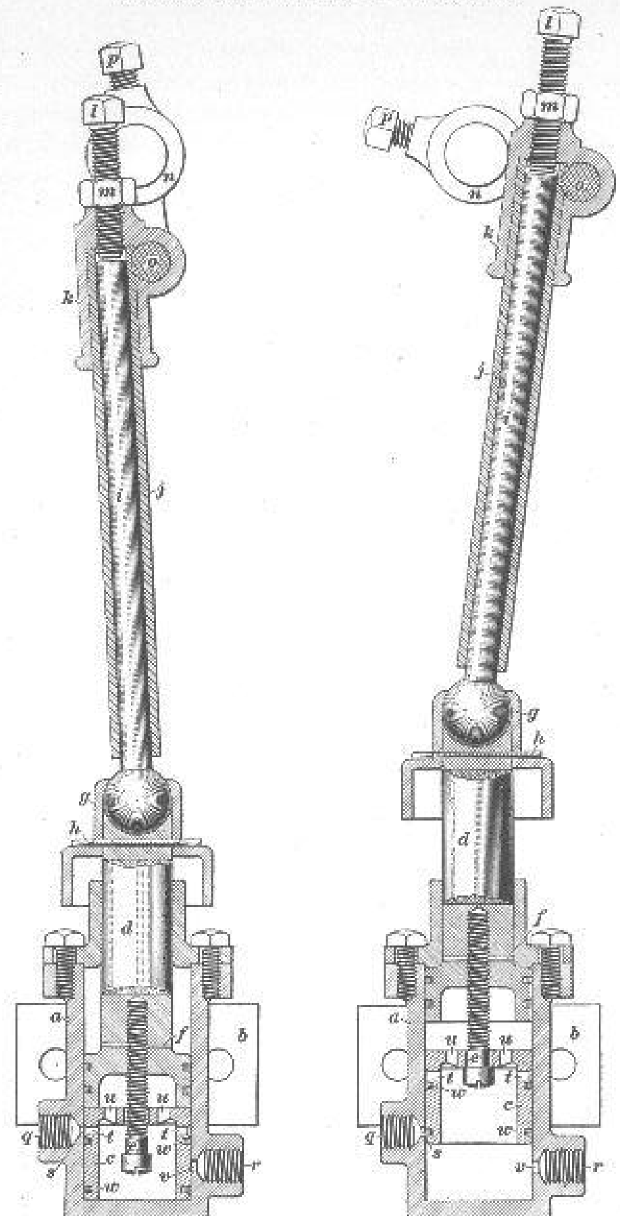


FIG. 32

69. Regulation.—If the bell ringer is not properly regulated the bell will either swing too high and turn over, or it will not swing high enough. If the bell swings too high the governor bolt *l*, Fig. 33 (*b*), should be turned out, thereby permitting the crank-box *k* and the sleeve *j* to move down on the connecting-rod *i* and reducing the upward movement of the bell-crank *n*. If the bell does not swing high enough, the governor bolt should be screwed in. This raises the crank-box and the sleeve on the connecting-rod, and the bell will swing higher.

70. Leaky Packing Rings.—Leaky packing rings *w*, Fig. 33 (*a*), will cause a blow at the exhaust port *r*, and will have more or less tendency to make the upward movement of the



(a) (b)

Fig. 33

piston *d* slow. A leak into the cylinder past the rings from passage *q*, view (*b*), in excess of what can escape freely at the exhaust port *r* will cause the bell to remain tilted with the valve at the upper end of the stroke. A leak by the packing rings on the piston *d* will be indicated by air escaping where the piston rod passes through the cylinder head. Such a leak will cause the piston to make a slow up stroke.

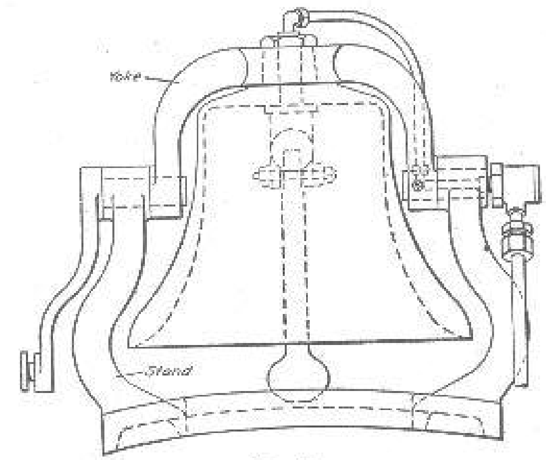


Fig. 34

71. Transportation Devices Corporation's Bell Ringer. With the bell ringer shown in Fig. 34, the bell remains stationary and the clapper is caused to strike one side of it rapidly. However, if operated by a cord, the bell swings in the usual manner. The bell ringer is placed on the inside of the bell with the clapper suspended from it as shown. The right-hand trunnion is ported for the passage of air, and the arrangement of the air coupling on the end of the trunnion is such as to permit it to turn in the coupling, as when the bell is rung by hand, without imposing a strain on the pipe. At this time the upper air pipe moves with the yoke.

A sectional view of the bell ringer is shown in Fig. 35. Air enters through the stem and, passing through a passage *a* into cavity *b*, forces the piston *2* to the right, thereby swinging the clapper slightly to the left. The continued movement of the piston in this direction finally opens port *c* and permits air to flow through the piston to the end chamber *d*, thereby exposing the entire area of the piston to air pressure. This area is, of course, greater than the area exposed in cavity *b*, so that the piston is moved to the left, thereby causing the clapper to move

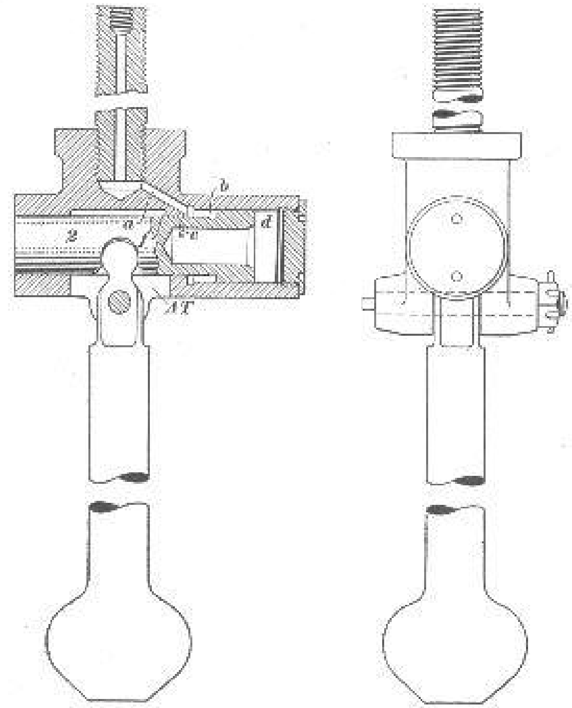


Fig. 35

to the right and strike the bell. The continued movement of the piston to the left first cuts off the passage of air through port *c*, and next connects this port and chamber *d* to the atmosphere at *AT*. This action causes the air that is always present in chamber *b* to move the piston to the right, but this movement does not cause the clapper to swing far enough to the left to strike the bell. The bell is only struck when the piston moves to the left, thereby swinging the clapper to the right.

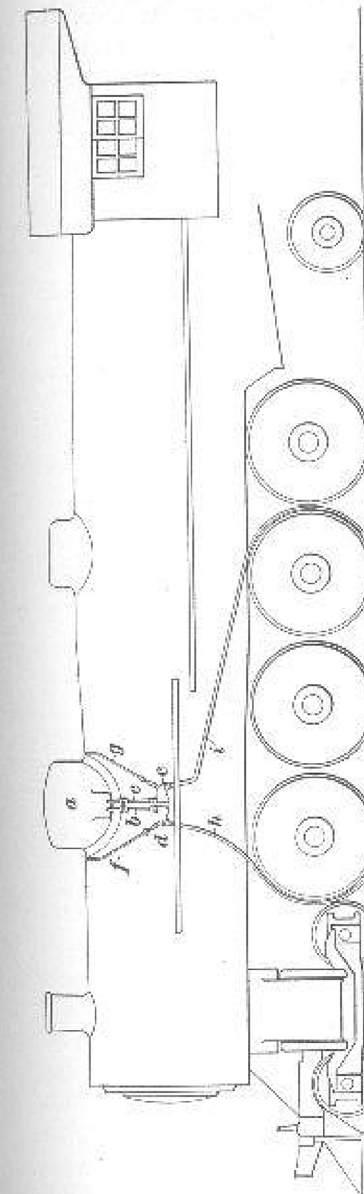


Fig. 36

SANDERS

KING SANDER

72. General Arrangement. The general arrangement of the King air-operated sander as applied to the left side of a Mikado type of locomotive is shown in Fig. 36. The sand in the sand box *a* is free to run through the pipes *b* and *c* into the sander traps *d* and *e*. Owing to the shape of the sander traps, the sand is retained in them until the air is turned into the pipes *f* and *g*, which are connected to sand traps on the other side of the locomotive. The sand is blown out of the traps and carried to the rails through the sand-delivery pipes *h* and *i*. The arrangement of the sand pipes, sander traps, sand delivery pipes, and air pipes on the left side of the locomotive is duplicated on the right side, and in addition two lines of air piping on this side extend to the operating valve in the cab.

