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No. 84

A Dollar's Worth of Condensed Information

Locomotive Building

By RALPH E. FLANDERS

PART VI
ERECTING PRACTICE

Price 25 Cents

CONTENTS

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NUMBER 84

LOCOMOTIVE BUILDING

By Ralph E. Flanders

PART VI

ERECTING PRACTICE

CONTENTS

LOCOMOTIVE BUILDING

ERECTING PRACTICE*

The Juniata Shops of the Pennsylvania Railroad at Altoona have a normal capacity for turning out a locomotive a day, the year round. Sometimes this capacity is exceeded. All the passenger locomotives used on the Pennsylvania lines, both east and west of Pittsburg, are built here, as well as many of the freight engines. There are but few other railroads in the country that make a regular business of building their own locomotives; and there are few other systems large enough to warrant such an undertaking, or to make possible a plant of the capacity of this one. It is large enough so that locomotives can be built in accordance with the best manufacturing practice for such work. In fact, conditions are perhaps a little better in this respect than in even the largest of the private plants, as the bulk of the work consists of comparatively few styles of locomotives.

We have described in previous parts of this review of locomotive manufacture (MACHINERY's Reference Series Nos. 79 to 83, inclusive), the detailed order of operations followed in manufacturing various important parts of the finished machine. It has been shown that accurate and rapid methods have been followed. The test of those methods, especially as regards accuracy, comes in the erecting department; for on the closeness with which the workmen follow the figures of the drawing, and on the fineness of their fitting, depend the rapidity and accuracy of the assembling. A study of the erecting methods at this plant serves to intensify the good impression gained from watching the detailed manufacturing operations.

The Organization of the Erecting Department

The erecting shop (see Fig. 2) is 579 feet, 9 inches long and 70 feet wide, and is served by four traveling cranes, two of 65 tons, and two of 35 tons capacity. The upper western end of the building is devoted to the wheel gang of twenty-eight men, whose work is described in MACHINERY's Reference Series No. 80, "Locomotive Building, Part II., Wheels, Axles and Driving Boxes." The middle section is used as storage space for boilers, frames, wheels, cylinder castings, etc., while the eastern end is used for the erecting proper—the south side being devoted to the frame gang, and the north to the actual setting up of the locomotive itself.

The work of erecting is divided between a number of gangs; these comprise the boiler-mounting gang of thirty-seven men, the frame gang of forty-eight men, the erecting gang of thirty-seven men, and the smaller sub-divisions, such as jacket gang, pipe gang, test gang, etc. These various bodies of men, whose work will now be described, are

*MACHINERY, Railway Edition, June, 1910.

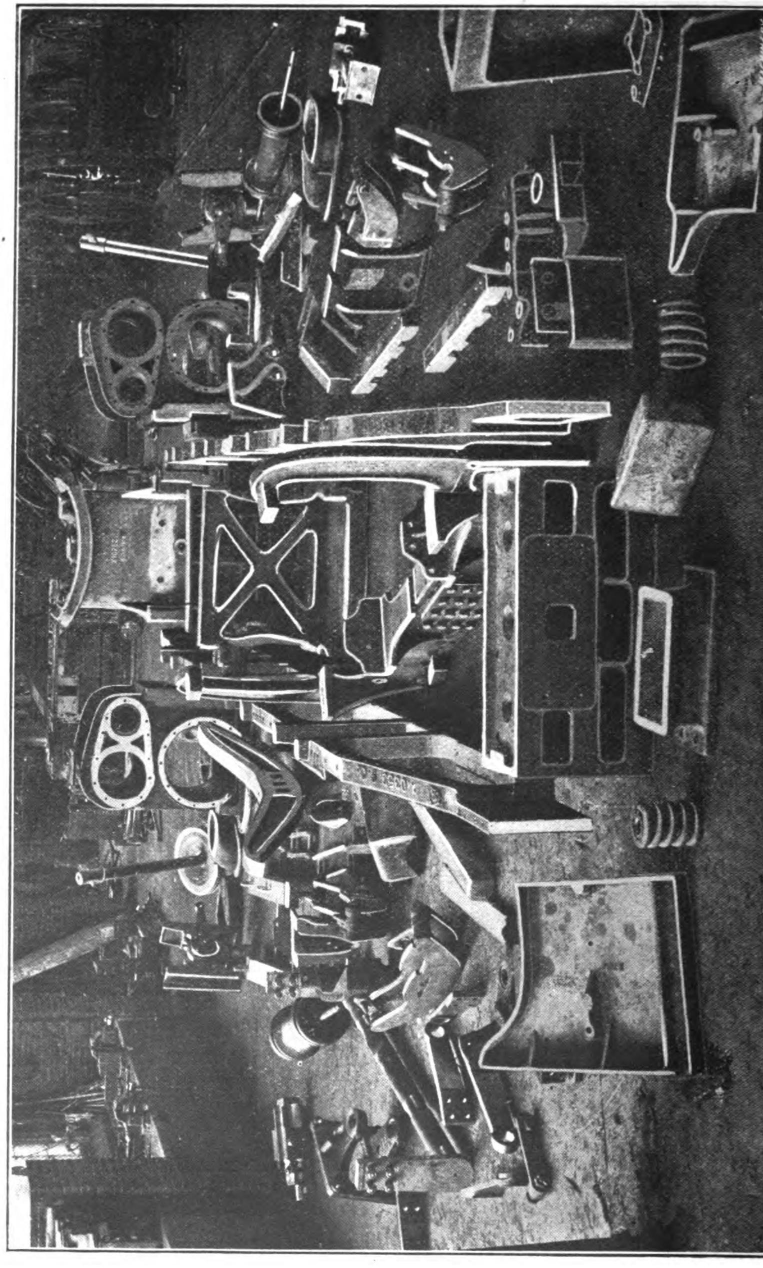

Fig. 1. Parts Ready for the Frame Gang in the Assembling Shop

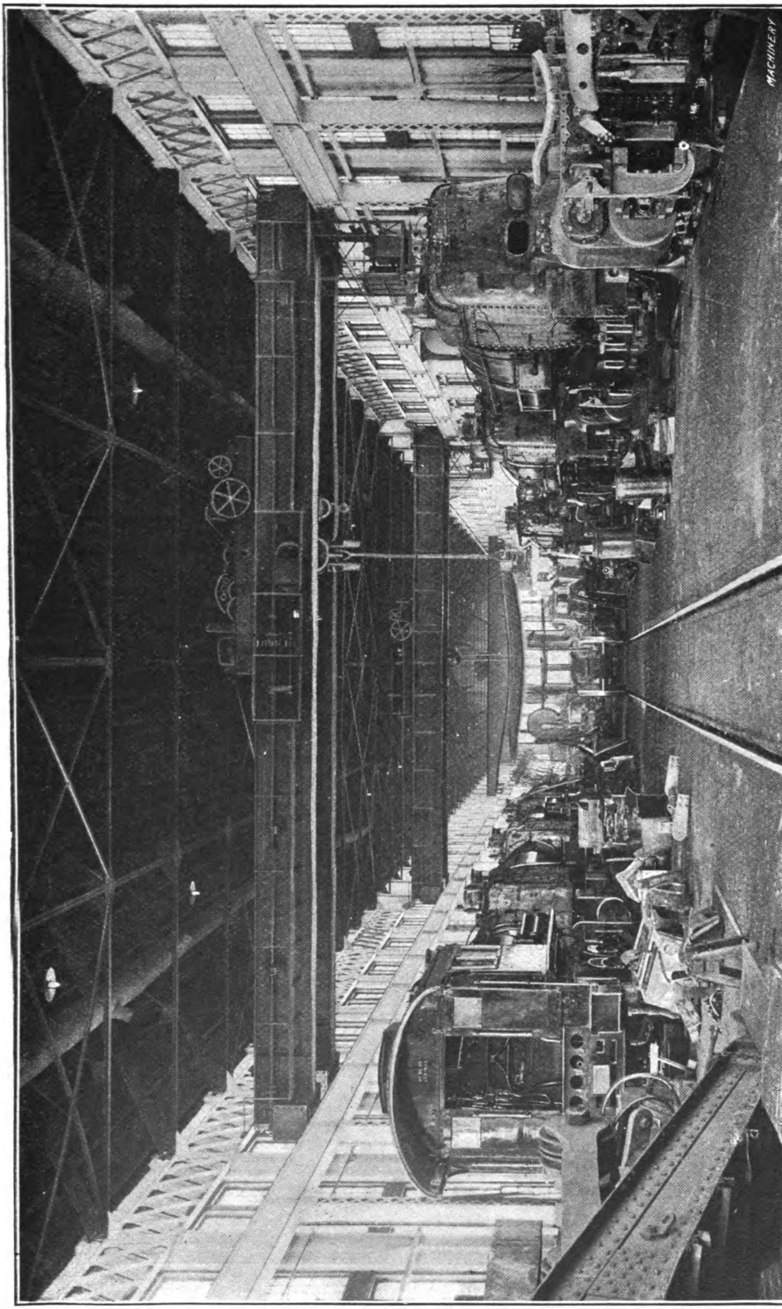

Fig. 2. Interior View of the Erecting Department in the Juniata Shops of the Pennsylvania Railroad at Altoona, Pa.