The sand pipe *b*, the sander trap *d*, and the sand-delivery pipe *h*, with a similar arrangement on the other side, are the two go-ahead sanders, because they are used to sand the rails when the locomotive is running forwards. The parts *g*, *e*, and *i*, with similar parts on the opposite side, constitute the back-up sanders, because they are used to sand the rails when running backwards. The operating valve in the cab is arranged so that the go-ahead and back-up sanders can be operated separately.

73. Sander Trap.—A sectional view of the King sander trap is shown in Fig. 37. The pipe from the sand box is con-

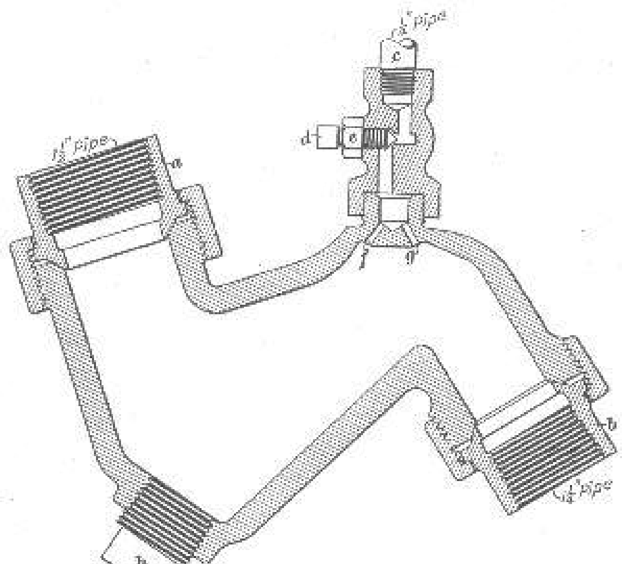


FIG. 37

nected to *a*, the sand-delivery pipe is connected to *b*, and the air pipe is shown at *c*. The purpose of the adjustment screw *d* with a locknut *e* is to limit the air pressure admitted to the sander trap to suit the grade of sand and the amount required during operation. Provided there is no change made in the main-reservoir pressure, the adjustment screw and the locknut can be spot-welded in place after being properly set. The air enters the sander through the ports *f* and *g*. The sand that flows by gravity from the sand box into the lowest port of the trap is agitated by the blast of air that passes through the port *f*,

while the sand is drawn out of the trap into the sand pipe by the siphoning action of the air that blows through the port *g*. The trap can be cleaned out by removing the plug *h*.

74. A view of the operating valve used to control the flow of air to the sander trap with the valve body *a* partly cut away is shown in Fig. 38. The valve disk *b*, here shown partly broken away, is made with a stem to which the handle *c* is con-

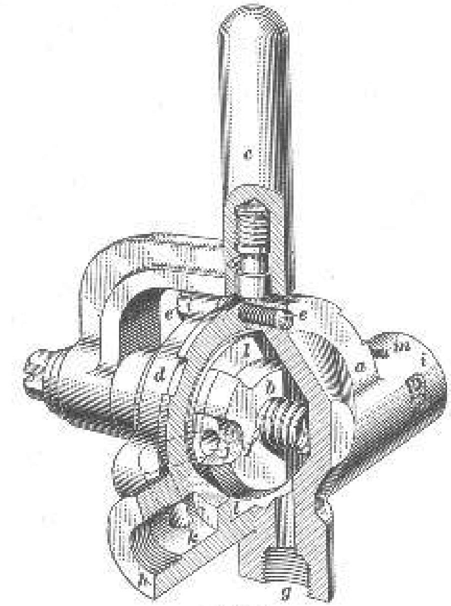
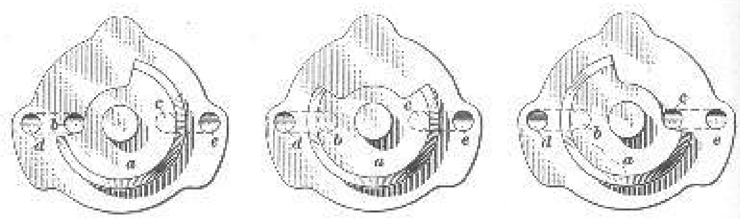


FIG. 38

nected, hence a movement of the handle will cause a rotation of the valve disk. The valve can be removed by taking off the cover *d*, which is held to the body *a* by three screws *e*, one shown. The valve disk is held against its seat by the spring *f*. The pipe from the air supply is connected at *g*, the pipe to the go-ahead sanders is connected at *h*, and the pipe to the back-up sanders is connected at *i*. A port *j* in the valve seat communicates with a passage shown by dash lines, that terminates in the port *k*. When port *j* is uncovered by the rotation of the valve disk *b*, the air in chamber *l* passes to the go-ahead sanders. A similar arrangement of passage and ports on the other side of the valve seat is used to convey the air to the back-up sanders. A warning port *m* is drilled into each outlet passage, through which a small amount of air discharges when the sanders are being operated.

75. The position of the valve disk *a* in relation to the ports *b* and *c* for different positions of the handle is shown in Fig. 39. In view (*a*) the valve disk has been rotated by the handle until port *b* has been uncovered, thereby allowing the air to pass through an interior passage to port *d* and to the pipe that leads to the back-up sanders. In view (*b*) is shown the position of the valve disk with the handle in mid-position and both sanders



(a) (b) (c)

FIG. 39

inoperative. The valve disk now covers both ports *b* and *c*. In view (*c*) the valve disk uncovers port *c* and permits air to pass through an interior passage to port *e* and to the pipe that leads to the go-ahead sanders.

GRAHAM-WHITE SANDER

76. Description. — The general arrangement of the Graham-White sander on the right side of the locomotive is shown in Fig. 40. With the exception of the pipes *a*, *b*, *c*, and *d*, which lead back to the engineer's valve in the cab, the arrangement on the left side of the locomotive is similar to that on the right side. The parts that make up the go-ahead sander comprise the pipe *e*, the sander trap *f*, and the sand-delivery pipe *g*; and the back-up sander is made up of similar parts, *h i*, and *j*. Each sander requires two air pipes, hence the four pipes that

are connected to the pipes *a*, *b*, *c*, and *d* lead over the boiler to the sanders on the other side of the locomotive.

77. Sander Trap.—A sectional view of the sander trap is shown in Fig. 41. The sand that is always free to pass to the sander trap from the sand box through the pipe *e* lies in the trap until blown out into the sand-delivery pipe *g* by a blast of air from the sanding nozzle *h*. A copper pipe *i* that is known

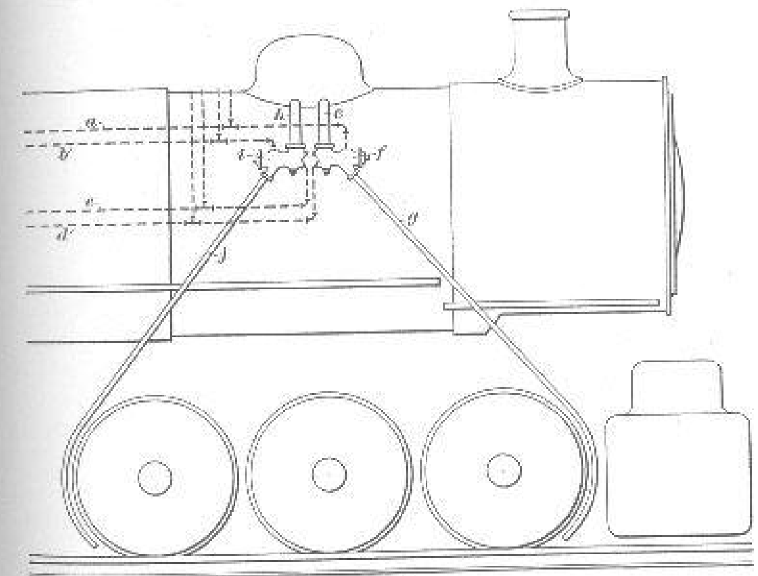


FIG. 40

as the cleaning pipe extends up into the sand pipe and is screwed into the upper end of the cored passage *j*. The pipe is closed at the top, and has drilled through it at an upward angle a series of holes *k*, which are arranged around the pipe spirally. The lower end of the passage *j* is closed by the plug *l*. The opening *m* in the passage *j* is directly above the center of the pipe *g*. The plugs *n*, *o*, and *p* are used when it becomes necessary to clean out the trap.

78. Operating Valve.—An exterior view of the outside face of the operating valve is shown in Fig. 42 (*a*); the valve as viewed from the front is shown in (*b*), and as seen from the inside in (*c*). The valve handle *e* is pivoted at *f*, and the lugs or wings *g* and *h* serve to depress the valve stems *i* and *j*, which are connected to and operate valves in the interior of the operating valve. These valves can be removed by taking off the cap nuts *k* and *l*. A globe valve, not shown, is placed in the pipe *mr* that connects to the main reservoir, so that the supply of air can be cut off should it be necessary to make emergency repairs to the valve.

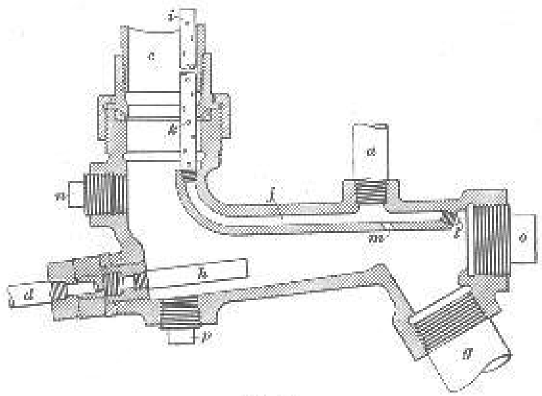


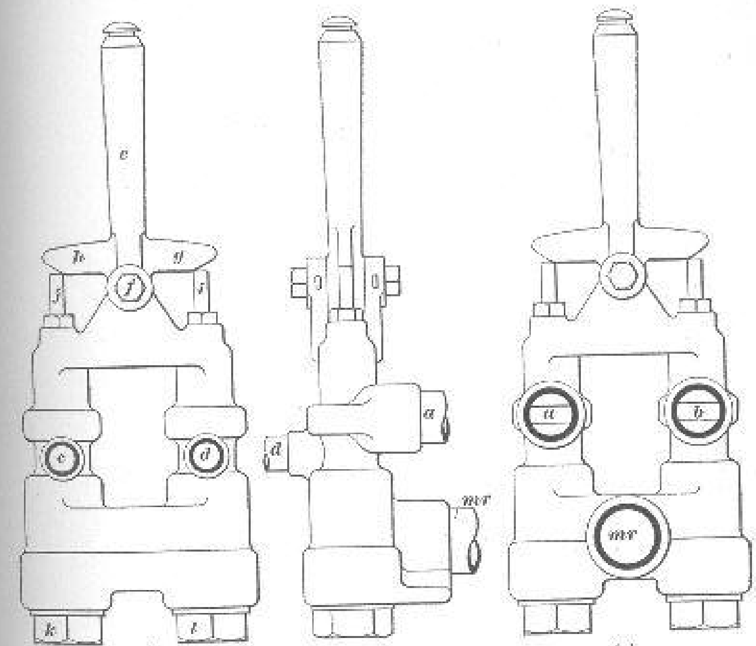
FIG. 41

The pipes connected to the front leg of the valves at *a* and *d* lead to the go-ahead sanders, and those connected at *b* and *c* lead to the back-up sanders. It will be noted that the air piping in the piping arrangement of the sander and in the view of the sander trap are lettered to correspond with the lettering on the operating valve.

79. Normal Position.—In normal position of the operating valve, as shown in section in Fig. 43 (*a*), the handle stands vertical and both valves *a* and *b* are held closed by the springs shown, as well as by the pressure of the air in chamber *c*, which is in communication with the main reservoir.

80. Cleaning Position.—In cleaning position of the brake valve, Fig. 43 (*b*), a blast of air is admitted to the sander for

the purpose of loosening the sand in the sand pipe and also for cleaning the sand-delivery pipe, preliminary to the operation of sanding and after sanding has been completed. Therefore, the cleaning operation always occurs before and after each sanding operation. When the handle is drawn backwards so as to operate the back-up sanders, the valve *a* is unseated and the air passes above it to the chambers *d* and *e*. Chamber *d* is



(*a*) (*b*) (*c*)

FIG. 42

connected by a pipe to the sanding nozzle *h*, Fig. 41, and chamber *e*, Fig. 43 (*b*), is connected to the passage *j* and the cleaning pipe *i*, Fig. 41. The air passes from passage *j* through port *m* and clears any obstruction out of the sand-delivery pipe *g*. The air also passes to the cleaning pipe *i*, in which the arrangement of the holes *k* is such as to cause a swirling downward blast of air through the sand pipe *e* and thereby insure the delivery of the sand from the sand box to the trap. The air that is passing through the sander nozzle *h* begins to blow the sand out of the trap and through the sand-delivery pipe *g*.

81. Sanding Position.—The operating valve is shown in sanding position in Fig. 43 (*c*). The movement of the valve handle from cleaning to sanding position causes the part *f* of the valve to close the opening *e* through which the air discharges

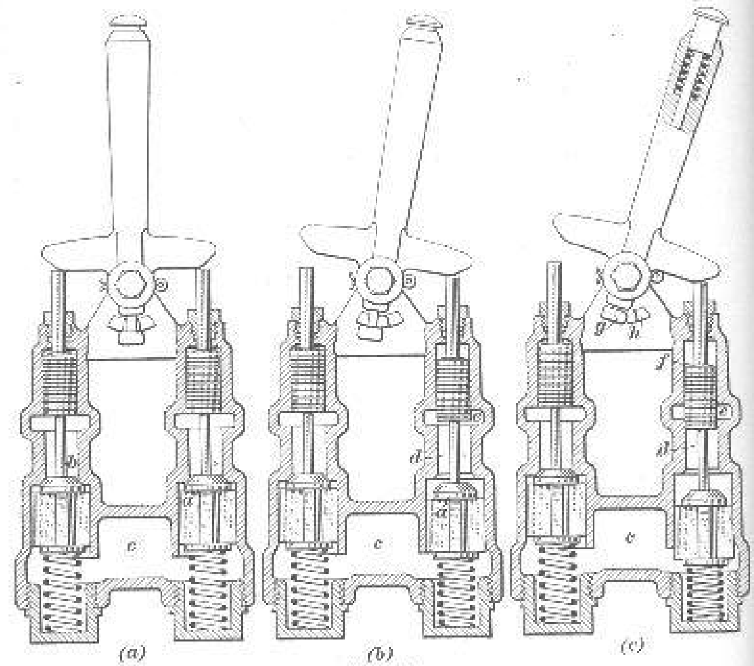


FIG. 43

in cleaning position. The air now passes from chamber *d* into the pipe that is connected to the sander nozzle in the sander trap and blows the sand out of the trap into the sand-delivery pipe and thence to the rail. If the button on top of the handle is released in sanding position, the part *g* of the latch will slip up behind the lug *h* on the valve and the handle will remain in this position and cannot be moved to normal position again until the button is pressed down. When the handle is being returned from the sanding to the cleaning position, a blast of air momen-

tarily passes from chamber *d* to the cleaning pipe before the valve seats, similarly to the action that occurs when the handle is being moved to sanding position.

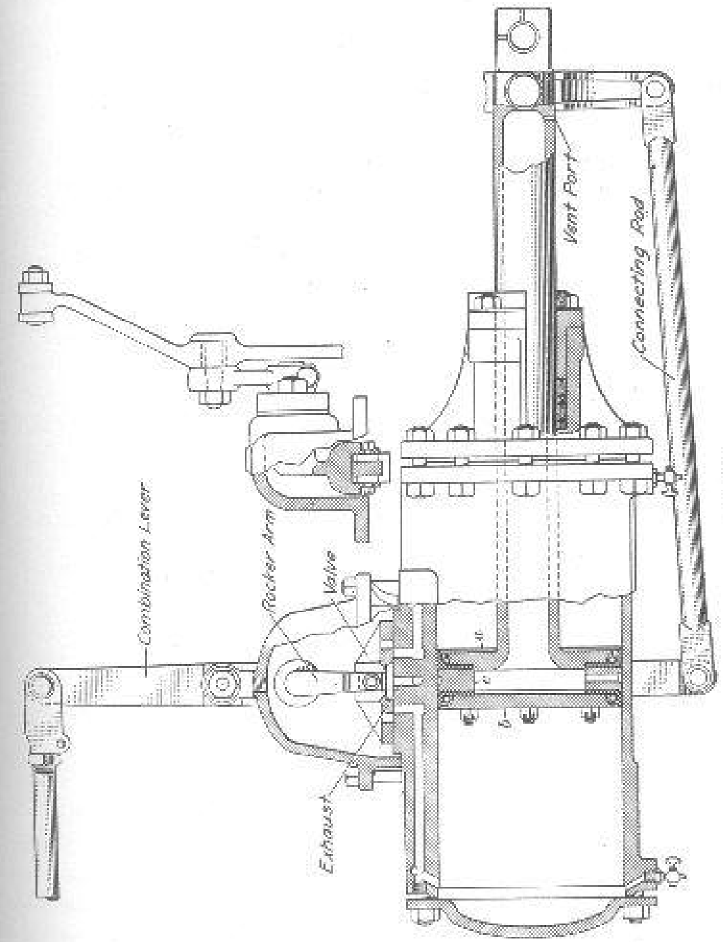


FIG. 44

When the handle of the engineer's valve is moved forwards, the go-ahead sanders are operated in the same manner as the back-up sanders.