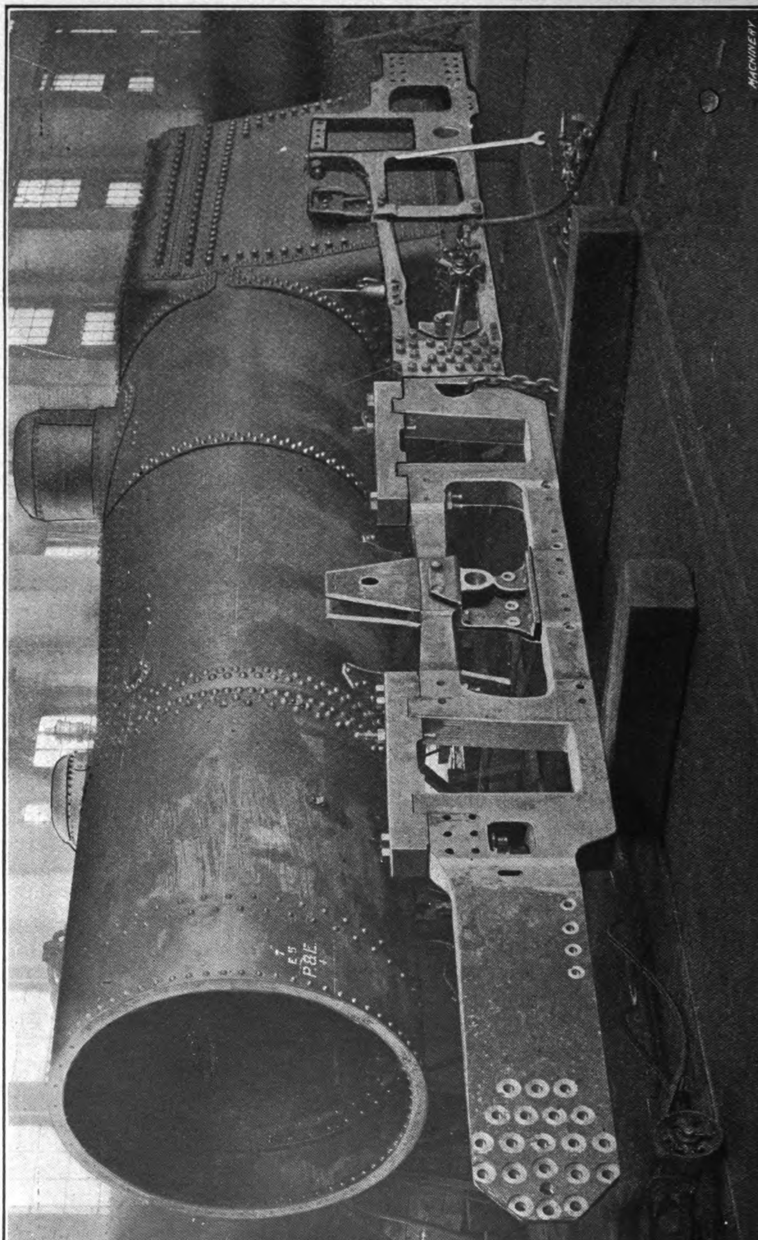

Fig. 3. A Frame Bolted and Fitted ready for Erection; Belpaire-Type Boiler in the Background

sufficient in number to turn out one machine a day under the favorable conditions which obtain here, both in manufacturing and erecting.

It is the business of the frame gang to set up the frames, and attach to them the saddle, cylinders, cross braces, foot plate, driver brake brackets, brake rigging, pilot, guides, crosshead, piston, etc. The material, as it is received by them, ready for assembling, is shown grouped together in Fig. 1. The particular parts here illustrated belong to a heavy consolidation-type freight locomotive of the H-8-B class,

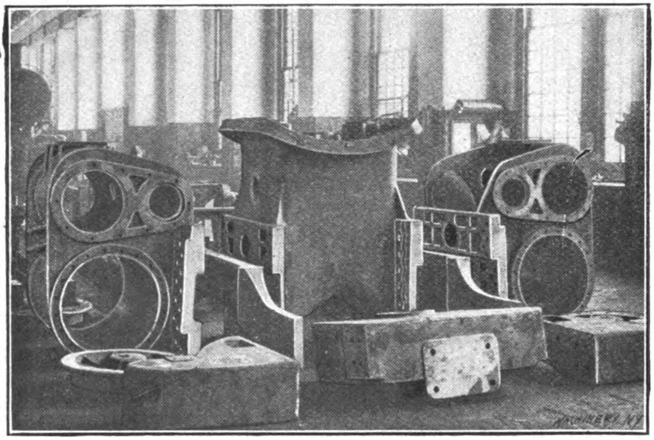

Fig. 4. The Cylinders, Saddle, Frame, etc., ready for Erection

illustrated on page 4 and described on page 32 of MACHINERY's Reference Series No. 79, "Locomotive Building, Part I, Main and Side Rods." The section of the shop devoted to the frame gang is that at the left in the immediate foreground of the picture in Fig. 2, which space is there shown temporarily occupied by nearly completed locomotives.

The first job of the frame gang is the fitting and bolting together of the frame itself. This is, of course, made with one or more joints which have to be reamed and bolted together. The bolt holes for these joints come already drilled and counterbored. The two sections of the Atlantic-type frame in Fig. 3 have been blocked up until they are true with each other, as shown by measurement with a line and straightedge. When thus lined up, the holes in the joint are reamed with a pneumatic motor, the reamer having a taper of 3/32 inch per foot, the standard for this work. The operator, of course, has to take care that his reamer runs in just far enough so that the taper bolt, when driven up tightly to its head, will at the same time have a force-fit bearing along its whole length in the taper hole. To do this rapidly and accurately requires some skill, but it is soon acquired. In putting the frame together, the distance between the pedestal bearings is carefully measured, as shown later in Fig. 14. It is very important that the distance between wheel centers should be accurate.

Other work which has to be done on the frame at this time is the

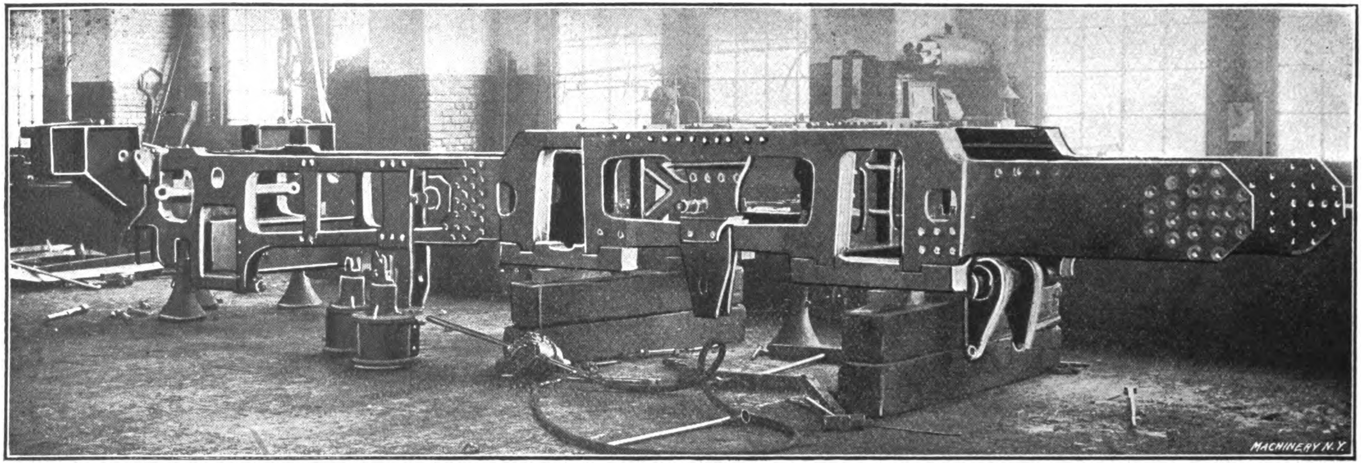

Fig. 5. Frame Assembled with the Cross Bracing, etc.

fitting of the pedestal caps, equalizing bar supports, and similar parts. At the same time a man with a pneumatic hammer and specially shaped chisel has been going over the whole frame, rounding all the exposed corners. It is considered that this operation strengthens the frame somewhat, as fractures are more likely to start on sharp featheredges than on smoothly rounded ones. After being thus fitted and finished, the frame is ready for assembling with its mate. It is then picked up by the crane and shifted to the point where the frame erection is to begin.

Setting Up the Frames

The frame is placed on blocking and jacks, an accurate spirit level being used to make sure that it is set horizontal. Next the foot plate is attached to it. Then the second frame is dropped into place beside the first and drawn firmly to its bearing against the foot plate, to which it is then clamped. The two frames are carefully checked up to see that they are level in themselves, and level with each other, straightedges being laid across from one to the other for that purpose. Being found O. K. in this respect, the various cross braces, etc., are clamped in place, taper reamed and bolted, firmly tightening the whole structure together. This work of reaming and bolting continues throughout the whole of the frame erection, as the different subdivisions of the gang do not wait for each other; all pursue their own work simultaneously.

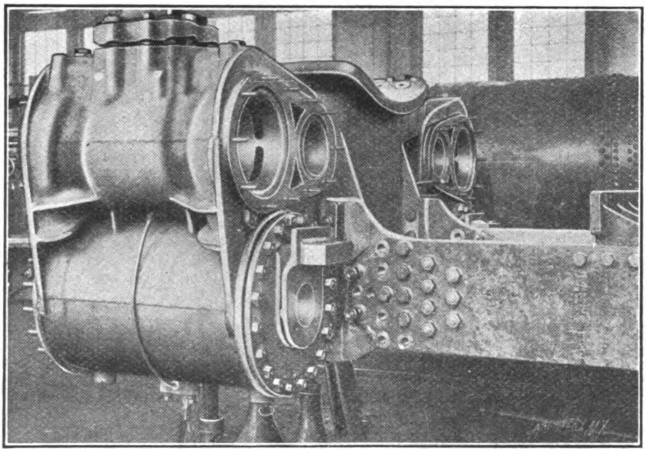

Fig. 6. The Assembled Cylinders Bolted to the Frame

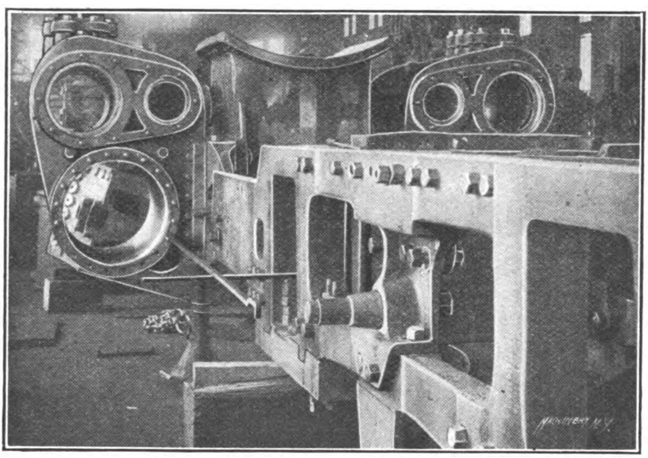

Fig. 7. Testing Alignment of the Cylinder Flanges with the Pedestals

The consolidation-type locomotive, for which the parts in Fig. 1 are intended, is remarkable, as may be seen, for the weight and rigidity of the cross bracing. This serves the purpose of increasing the tractive power by its dead weight, as well as of strengthening the whole structure. Such rigid cross bracing was impossible with the Stephenson valve gear, which filled about all the space between the frames.