The amount of sand delivered to the rails can be regulated by adjusting the sanding nozzle in the trap. If a greater quantity of sand is required, back off the nozzle and tighten the jam nut. If a less quantity is desired, back off the jam nut and insert the nozzle deeper into the trap.

POWER REVERSE GEARS

GENERAL REMARKS

82. Power reverse gears were first applied to the Mallet type of locomotive, but their employment is now general owing to the increased size of all classes of locomotives. Power reverse gears are so arranged that the movement of a valve controlled by a small lever in the cab results in the admission of air to a cylinder in which it acts on a piston connected to the reach rod of the valve gear. The movement of the piston is transmitted back to the valve and causes it to cut off the admission of air to the cylinder and at the same time hold the valve gear in the desired position. Therefore, the movement imparted by the valve through the reverse lever is always in the opposite direction to the movement imparted through the piston.

TYPE E, FRANKLIN POWER REVERSE GEAR

83. Description.—A sectional view of the Franklin type E, power reverse gear is shown in Fig. 44. The upper end of the combination lever is connected to the reverse lever; the lower end is connected by means of the connecting-rod and the trunk arm to the piston trunk. Between the ends, the lever is connected to the rocker-arm that serves to actuate the valve.

The rocker-shaft operates air-tight where it passes through the valve chest. It will be evident from the arrangement of the parts that a forward movement of the reverse lever and of the upper end of the combination lever with the lower end held fixed will move the valve to the right. A forward movement of the piston and of the lower end of the combination lever with

the upper end stationary will cause the valve to move to the left. As shown by the detail in Fig. 45, the forks of the rocker-arm carry two trunnion pins *j* on which the trunnion blocks *c* work freely. These blocks make a neat sliding fit in the slots *a* in the valve, so that when the rocker-arm is moved the blocks will move the valve horizontally and at the same time have a slight vertical movement in the slots. This arrangement permits the valve to be moved without any tendency to lift it from its seat, owing to the slight arc described by the end of the rocker.

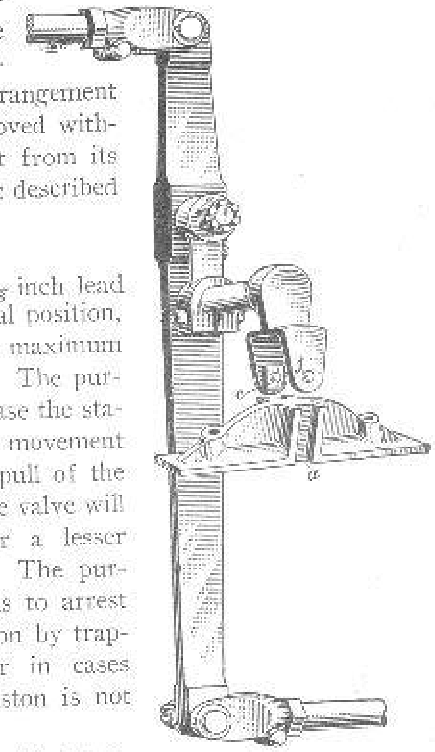


Fig. 45

84. The valve has $\frac{1}{128}$ inch lead at each end when in central position, $\frac{1}{8}$ inch exhaust lap and a maximum valve travel of $1\frac{1}{4}$ inches. The purpose of the lead is to increase the stability of the gear against movement arising from the varying pull of the valve gear. With lead, the valve will open the port wider for a lesser movement of the piston. The purpose of the exhaust lap is to arrest the movement of the piston by trapping air in the cylinder in cases where the pull on the piston is not excessive.

The trunk piston *a*, Fig. 44, is hollow and its construction is such that a space exists between the end of the trunk and the follower *b*. A series of holes, one shown, are drilled through the bull ring *c* into this space, so, should either cup packing leak, the air can escape through the vent port to the atmosphere instead of passing to the other side of the piston. The proper operation of the gear requires the pressure on one side of the piston to be higher than on the other side; hence, without the holes in the bull ring, a leaky packing cup would cause an equality of pressure. Also, the holes prevent the air that would leak by one packing cup from getting between the other packing cup and the cylinder wall, thereby preventing to some extent the pressure in the cylinder from forcing the cup packing against the wall and impairing the effectiveness of the packing in retaining pressure.

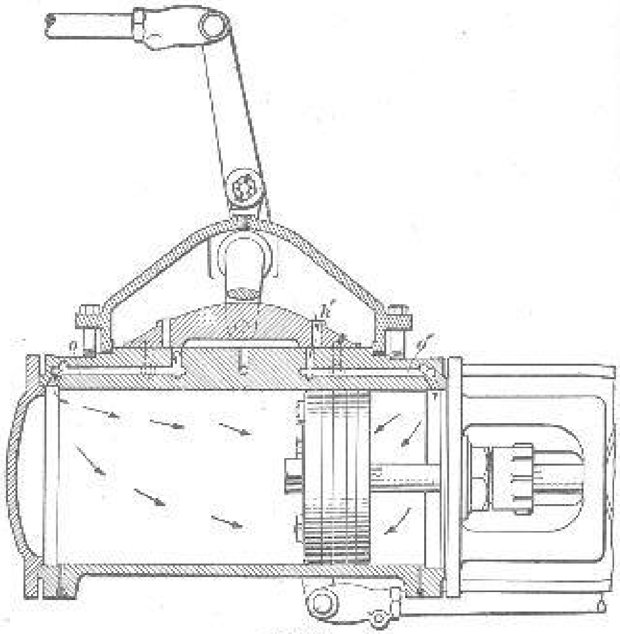


Fig. 46

85. Operation.—Either one of the conditions shown in Figs. 46 and 47 exists when the power reverse gear is holding the locomotive valve gear at cut-off. If the valve gear is exerting much of a pull on the piston of the reverse gear, the valve will move to the position shown in Fig. 46. That is, the forward movement of the piston acting on the lower end of the combination lever after the reverse lever has been latched, will carry the valve far enough to the left for port h' in the valve to open the port o' to the front end of the cylinder, thereby

stopping the piston. As it did not require full main-reservoir pressure to move the piston forwards, the pressure in the front end of the cylinder exceeds that in the back end. With a lesser pull on the reverse-gear piston, the valve will assume the position shown in Fig. 47. In this case the valve has not moved so far to the left, and the air trapped in the front end of the cylinder by the exhaust lap is compressed by the piston until it stops any further movement. In any event, the valve is never

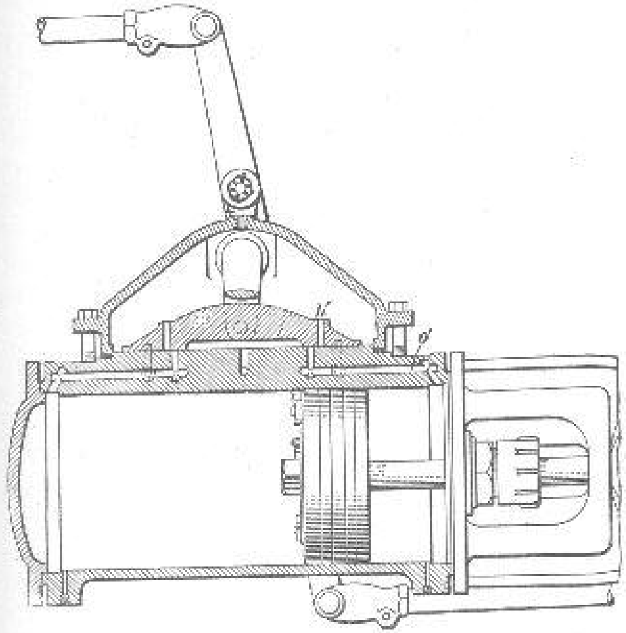


Fig. 47

in central position when the reverse gear is holding the valve gear at cut-off.

The valve is always displaced from mid-position an amount that will depend on the pull the valve gear exerts on the trunk piston.

86. The detailed operation of the gear, Fig. 44, when the reverse lever is moved is as follows: Let it be assumed that it is desired to lengthen the cut-off for forward gear. The forward movement of the reverse lever draws the upper end of the combination lever backwards because the lower end of the lever fulcrums for the instant on the end of the connecting rod. The backward movement of the lever draws the upper end of the rocker in the same direction; the lower end moves forwards and draws the valve with it. The valve first opens the port to the back end of the cylinder for the admission of air and next opens the front end of the cylinder to the exhaust. When sufficient air escapes from the front end of the cylinder, the air in the back end moves the piston and the lower end of the combination lever forwards. Such a movement would, were the upper end of the combination lever held stationary, move the valve to the left and shut off the admission of air, but with this end of the combination lever being still moved forwards by the reverse lever the effect is to hold the valve practically stationary and in a position to admit air to the cylinder. In other words, the forward movement of the crosshead throws the valve backwards at the same rate that the reverse lever thrusts it forwards, and so the entire action is smooth and continuous, the combined effect being to hold the valve in the position just stated. But with the reverse lever latched and the upper end of the combination lever stationary, the forward movement of the piston will then move the valve back, closing first the front end of the cylinder to the exhaust and next the admission of air to the back end of the cylinder. It is possible, if the pull on the reverse gear is not too much, that the air trapped in the front end of the cylinder will arrest the movement of the piston. Otherwise, the piston will be moved forwards by the pull of the valve gear until stopped by the admission of air as shown in Fig. 46. If the pull on the piston is excessive, the valve may be moved far enough to the left to open the back end of the cylinder to the exhaust. In this event, the total air pressure would be exerted on the front end of the piston to hold it in position.

87. When the reverse lever is moved toward the back corner, the valve opens the port to the front end of the cylinder for the admission of air and later opens the back end of the cylinder to the exhaust. The piston moves to the left as soon

as sufficient difference in pressure is established on it to overcome the resistance of the valve gear, and is stopped at the cut-off indicated by the reverse lever as already described.

88. Reverse-Lever Movement Limited in Absence of Cross-Head Movement.—The reverse lever has only a limited movement when the piston and crosshead of the power reverse gear are stationary, because the length of the valve is such that a small movement either way from mid-position brings the end of the valve up against the wall of the valve chest. The effect of thus limiting the travel of the valve is to restrict the movement of the reverse lever unless the crosshead moves at the same time: and, as the crosshead cannot move unless air pressure is present to operate the piston, a failure to move the reverse lever the full sweep of the quadrant is an indication that there is no operating pressure present and the engine must not be moved.

DISORDERS

89. Failure to Obtain Required Cut-Off.—By a failure to obtain the required cut-off is meant that the position of the reverse-gear piston and the locomotive valve gear does not correspond to the position of the reverse lever. This condition is brought about by a failure to maintain the gear without lost motion. Lost motion may occur at the reverse lever, at the pin connections at the top and bottom of the combination lever, and at the crosshead-pin connection. The trunnion blocks or the slots in the slide valve may be worn or lost motion may exist where the rocker passes through the valve-chest gland. The lost motion is multiplied by the ratio of the combination lever with the result that the position of the piston will vary considerably from that indicated by the reverse lever. For example, if the lost motion in the various connections totals $\frac{1}{2}$ inch and the ratio of the lever is 4 to 1, that is, the total length of the lever is four times longer than the short portion, the piston will be $4\times\frac{1}{2}$, or 2, inches from the center of the cylinder with the reverse lever on center, and the valve gear will not be in mid-gear. The same difference will exist for all cut-offs.

90. Lost motion in the various connections of the reverse gear when moving the reverse lever toward the corner, causes the piston to move nearer to the end of the cylinder than it should, thereby giving a longer cut-off than desired. When drawing the reverse lever up, lost motion causes the piston to move nearer to the center of the cylinder and the cut-off will be shorter than it should be. When a movement of the reverse lever less than the number of notches of lost motion is desired, the piston of the reverse gear can be made to assume a position that corresponds to the position of the reverse lever if operated as follows: Move the lever in the required direction the number of notches of lost motion plus two notches more, this latter to get the valve shifted. Then move the lever in the reverse direction while the piston is still moving, the difference between the above number of notches and the number of notches of movement desired.

To obtain the desired cut-off for a movement of the lever in excess of the notches of lost motion, place the reverse lever the number of notches of lost motion short of the desired cut-off, when either dropping the lever down or drawing it up.

91. Creeping.—The term *creeping* is applied to the movement of the piston of the reverse gear with the engine in motion and the reverse lever latched. The act of creeping is started by air leaking from the cylinder past the valve or the piston-rod packing or by air leaking from one end of the cylinder to the other owing to defective piston packing, but the extent of the creeping movement depends entirely on the amount of lost motion in the gear connections.

The reason is as follows: When the movement of the piston is finally arrested during a shift of the reverse lever, all of the slack in the gear connections has already been taken up so that, in the event of a leak a slight movement of the crosshead causes the valve to open the port to replenish the air that is being lost. However, the movement of the crosshead in the reverse direction to bring the valve back to its former position will be greater because the slack in this direction is out and has first to be taken up before the valve starts to move. Therefore, creeping is a

movement first in one direction and then in the other, the greater movement being in the direction in which the most slack exists. The action of the reverse gear when creeping is to shorten the cut-off to a greater extent than to lengthen it.

If lost motion is kept out of the gear connections, the amount that air leakage causes the gear to creep is scarcely perceptible. The creeping of the gear can then be said to be due principally to a failure to keep lost motion out of the gear connections.

FRANKLIN PRECISION POWER REVERSE GEAR

92. Description.—The Precision power reverse gear was introduced by the Franklin Railway Supply Co., Inc., to overcome the effect of the development in service of lost motion in the various connections of the gear just described. The rods, levers, and pins heretofore used to connect the piston to the valve have been eliminated with the Precision gear, these two parts being directly connected. A hand wheel is used to operate the gear so that it is slower in action than the reverse-lever type of gear.

A typical arrangement of the gear is shown in Fig. 48, the hand wheel and indicator are shown in Fig. 49, and a sectional view of the reverse gear proper is shown in Fig. 50. A sectional view of the valve and its seat and a top view of the valve seat are shown in Fig. 51. The indicator is fastened to the boiler head, and its screw shaft is threaded for the purpose of causing the indicator block, the top of which is arrow-shaped at *a*, Fig. 49, and flush with the top of the plate having the cut-off marks, to move along the plate and thus designate the point of cut-off when the hand wheel is turned. A 1½-inch left-hand triple thread is used on the screw with six threads per inch and with ½ inch lead. With a left-hand thread, the indicator block is caused to move forwards when the hand wheel is turned to the right and backwards when turned to the left. The cylinder is 10 inches in diameter and is 24 inches long. The air passage to the front end of the cylinder begins at the rear port in the valve seat and is cored through a boss along the cylinder wall; the front port leads directly to the back end of the cylin-