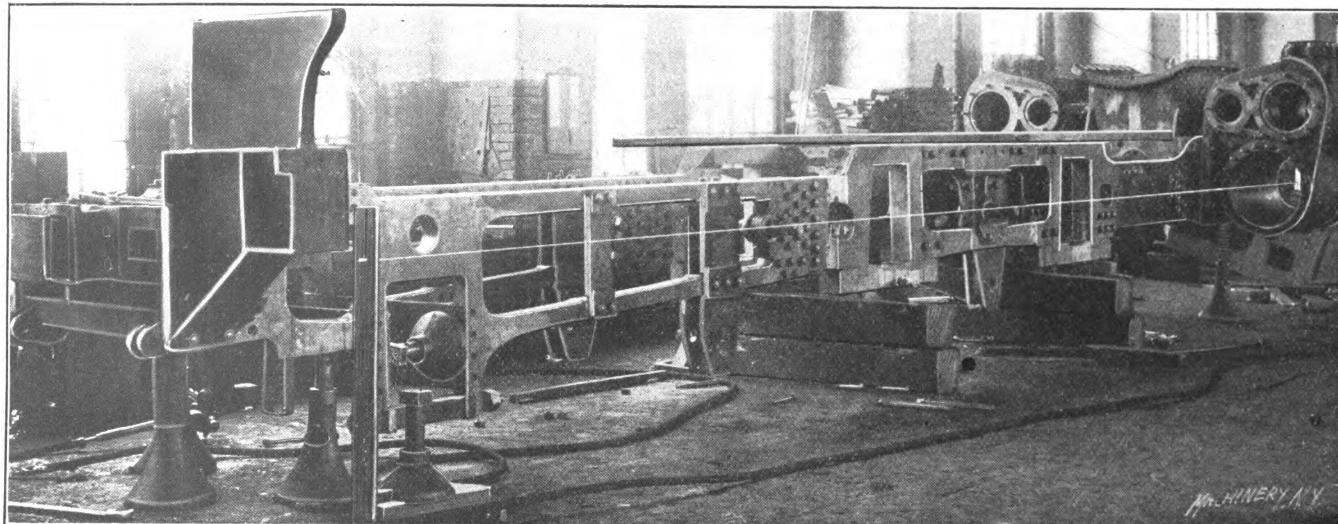

Fig. 8. Lining Up the Frame from the Cylinder Bore

The cylinders have next to be bolted in place. As shown in Fig. 4, the standard practice of the Pennsylvania Lines East is to use three-part cylinder castings, with the frame passing through a mortise in the joints between the saddle and the cylinders. This structure has the great advantage of permitting rapid and inexpensive replacement of cylinders in case of accident. It has been found practicable, for instance, to replace a cracked cylinder from stock and have the engine out on the road again, at work, within ten hours of the time of the accident. This would be impossible with a two-piece cylinder. The standard construction for the Pennsylvania Lines West, however, is a two-piece cylinder with the saddle split at the center line, and with the castings resting on top of the frames, instead of having the latter pass through them, as is the case in other designs frequently met with.

In any event, the cylinder casting and the forward extensions of the frame to which they are bolted, are assembled as a separate unit. The mortises and shoulders on the frame locate the castings, which are forced into place by wedge fits. If the machining is properly done, as it is expected to be in this shop, the cylinders, when bolted into place with the saddle and frames, will be parallel with each other, at the same height and the proper distance apart. When these parts have been assembled and found accurate in these dimensions, they are reamed and bolted together, and dropped into place in front of the frames, which are now in the condition shown in Fig. 5, ready to receive them. The crane lowers them into place, until bolts can

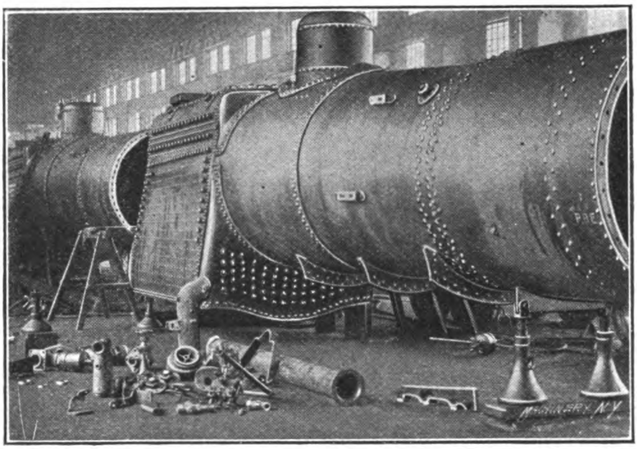

Fig. 9. Boiler and its Fittings ready for the Boiler-mounting Gang

be passed through two mating holes of the frame-splice on each side. The crane hook is then gently raised and lowered until the level shows that the castings are horizontal. The cylinders are then accurately adjusted and supported in this position by the jacks shown in Fig. 6.

Lining Up the Frames and Cylinders

Before finally reaming and bolting the splice in the frame (see Fig. 6) which holds the cylinders in place, the alignment of the whole structure as thus far built must be tested so that it may be jacked up and altered as may be required to bring the center lines of the cylinders into proper relation with each other and with the frame. The first step in this operation consists, as may be seen in Fig. 7, of testing the alignment of the cylinder flanges with the pedestals. A straightedge is passed through the two forward pedestals, resting on two supports of iron, to bring it to the proper height. A measuring bar is used, which is laid on this straightedge and brought up solidly against the face of the flange. The distance from the flange to the straightedge is marked. The same test is then made on the other side. If the measurements do not come the same, it will be necessary to correct the machining on the joint between the frame extension and the cylinders, so as to bring each side of the engine in line with the other.

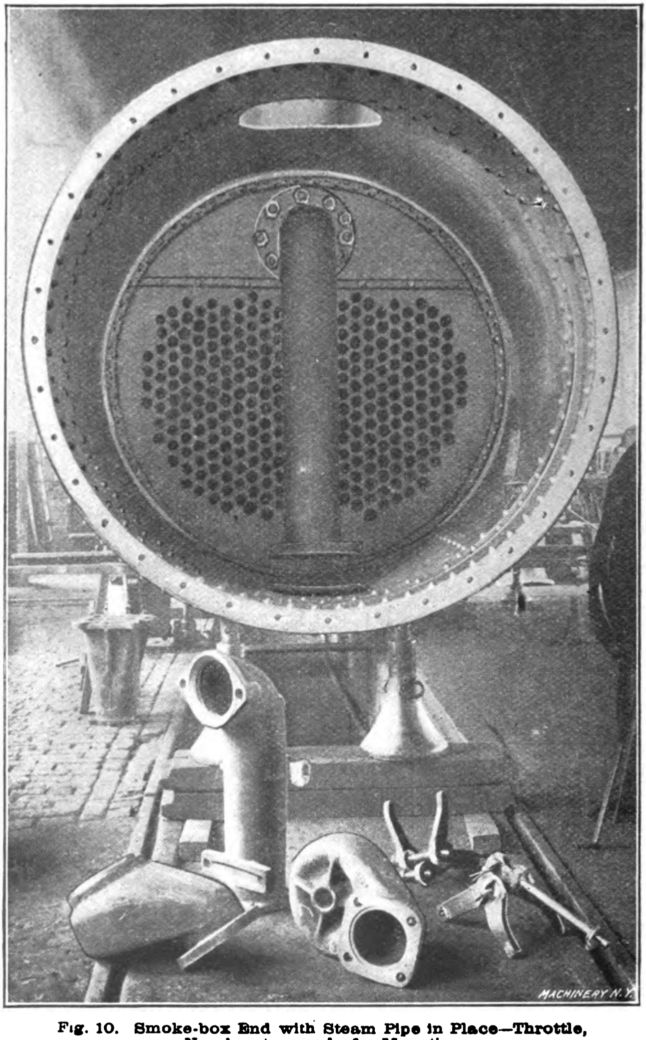

Fig. 10. Smoke-box End with Steam Pipe in Place—Throttle, Nozzle, etc., ready for Mounting

The next lining-up operation consists in stretching lines through the bore of the cylinders, exactly on the center line, and testing the frame by them. This is shown in Fig. 8. The cord is supported at one end by a post mounted on a block of wood, which is anchored by any convenient weight—a heavy jack in this case. At the other end it is supported by a stick clamped in place by one of the flange bolts at the front end of the cylinder, and split to hold the pin to which the string is knotted. Both supports are adjusted up or down and to the right or left, as may be required to get them exactly on the center lines of the cylinder at each end. This is tested by a wire feeler or contact piece of a length slightly less than half the diameter of the cylinder. When one end of this touches the bore of the cylinder at any point, the other end must be just barely able to scrape the stretched line. With the line thus centered at each end of each cylinder bore, the erector proceeds to check up his frame.

In Fig. 8 a straightedge is shown laid across the two frames, ready to take measurements down to the line. This is done at various points along the length of the structure. Sidewise measurements are also taken between the line and the faces of the pedestal bearings, etc., to make sure that the frame is true sidewise. If it were out in any way, it would be sprung in one direction or the other, by jacks, into proper position, where it would be held while the rest of the erection proceeded. The clamping and bolting on of the various cross braces, etc., would then serve to hold it in this corrected shape. After all the parts shown in Fig. 1 have been assembled, the frame, which is now in the condition shown later in Fig. 13, is ready for the erecting gang.

The Boiler Mounting and Testing Gangs

While the work just described has been in progress, the boiler-mounting gang has been busy up toward the center of the shop. The raw materials with which they have to deal are shown in Fig. 9. Their work consists, as may be seen, in putting in the dry pipe, steam pipe, throttle, blow-off cock, and similar parts, shown scattered on the floor at the left of the engraving. Fig. 10 shows the smoke-box end with the steam pipe in place, and with the double-fulcrum type of throttle on the floor ready for mounting.

When the boiler has thus been provided with its main fittings, it is turned over into the hands of the man in charge of the boiler testing. It is located over a pit, as shown in Fig. 11, where connection is made with steam and water pipes, as may be required. The operation is a hydraulic test to a pressure of 256 pounds per square inch, the standard working pressure for the modern locomotives on the line being 205 pounds per square inch. After the satisfactory conclusion of this hydrostatic test, it is put under a steam test of 205 pounds, the two tests together lasting from 10 to 12 hours. The purpose of the steam test is, of course, to note the effect of the heat in conjunction with the pressure, and make sure that the expansion strains thus generated do not open any seams not affected by the cold test.

Insulation and Jacket Gangs

After the testing, the workmen in charge of the insulation and jacketing at once get to work. The magnesia lagging comes in sections which are applied and held on by wires, thin metal straps, etc. These

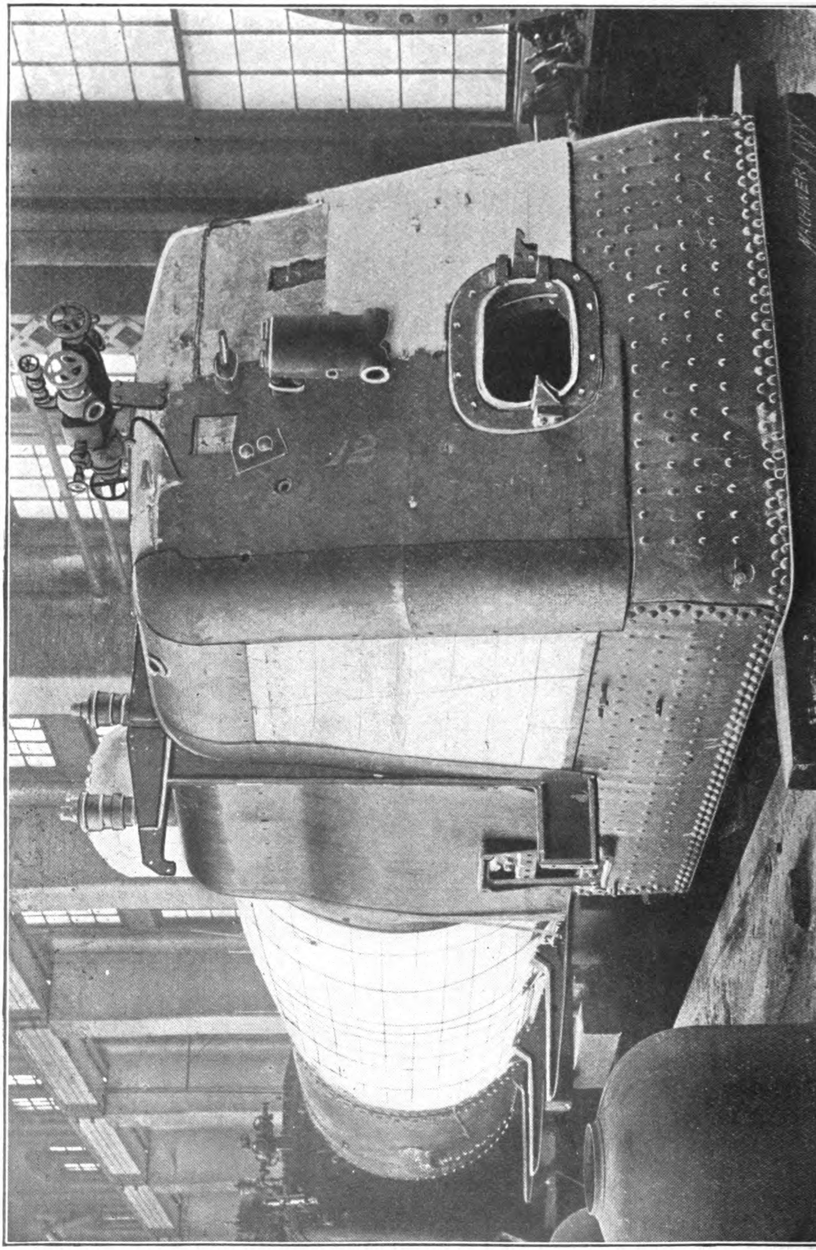

Fig. 11. Jacketing the Boiler

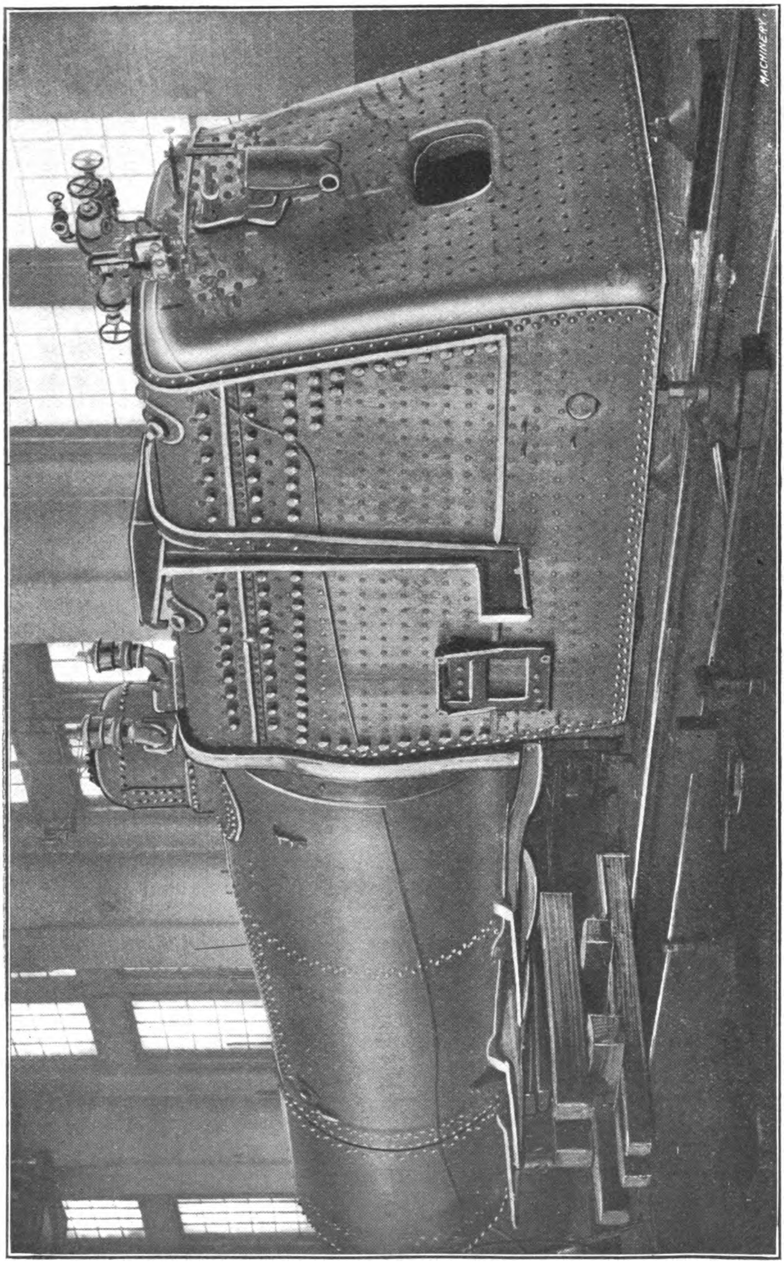

Fig. 12. Insulation in Place and Jackets Fitted

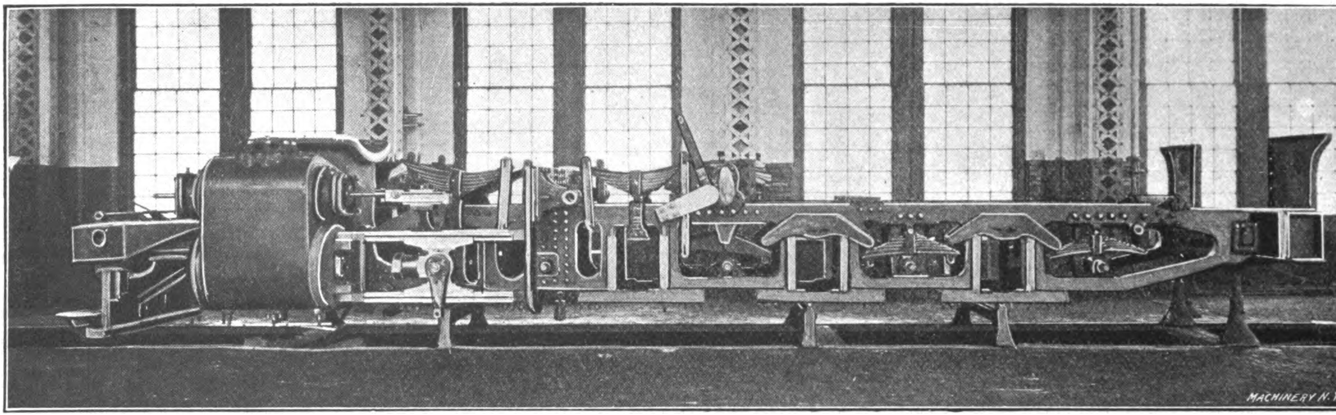

Fig. 13. The Frames and Attached Parts as received by the Erecting Gang

are applied to cover the entire surface of the boiler, with the exception of the smoke box and lower portion of the fire box. The jacket gang then covers the whole with a soft steel jacket. On work of this kind experience and intelligence make a tremendous difference in the rate of progress. It is truly "fussy" work. These gangs begin immediately after the testing of the boiler, and continue their work practically through the rest of the erecting operations, up to the time the engine is run out of the shop. Evidences of their activity are to be seen in Figs. 11 and 12. The succeeding illustrations also show that they sometimes get a little ahead on their work, and sometimes fall a little behind. But it all has to come out even in the end.