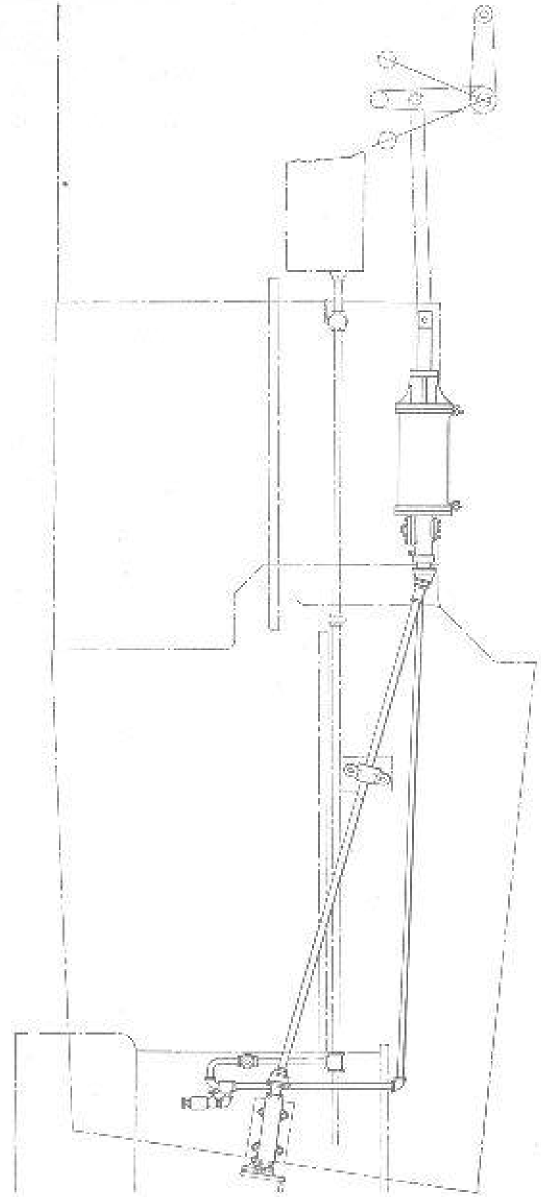


Fig. 48

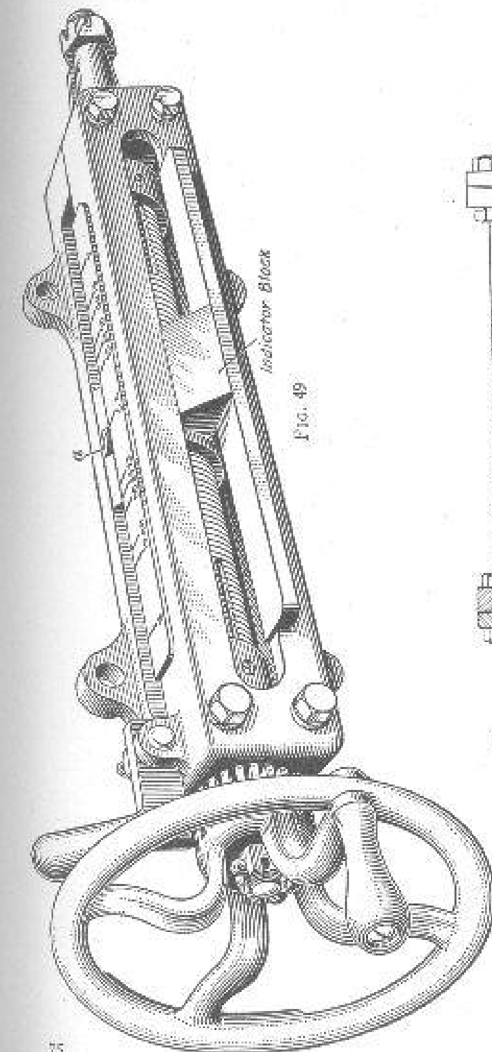


Fig. 49

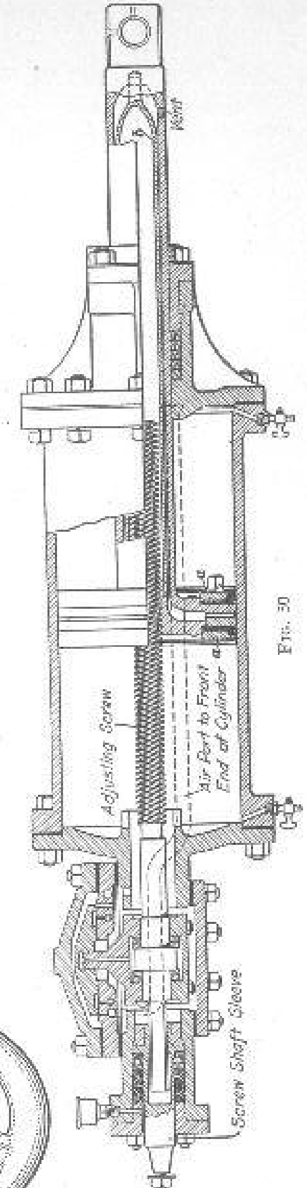


Fig. 50

der. Two cup packing rings *a*, Fig. 50, held in position by two followers and a bull ring and pressed outwards by two expander rings, serve to make the piston air-tight. Should the packing cups leak, the air will pass into the groove around the bull ring, and into holes, of which there are six through the ring and the piston, thence into the core of the piston trunk and out through the small tapped hole at the front. The hole thus serves as a tell-tale for leakage.

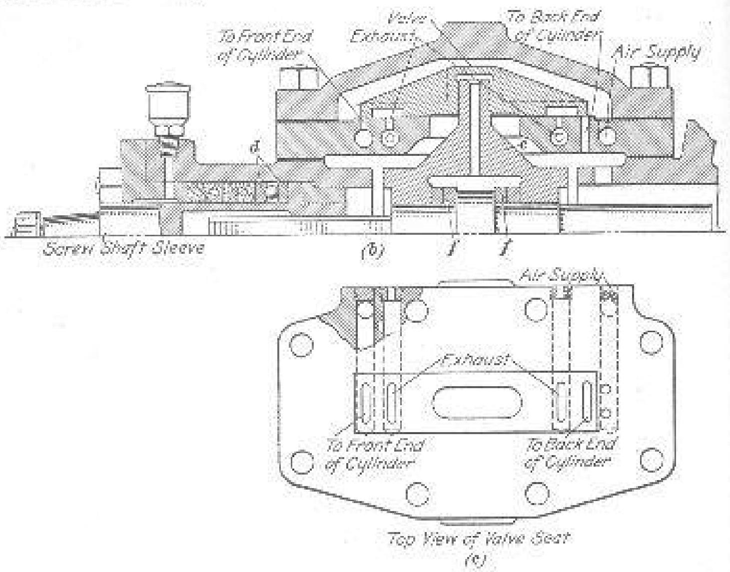


FIG. 51

93. The adjusting screw in the piston has a $1\frac{1}{2}$-inch triple Acme thread, right- or left-hand, three threads per inch and 1 inch lead. A left-hand screw is used when an outward movement of the piston is required to place the valve gear in forward gear; a right-hand screw is employed when an inward movement is necessary. The back end of the trunk tube *b*, Fig. 50, that is screwed into the piston head and is packed with grease prevents the escape of air that may leak along the adjusting screw from the back end. The adjusting screw is square in section and has a sliding connection in the screw-shaft sleeve; this permits the screw to be turned and moved longitudinally, thus moving the valve. The front end of the screw-shaft sleeve turns within a bushing. The screw-shaft thrust bearing *d* permits the sleeve to be turned easily, notwithstanding the air pressure against it. The ball race next to the sleeve turns with it and the race that is next to the packing remains stationary with respect to it.

94. A valve operating arm and cap *e* secured to the shaft of the adjusting screw by four through bolts is used to connect the screw to the valve; this connection is made by the upper portion of the arm that extends up into a slot in the valve. Two bronze bearing rings *f*, one on each side of the integral collar on the adjusting screw, mate against steel bearing rings that bear against the shoulders of the valve operating arm. These rings are lubricated by filling the oil hole in the arm with oil when assembling the gear.

The valve when central on its seat is $\frac{1}{32}$ inch shorter than the dimension between the outside edges of the inlet ports in the valve seat, so that the valve has each inlet port open $\frac{1}{64}$ inch lead when in mid-position; the exhaust lap is $\frac{1}{4}$ inch.

95. Operation.—It will be assumed that the power reverse gear is in the position shown in Fig. 50 and that it is desired to place the locomotive valve gear in forward cut-off. In central position as shown, the valve has each inlet port open $\frac{1}{64}$ inch, so that there is pressure on both sides of the piston.

The indicator screw shaft is left-hand, hence turning the hand wheel to the right causes the indicator block to move forwards. With the adjusting screw left-hand, the valve will move backwards and the port to the back end of the cylinder will open wider; as the movement of the valve continues, the other port will open to the exhaust. The increase in pressure behind the piston in combination with the decrease in pressure in front causes the piston to move forwards. Such a movement would carry the valve in the same direction and cause the port to close were it not that the valve is being drawn backwards by turning the adjusting screw by the hand wheel.

96. The piston cannot be moved forwards any faster than the valve is being moved backwards, so that the valve is practically stationary with respect to its seat and the port remains open during the rotation of the hand wheel. However, as soon as the wheel is stopped, the forward movement of the piston will cause the valve to close the port and the piston will continue to move in this direction until stopped by the admission of air through the port leading to the front end of the cylinder. If the pull of the valve gear is enough, the valve may be pulled far enough forwards to connect the back end of the cylinder to the exhaust. In this event the total air pressure would be exerted in front of the piston to keep it from moving forwards.

It requires nineteen turns of the hand wheel to move the piston from one end of the cylinder to the other, each turn of the wheel causing the piston to move 1 inch. The indicator block moves only half as fast as the piston, owing to the hand-wheel screw shaft having twice as many threads per inch as the adjusting screw.

ALCO REVERSE GEAR

97. Description.—A sectional view of the cylinder of the type G Alco reverse gear, manufactured by the American Locomotive Company, is shown in Fig. 52. In this view the reverse cylinder valve body cap is shown removed. A sectional view of the reverse cylinder valve body as well as a view of the valve and its seat is shown in Fig. 53. In the latter view the valve stem is shown in place in the seat.