The Work of the Erecting Gang

Meanwhile the frame with its attached parts, as set up by the frame gang, has been picked up by the crane and moved over onto the floor on the north side of the shop, and set down on jacks and trestles over the erecting pit, as shown in Fig. 13. The locomotive is supposed to be in the condition here illustrated when the erection gang receives it. Sometimes, however, the frame gang meets with delays, in which case the finishing touches are put on after the job is moved.

The first thing done in the new location is to again carefully level up the frame (the line is still in place in Fig. 15), and test its alignment in all directions with the cylinder bore. This is done both as a check on the previous work, and because mounting it on a new foundation invariably springs the structure to some extent. It will be seen that the trestles are of a special construction, which provides for both longitudinal and vertical adjustment. The use of these special trestles, in connection with the jacks, makes it very easy to bring the frame back into alignment if it is found to be out in any direction.

One of the next operations is that of marking off and fitting the shoes and wedges for the pedestal bearings. For this work the shoes and wedges are mounted in place as seen in Fig. 14, and firmly held there

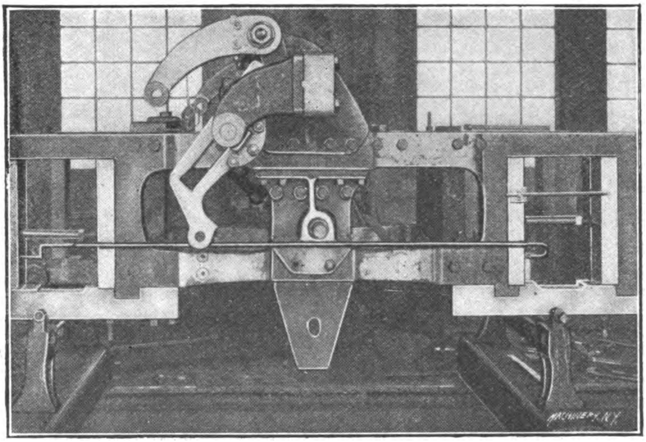

Fig. 14. Testing the Pedestal Bearing Spacing and Marking off the Shoe and Wedge Fits

by the simple screw jacks shown. The shoe is left with a slight amount for finish, and it is the face of the shoe that has to be machined to give the desired fit for the driving boxes. For marking the amount to be removed, a scratch gage is employed, as shown; the block for this gage has a ledge, which guides it along the inner surface of the shoe while the scribing point is set to the required dimension from the face of the ledge; this marks the finish line on the shoe. The shoes are then taken to the planer and finished down to the line. This operation is necessary, because of the difficulty of getting the required closeness of fit by machining taper parts like the wedge and the tapered jaw of the pedestal to exact dimensions.

Fig. 14 also shows one of the inspecting operations performed by the erection gang. As shown, a fixed gage is being applied to test the distance between the faces of the shoes of two adjoining pedestals. This measurement must show accuracy to within the distance of one or two "pieces of paper" at the most—that is to say, within about 0.010 inch.

This accuracy is necessary, of course, both for the proper working of the side rods (which are bored to the same accuracy in length), and for the proper location of all the various parts of the valve mechanism, etc., the position of which is determined by measurements from the main bearings.

Fitting the Boiler

While this has been going on, another sub-division of the erecting gang has been fitting the boiler into place. In Fig 15 the boiler is shown dropped into place by the crane. It rests on the sadde at one end, and on the expansion pads at the rear end of the frame at the other. A chalk line has previously been drawn along the center line of the locomotive. This is leveled up by wedging the rear end of the boiler

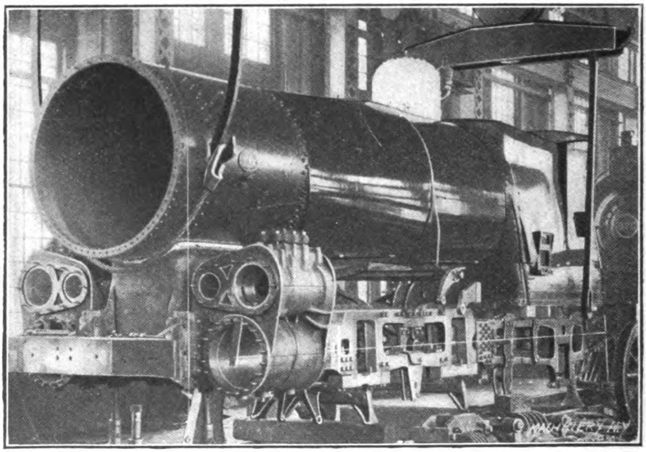

Fig. 15. Trying the Boiler in Place for the Saddle Fit

to the proper height. The boiler is, of course, also centered on the frames. This is done at the rear end by taking measurements from the outside of the boiler at the fire box to the side of the frames on both sides At the front end the measurements are taken by a double plumb line, shown dimly in the engraving, hung over the front of the smoke box, from which measurements are also taken to the front ends of the frames. The boiler is wedged over one side or the other in the saddle fit to center it at the front, if this is necessary. At the same time the mud ring is tested with a level to make sure that the boiler is not placed out of the vertical at one side or the other. The boiler being thus accurately set, the flange of the saddle is heavily chalked, and a line is drawn with a scratch gage far enough away from the surface of the boiler to just finish out clear around the whole flange.

Note is taken of this measurement. If this finished line is 3/8 inch from the boiler, for instance, it is evident that the fire box will be 3/8 inch nearer the frames when the saddle is finished down to its bearing. The four expansion pads or bearings on which the boiler rests at the

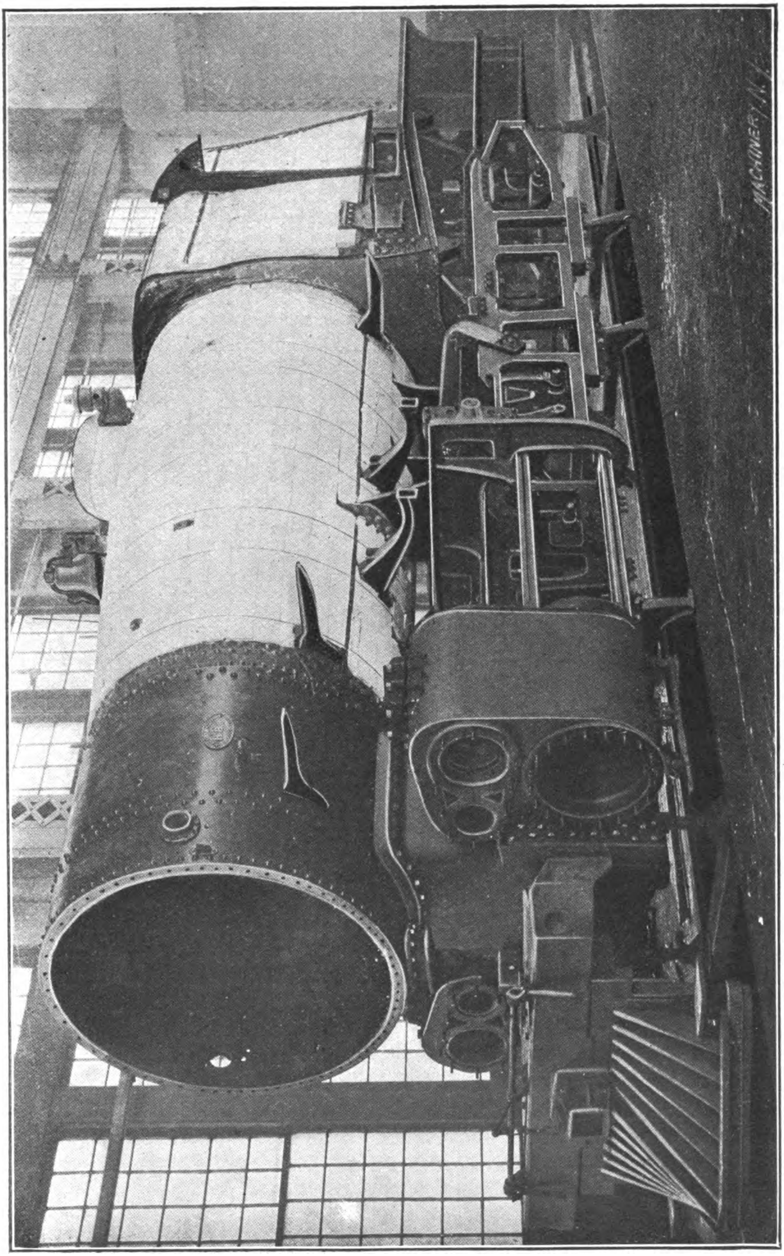

Fig. 16. The Boiler Mounted on the Frame

fire box end, are therefore marked to finish out to a dimension ⅜ inch less than that given by the position of the boiler in this trial setting. The holes for the side saddle bolts are also marked through onto the boiler at this time, after which it is again lifted off the frames.

Three or four men with pneumatic hammers now get to work on the job of bringing down the saddle to the proper bearing. Canvas curtains or screens are set up on the saddle, so that the chips made by one operator will not fly into the eyes of another. Many hands make light work on this job, so that by the time the bolt holes are drilled in the boiler and the expansion pads have been planed off to the proper height, this work of chipping and fitting is done.

The boiler is now permanently mounted in place on the frame, as shown in Fig. 16. The steel sheet which is bolted to the guide yoke and

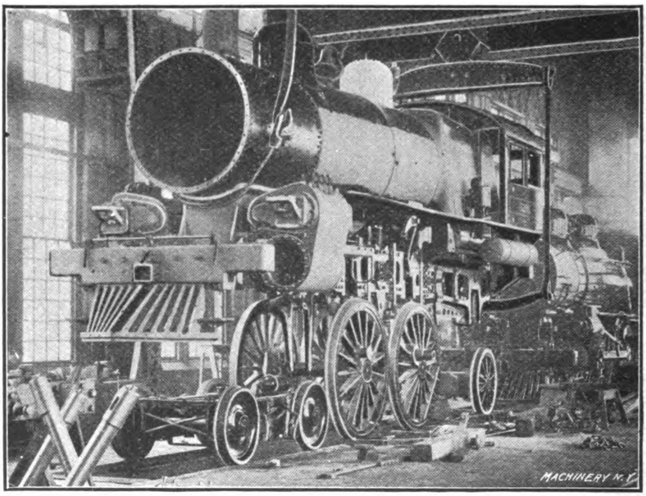

Fig. 17. Lifting the Locomotive onto the Wheels

supports the boiler at the center is now marked off, drilled, and fitted into place. The bolting of the boiler to the saddle and to this central support, and the clamping in place of the expansion pads, now definitely lines up the frame and holds it firmly in the position in which it was set onto the trestles and jacks. The rigidity of the boiler is added to that of the frame, making a stiff, true structure of the whole.

While the operations just described have been going on, the crane has been bringing down the truck, drivers and trailer (if the locomotive is to have a trailer). The crane now picks up the boiler and its attached frame; the truck, drivers and trailer are rolled into place under it, and accurately located, and the engine is gently dropped onto its wheels. This operation is shown in Fig. 17.

Setting Up the Valve Motion

The locomotive is now ready for the assembling of the main and side rods, and of the valve gear. For this the machine work has all been done, the holes have all been drilled, and nothing remains save to put the parts in place and bolt them together. Absolute dependence is placed on the accuracy of the machining operations, and in the checking up of the frame and cylinder measurements as shown in Figs. 7, 8, and 14. Accuracy in the measurement of all the parts concerned is an absolute necessity for the proper building of locomotives with the Walschaerts valve gear, as this type of motion does not lend itself to the changes and corrections which are easily possible with the Stephenson link motion. As this accuracy, however, is a good thing in itself, in the way of shortening the time and expense of fitting and erection all along the line, it should be undertaken on any locomotive and with any type of valve gear. It is a paying practice from every standpoint.

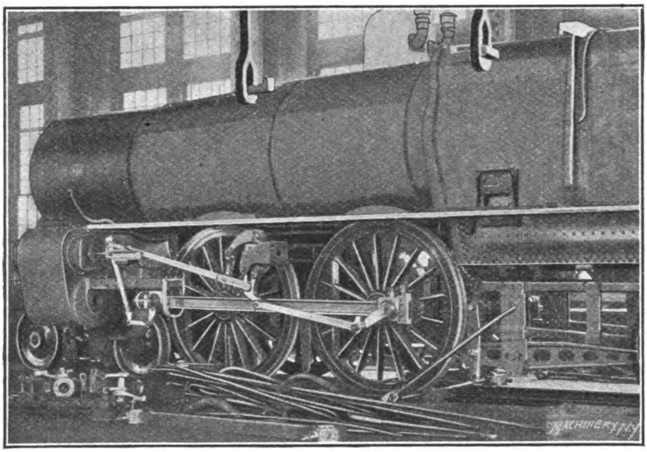

Fig. 18. The Locomotive with Rods in Place ready for the Valve-setting Gang. Note Pile of Pipe in Foreground for the Pipe-fitting Gang

A locomotive with the valve gear assembled is shown in Fig. 18. About the only fitting which it is expected to find necessary, relates to the valve stem guide (see *T*, Fig. 20), which may have to be lined up a little to bring it accurately in line with the valve stem. There may also be an interference of the radius rod *R* with the valve-stem slide *O*, or with the yokes which support the pivots of the link *D*. Barring these interferences, which can be removed by a little chipping, the whole mechanism should go together with perfect freedom and with the proper amount of play.

Tramming for the Dead Centers

Valve setting with the Walschaerts gear is, as explained, a much simpler matter than with the Stephenson gear, since there is less leeway left for the workman in the way of adjustments. The first thing to do, as with any form of valve gear, is to locate the dead center points. This is done by the method shown in Fig. 19. First, the main driving axle is provided with an accurate center, as explained on page 27 of MACHINERY's Reference Series No. 80, "Locomotive Building, Part II, Wheels, Axles and Driving Boxes." From this center an arc is struck on the side of the tire as shown at *a-a*. For this work the driving wheel has been mounted on the regular roller supports *X* operated by a ratchet wrench and long lever, as shown also in Fig. 18.

The wheel is now turned until the cross-head is within a quarter of an inch or so of the end of the stroke. Here, by means of a tram *g*, a line is drawn on the side of the cross-head to mark the position. At the same time by means of a longer tram *h* a line *b* is marked across the arc on the tire of the driving wheel, the setting being taken from any convenient point *f* on the frame or other stationary member. The wheel is now turned past the center a little ways, and then reversed and again moved toward the center. This is done to take up the backlash or play. When tram *g* shows that it is again at the same distance from the end of its stroke as before, tram *h* is used to mark a new

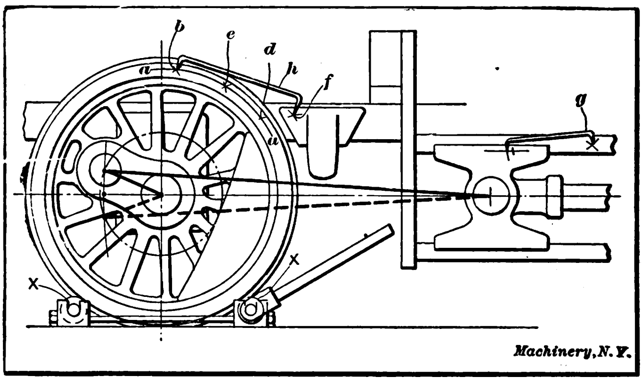

Fig. 19. Tramming the Wheels to Find Dead Center

line *d*, being set at the same point on the frame as before. With the dividers, the distance between *b* and *d* on the tire is now halved, and this point is marked at *e* with the prick-punch. The main driver is again rotated by means of the roller mounting and ratchet wrench, until the tram *h* lines up with points *e* and *f*, when the engine is evidently on the dead center. This operation is repeated at the other end of the stroke, and also for the cylinder on the other side, so that either side may be set to either dead center.

Marking the Admission Points

The Walschaerts gear for an Atlantic-type locomotive is shown in two positions in Figs. 20 and 21. In the first case the piston *P* is at mid-stroke, with the reserve lever and arm *G* set on the center. In the second case the piston is at dead center, and the reverse lever is set at the extreme end of the quadrant on the forward motion. The operator in charge of the valve setting has to check up the gear to make sure that the lead is approximately constant for both valves at each end of the valve for all positions of the reverse lever. He investigates this by marking the lead on valve-rod cross-head *O*, as will now be explained.

He begins by scribing on valve-rod cross-head *O* the admission points of the valve—that is, the points at which the valve is just beginning to let steam into the cylinder. To do this, as shown in Fig. 22, the lead lever *L* and radius rod *R* have to be disconnected so that valve *V* can be moved back and forth freely. A horizontal line is then drawn on the face of valve-stem cross-head *O* with a scriber and rule. Each end of the valve chest is provided with inspection holes, as shown.

Fig. 22 shows the operation of finding the admission point at the left-hand port. Valve *V* is gently tapped into a position where the feeler shown, which is made of very thin metal, will just begin to enter between the edge of the port and the edge of the valve ring. This point can be seen by means of the lamp and mirror provided, which send the light down into the port. When this position has been found by feeling and sight, a tram, as shown, is set into a center point in a button permanently mounted on the valve chest end for the purpose, and a line is scribed across the horizontal line on the face of the valve-stem cross-head. The valve is now moved to the right, to the other end of the stroke, and the feeler, mirror and lamp are used in the same way to determine the admission point at the front end of the cylinder. This point is also scribed on the valve-stem cross-head in the same way.

The valve gear is now connected up again, and the engine is set on one of the dead center points, determined by the process previously shown in Fig. 19. This will bring the mechanism into the position shown in Fig. 21. The scriber is next applied in the same way as in Fig. 22, cutting a mark across the horizontal line on valve-stem cross-head *O*. Next, the reverse lever is thrown clear over and a second line scribed on *O*. Then the engine is returned to the opposite dead center, as indicated by the tire marks just made, and a third line scribed on *O*. Finally the reverse lever is thrown clear back, and a fourth line is scribed.

The Significance of the Valve Setting Marks

Now, if everything is all right, the lines thus drawn will appear as shown at Case No. 1 in Fig. 23. Here the two inner short cross lines were drawn by the method shown in Fig. 22, and show the points of admission, while the longer lines outside of them show the positions of the valve at the dead center points. The distance between the short and long lines on each side is evidently the amount of lead at each end of the stroke, which should be equal. Also, the lines drawn for the forward motion and for the backward motion should coincide, as shown, making one lead line, showing that the lead is equal for both full forward and full back motion.