The valve body is secured to its seat on the cylinder by studs, and has air passages that register with air passages that lead to the front and back end of the cylinder. Also, the valve body has an exhaust passage as well as two air-supply passages, the one not used being plugged. A gasket serves to make an air-tight joint between the valve body and its seat on the cylinder. The gear is controlled by a flat rotary valve *a*, movement to which is imparted by the valve stem *b* and the valve arm *c*, the latter being connected to the upper end of the floating lever *d*. As shown in the other views, the lower end of the floating lever is connected to the crosshead by the floating-lever rod; between the ends the floating lever is connected by means of a rod to the reverse lever. The arrangement is such that a movement of

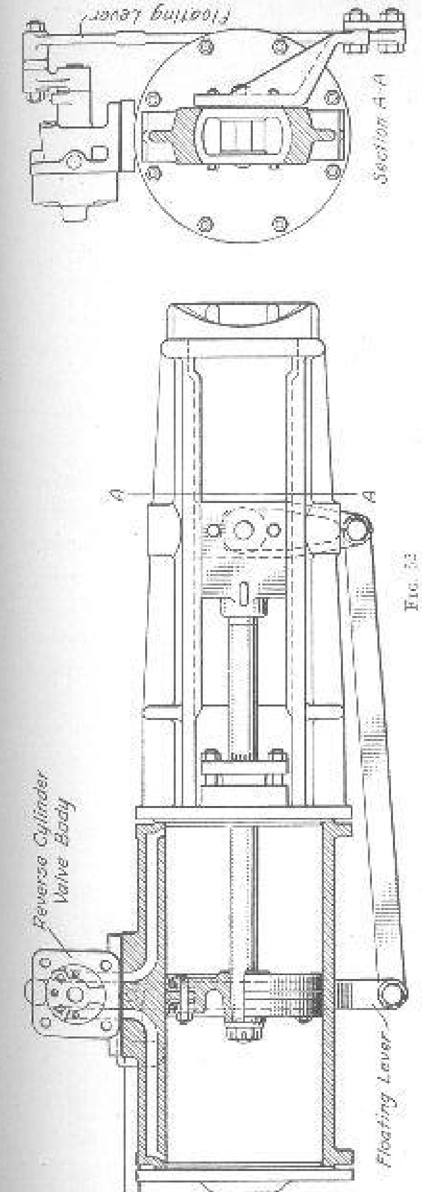


Fig. 52

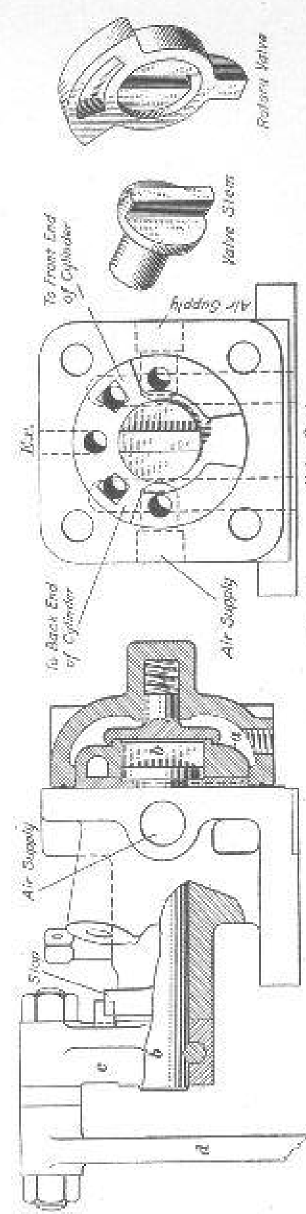


Fig. 53

the reverse lever will cause a rotation of the valve in one direction, whereas the crosshead movement that results from the action of the reverse lever, will rotate the valve in the opposite direction. The lead of the valve should not be less than $\frac{1}{32}$ inch and the exhaust lap not less than $\frac{1}{16}$ inch.

98. Operation.—The operation of the Alco gear is similar to that of those previously described, so that a detailed description is unnecessary. With pressure in both ends of the cylinder, a forward movement of the reverse lever acts on the floating lever and, through the medium of the valve arm, rotates the valve stem and the rotary valve. The valve, Fig. 54, first opens port *a* to the back end of the cylinder for the admission of air; next the valve opens the front end of the cylinder to the exhaust through the exhaust cavity in the valve and port *b*. The air will continue to pass to the back end of the cylinder and exhaust from the front end until the required difference in pressures is established on the piston to start it moving. The movement imparted to the lower end of the floating lever with the crosshead moving forwards would cause the valve, in the absence of the reverse-lever movement, to close port *a* for the admission of air to the cylinder. However, with the reverse lever moving forwards the valve remains practically stationary until the reverse lever is latched; then the crosshead movement will rotate the valve so as to stop the admission of air to the back end of the cylinder. The position finally assumed by the valve will depend on the pull on the reach rod. With a moderate pull the piston will be stopped owing to the exhaust lap of the valve trapping air in the front end of the cylinder. With a heavy pull the forward movement of the crosshead may cause the valve to be rotated enough to open the port to the front end of the cylinder for the admission of air.

99. Moving the reverse lever toward the back corner of the quadrant admits air to the front end of the cylinder and starts the exhaust from the back end. When a sufficient difference in pressures has been formed on the piston to overcome the resistance of the valve gear, the piston moves back and places the valve gear at a cut-off corresponding to the position

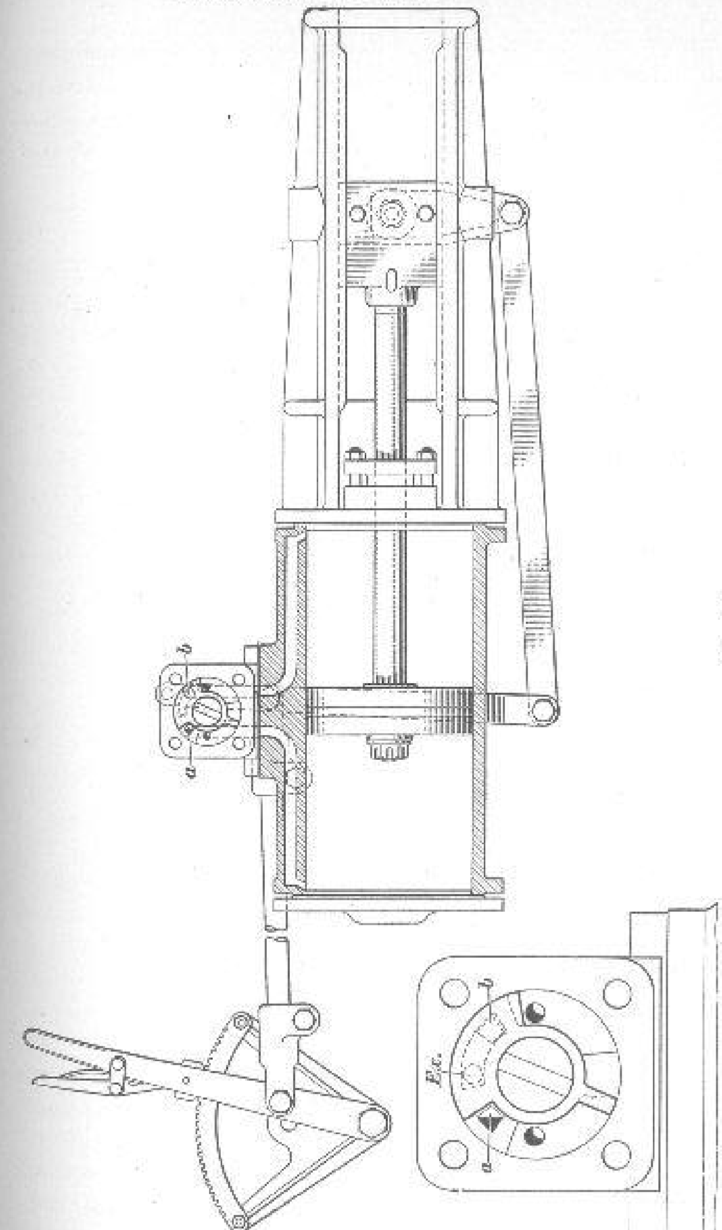


FIG. 54

of the reverse lever. The piston will be stopped and held in position as already explained.

Stops on the valve body permit a very limited movement of the reverse lever when there is no air pressure on the gear. This feature warns the engineman not to move the engine until the air is turned on.