It is more likely, however, that the marks will appear as in Case No. 2. That is, it will indicate more lead at one end of the stroke than at the other. If that is the case, it is necessary to lengthen or shorten the valve rod, as conditions may require, so as to equalize the lead at both ends of the stroke. The usual practice is to provide a threaded adjustment by means of which this change may be quickly made. The

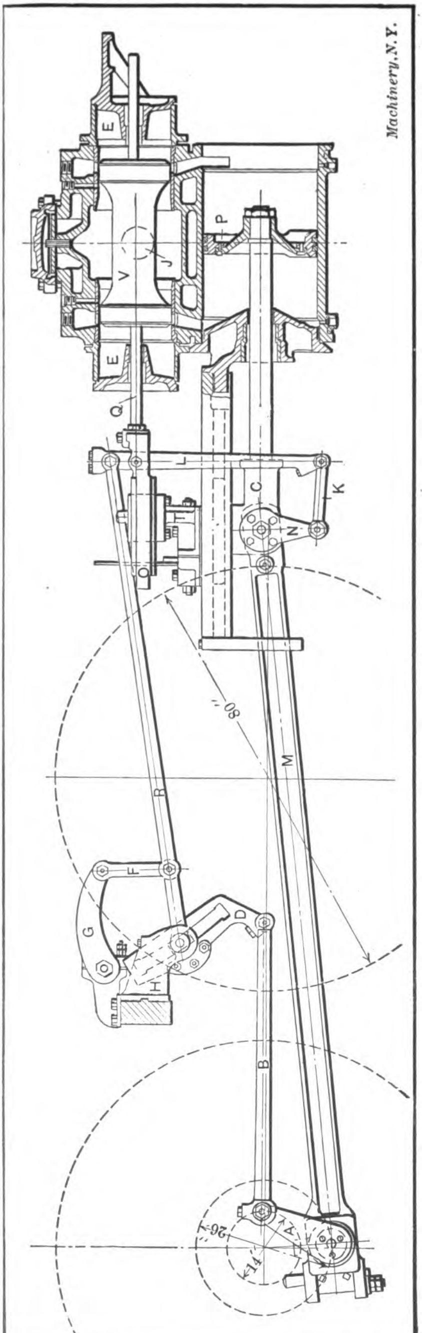

Fig. 20. Section showing Cylinder and Walschaerts Valve Gear as used on Atlantic-type Passenger Locomotive with Inside Admission Piston Valve

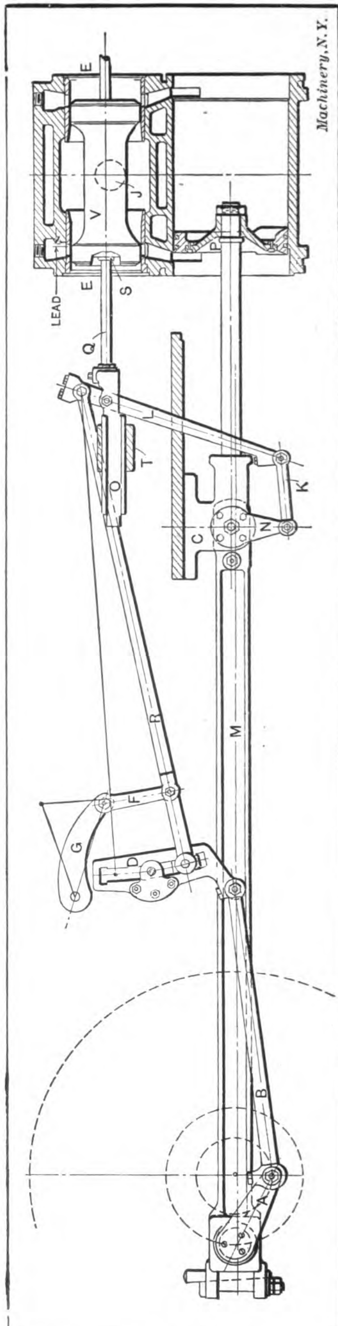

Fig. 21. Walschaerts Valve Gear with Engine on Dead Center, showing Function of Lead-lever L

practice of the Pennsylvania road is to leave stock for fitting at shoulder *S* on the valve rod (see Fig. 21) and adjust the position of the valve on the rod by facing off this shoulder, or by putting in washers if that is required. The adjustment thus made is permanent. This policy is followed with the idea of setting the valve as it should be set, in the shop, and not leaving any leeway for changes by engine men on the road. It is thought best to take the matter of valve gear adjustment out of the hands of the engine men entirely, as it should be made right in the first place and should then stay right.

Now, in both Cases 1 and 2, the marks come the same for both forward and backward motion. This is as it should be, but they do not usually coincide exactly. For instance, Case 3 may be met with; here the lead is long for the forward motion and short for the backward at the front admission, and *vice versa* for the back admission. A little study of Fig. 21 will show the cause of this. Now in order to have the leads the same for both the forward motion and the backward motion, it is evident that, when the engine is on dead center as shown, it should be possible to swing the reverse lever from one end of the quadrant to the other without changing the lead; and to make this possible it is evident that the arc-shaped slot in link *D*, when the engine is thus set, must be accurately struck from the center of the pivot by which radius rod *R* is connected with lead lever *L*.

Now, in erecting the locomotive, if bracket *H* (see Fig. 20), which supports link *D*, is set too far forward or too far back, it is evident that link *D* will be tipped forward or back to correspond, throwing the center of its slot below or above the proper point at the pivot of the radius rod. Then the operation of the reverse lever will move the valve, giving a variable lead. If this mistake in the location of the links supporting the bracket has been made, about the only way out of the difficulty is to lengthen or shorten the return crank rod *B*, so as to again tip the link back to its proper neutral position. A study of the diagrams for Cases 3 and 4, in connection with Fig. 21, will show why the rod should be lengthened for one case and shortened for the other.

Now it is possible that, instead of having the marks come as in Cases 3 and 4, they will come as in Cases 5 and 6. That is, the lead will be too great at both ends of the forward motion, and too small at both ends of the backward motion, or *vice versa*. In a case of this sort it is evident that something else is at fault besides the position of link bracked *H*, or the length of return crank rod *B*. A difficulty of this kind is almost certain to be caused by the wrong location of return crank *A* on the crank-pin. In fastening it in place it is either swung too far forward or too far backward, as the case may be. If it is swung too far forward it is evident from Fig. 21 that the lead will be reduced on the forward motion at each end of the stroke, the gear being there shown in the forward position. If the reverse lever is thrown over and the radius rod *R* lifted to the upper end of link *D* for the backward motion, it is evident that, since we are on the other side of the center of the link, the lead will be increased at each end. This gives us Case 6. This can only be remedied by re-locating return crank *A* in the proper position, which must evidently be done by swinging it backward as much as may be required. An adjustment in the opposite direction must, of course, be taken for Case 5.

An examination of Figs. 20 and 21 shows plainly that the action of lead lever *L*, through its connection by link *K* and bracket *N* with cross-head *C*, must be relied upon entirely for obtaining the lead. The difficulties shown in Cases 3, 4, 5 and 6 arise from the fact that the connections through the return crank *A* and rod *B* are allowed to influence the lead, when they should not. In the position shown in Fig. 20 with the reverse lever on the center, the action of the return crank is entirely cut out; here the motion of the cross-head *C* will evidently give the normal lead to the valve. With the engine on dead center as shown in Fig. 21, swinging the reverse lever through the whole of its throw, and raising radius rod *R* from bottom to top of the link, should not move the valve, since the center of the slot should be con-

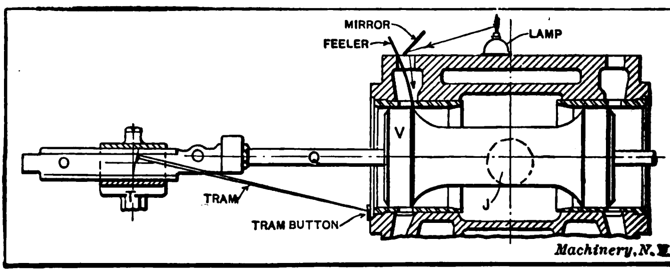

Fig. 22. Marking the Admission Points on the Valve-rod Cross-head

centric with the pivot between *R* and *L*. It should, in fact, allow the same lead as for Fig. 20. All the difficulties met with come from the fact that, either owing to the improper position of bracket *H* or of return crank *A*, the link is not so set that radius rod *R* can be thrown from one end to the other without altering the lead.

It is expected, of course, that before all the separate parts making up the valve motion come to the erecting shop, they shall have been inspected and found to be true to dimensions. It is also expected that the valve gear shall have been properly designed in the first place. With these two conditions looked out for, as they invariably are, the erecting shop's responsibility lies in the position of return crank *A* and the location of bracket *H*, and in getting the proper length of valve rod *L*. It is expected that the erecting gang will work close enough so that Cases 3, 4, 5 and 6 shall not appear in any engine bad enough to require alterations to be made. If changes of this kind are necessary, the case is one which requires investigation on the part of the foreman to locate the workman who has been at fault.

The diagram in Fig. 23 is correct for the right-hand side of the locomotive, with a piston valve giving inside admission. For the left-hand side, the diagram should be reversed, as though it were seen in a mirror. After studying the drawings the student will be able to make his own diagrams for engines having outside admission—a condition sometimes met with in practice where the Walschaerts gear has been applied to a slide valve.

The six cases shown will seldom be found in the unmixed form; the valve setter is more likely to find a mixture of Cases 3 and 5, for in-

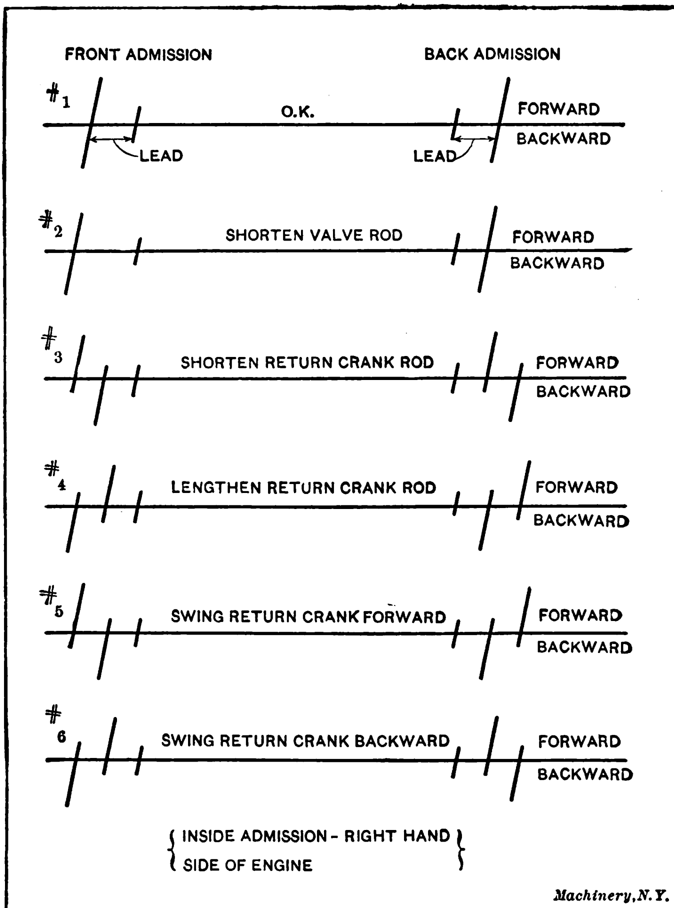

Fig. 23. Diagram showing Significance of Variations in Lead, as given by Admission and Dead Center Lines on the Valve-rod Cross-head

stance, or of Cases 2, 3 and 6. Where these mixed errors are serious, he should adjust one factor at a time, beginning with the correction of the length of the valve rod. At the Juniata shops a permanent record is kept of the amount of lead at each end of the stroke on both sides of each engine turned out. This is done for a number of positions of the reverse lever, from the neutral position to full motion in each direction. These reports are marked with the valve setter's name, and are kept for reference in case of complaint as to the running of the locomotive in service.