100. Testing Packing Cups.—To test the front piston packing cup place a wooden block between the crosshead and the front cylinder head of such a length as to block the crosshead about 3 inches ahead of central position. Then move the reverse lever back slowly until the valve arm is against the stop; this operation drains the air from the back end of the cylinder and leaves full main-reservoir pressure in the front end. A blow of air at the exhaust port now indicates that the front cup or follower studs are defective. To test the other cup transfer the block to the other side of the crosshead and move the lever in the reverse direction.

FRANKLIN STEAM GRATE SHAKER

ARRANGEMENT AND OPERATION

101. General Arrangement.—The general arrangement of the Franklin steam grate shaker is shown in Fig. 55. The piston in the operating cylinder transmits through the operating lever a partial turning movement in either direction to the cross-shaft on which the power levers are connected. When the connecting latches are thrown in and the lever locks thrown back, the back-and-forth movement of the power levers with the grate shaker in operation will impart a similar movement to the fulcrum levers with the result that the grates will open and close. The power levers are fitted tightly on the square section of the cross-shaft; the fulcrum levers turn on the round portion of the shaft. The operating cylinder and the shaft brackets are connected securely to the back boiler head by means of studs and nuts.

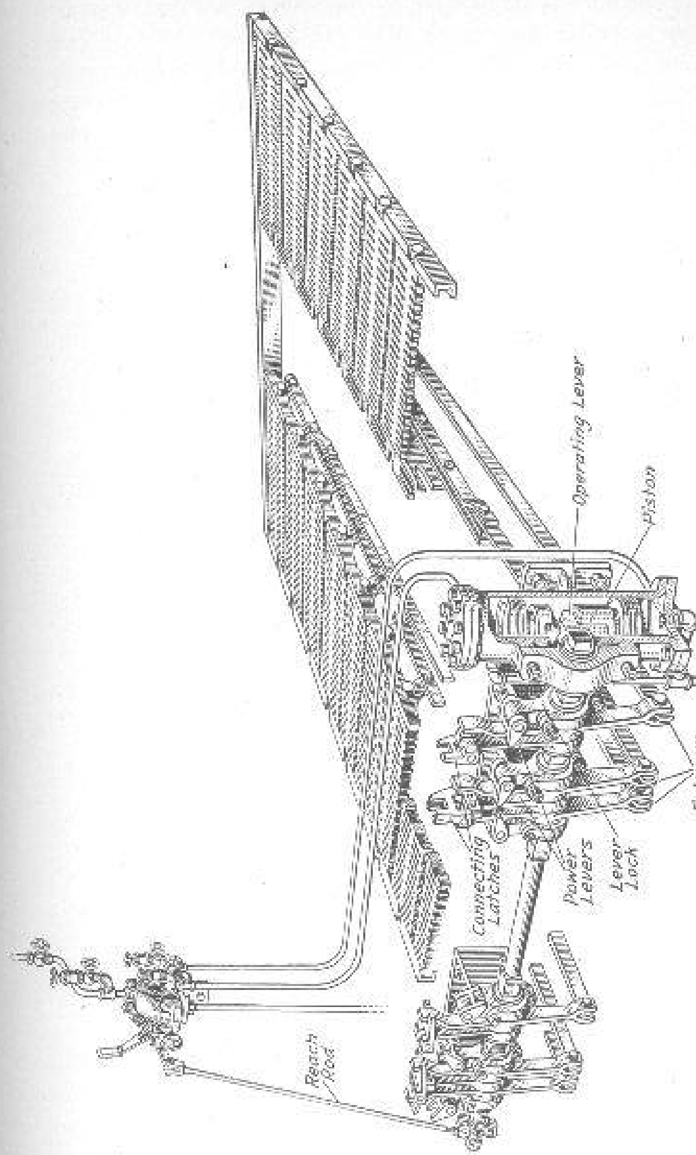


Fig. 55

A forward movement of the handle of the operating valve admits steam to the top of the cylinder and exhausts it from the bottom; a backward movement of the handle reverses the flow of the steam. After each movement of the operating-valve handle, the slide valve in the operating valve is returned to mid-position by the reach rod. This position of the valve shuts off the steam to the cylinder and also arrests the movement of the piston, when nearing the end of its stroke, with a cushion of steam.

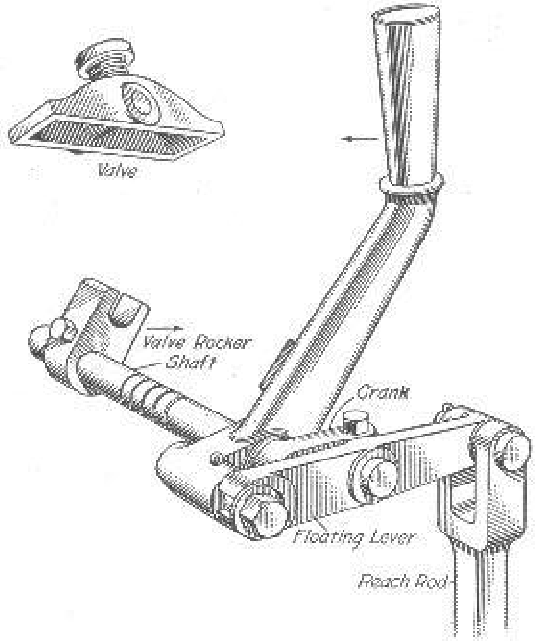


Fig. 56

102. Valve Operating Arrangement.—The arrangement of the parts for operating the valve is shown in Fig. 56. The hand lever turns freely on the valve rocker-shaft so that the lever if moved forwards or in the direction of the arrow will depress the left end of the floating lever. The right end of this lever fulcrums momentarily on the reach rod, so that the crank will be pulled down, thereby turning the rocker-shaft,

and moving the valve to the right. The movement of the piston that follows the admission of steam to the cylinder now turns the cross-shaft; the shaft clamp then pushes the reach rod upwards. As the movement of the hand lever has stopped, the

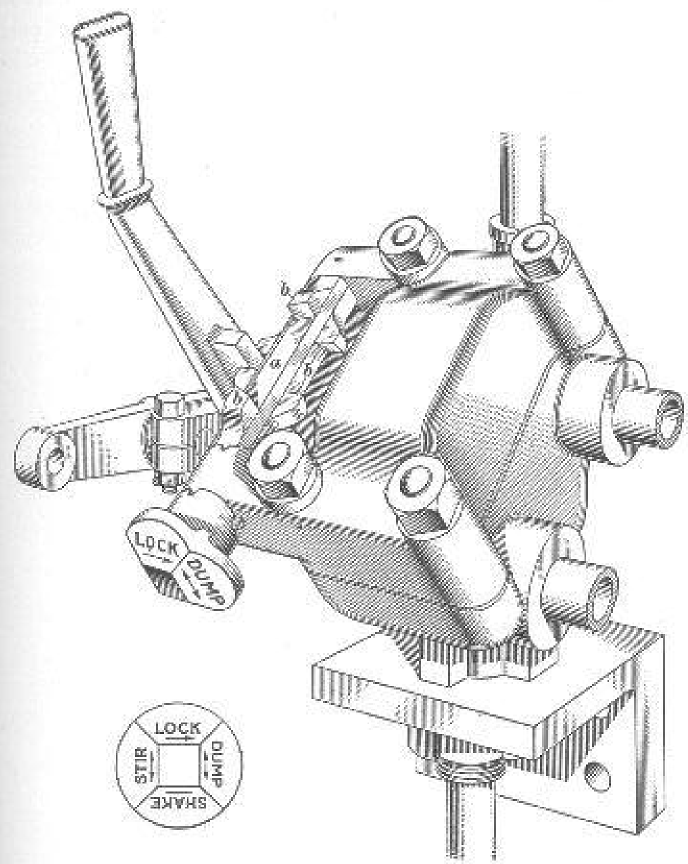


Fig. 57

left end of the floating lever fulcrums on it and the valve will be moved to the left to mid-position. The grates are now open; they can be closed and tilted in the other direction by moving the hand lever backwards. The action of the cross-shaft and the reach rod then centers the valve as before. The operation of the hand lever merely causes the valve to open the port; the valve is caused to close the port by the action of the reach rod. A full movement of the hand lever causes the piston to make a complete stroke; less than a full movement results in a partial movement of the piston. In the foregoing respects, the operation of the grate shaker resembles that of the power reverse gear.

103. The stroke of the hand lever and hence the movement of the piston can be limited by turning a knob, Fig. 57, which in turn revolves a small cylinder *a* studded with bosses *b* that so limit the movement of the lever as to allow dumping, shaking, or stirring, or permit the hand lever to be locked in central position, thus holding the grates level. The arrangement is operated by pulling out the knob against the resistance of a spring, and then turning the knob until the position corresponding to the intended operation is at the top. After operating the grate shaker, the hand lever is returned to mid-position and the knob to lock position as shown, so that the lever cannot be accidentally moved.