Miscellaneous Finishing Operations

Subdivisions of the erecting gang have been at work on various parts of the machine while the special operations described in the previous paragraphs have been in progress. The stack has been put in place, the bell has been mounted, the cab has been fitted, the brakes have been connected up, and the air pump mounted. The jacket gang has finished the fitting of the jacketing on the boiler and also on the cylinders and valve chest. The men on these various gangs have been swarming all over the locomotive together, and it requires a real "team spirit" for them to work effectively and still keep out of each other's way. Good work in erecting under conditions of this kind requires the maintenance of the proper feeling of the men toward each other, and toward the job on which they are engaged. If they do not have this feeling, the time required will be double that in which it ought to be done, or even longer.

One of the gangs whose work should be mentioned in particular, is the pipe gang. These men are a sub-division of the boiler-shop force, not being directly under the control of the erecting shop foreman. An interesting feature of their work is the fact that all the piping used about the locomotive is cut to length and bent to shape before being brought to the locomotive. This means that good work is done, not only in building the boiler correctly to the drawing, but also in locating the various connection holes, and in the actual work of cutting and bending the pipe. The resulting arrangement of piping work at the boiler end in the cab is very pleasing indeed, in its general appearance. This is shown in Fig. 24. The picture was a difficult one to get, owing to the abundance of black paint and shadows, but it illustrates the high character of the work done. On the floor in front of Fig. 18 is shown a pile of cut, bent and threaded pipes as they come from the boiler shop, ready for piping.

Another point of interest that may be mentioned is the method of locating the gage cocks. Their function, of course, is to determine the depth of the water over the crown sheet. The holes for these cocks might be located by measurements from the drawings, but to be on the safe side it is the practice here to actually take the measurements from the crown sheet itself. This is done in two ways, which are used to check up each other. A straightedge, carefully leveled up, is run in through the fire door, and a measurement is made from that to the crown sheet on the inside. A line is then drawn on the face of the boiler at the same height on the outside. This is used as the datum line for locating the gage cocks.

To check up this datum line, a hydrostatic device is used. A rubber tube is carried into the fire box, with its end held up against the under side of the crown sheet. A glass tube is inserted in its outer end at about the level of the crown sheet, and water is poured in until it commences to run out on the inside from the open end. The height of the water in the glass tube then locates the height of the end of the pipe on the inside, and thus the height of the crown sheet.

Results in Erection Work

It may be interesting to give some figures as to the number of men in the various gangs required for the normal output of one locomotive

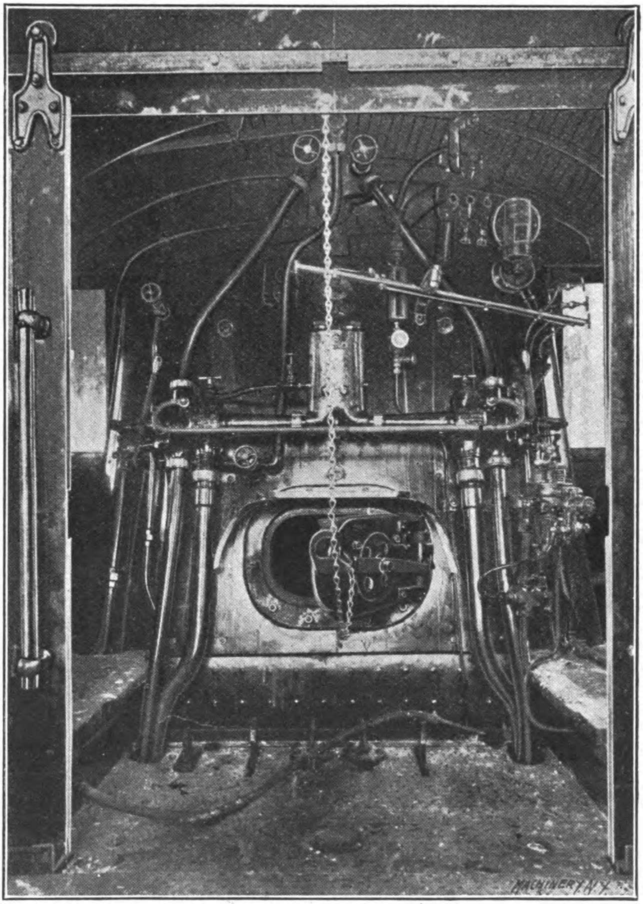

Fig. 24. View into Cab of Locomotive, showing Neat Arrangement of the Piping, Valves, Injector, etc.

per day, and also to give some notion of the length of time required for the various processes of erection. The frame gang is composed of 48 men, and it spends about 27 working hours on the frame of a heavy locomotive. Not all of them, of course, are working on the same frame at the same time, but each engine is in the hands of the frame gang for the length of time indicated. The boiler-mounting gang com-

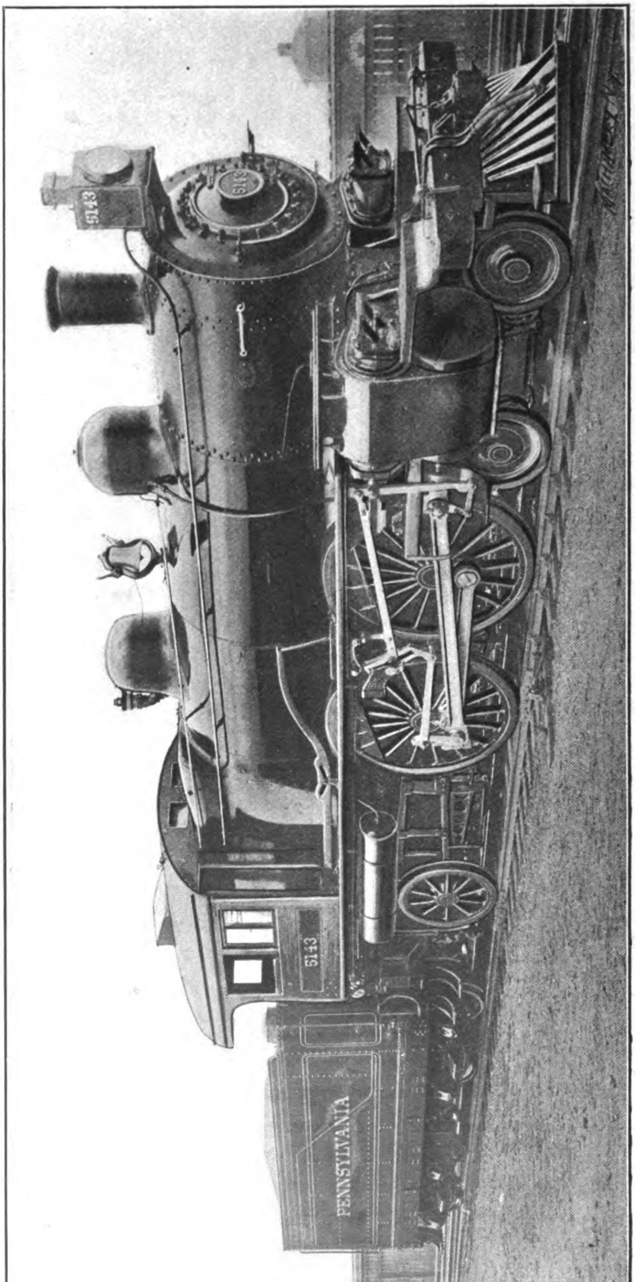

Fig. 25. Completed Passenger Locomotive of the Standard Atlantic Type, used on Regular Pennsylvania Express Train Service

prises 37 men, and the boiler stays in their hands for about 29 hours. The erecting gang is composed of 37 men, and the locomtive is in their hands for about 33 hours. The work of all these gangs overlaps, as explained; and there are besides these the miscelleaneous workmen such as the sheet-iron workers, pipe fitters, painters, etc. The quick work which these figures indicate is only made possible by accuracy in the machine shop operations, and by good organization on the part of the erecting force.

The rate of erection appears, to a person not acquainted with locomotive building practice, to be of almost bewildering rapidity. The machine-tool machinist is likely to think of a locomtive as being built rather slowly, something like a house. The writer had still some remnants of this idea left on his first visit to the shop. He had watched for a few hours the progress of a locomotive which was approaching completion. At the suggestion of the erection foreman he had climbed up into the cab, to examine the piping arrangements and other features to be seen there. What was his amazement, after a few minutes' conversation, to be approached by one of the workmen with an invitation to vacate, as he desired to run the engine out into the yard. The writer then realized for the first time that they had been getting up steam meanwhile from a stationary boiler, and that a touch on the reverse lever and the throttle was all that the big engine needed to get itself under way. The last finishing touches of the painters were put on as the locomotive rolled out into the yard.

That same evening, the writer saw the new machine going by, pushing away at the back end of a long freight-train which was starting on its twelve-mile struggle up the grade to the summit tunnel at Gallitzin. The long preliminary "workouts" which used to be considered necessary are not the regular practice here. The locomotive is expected to be built well enough to go into pusher service, at least, directly from the start. Practically all of them are subjected to this severe test.

It may be interesting to know that in the case of the consolidation locomotive which is illustrated in some of the photographs here used, 23,734 separate pieces in all are required for the whole machine. The number is probably somewhat less for the standard Atlantic-type locomotive from which the other illustrations were taken. This latter engine is shown complete, ready for the road, in Fig. 25.

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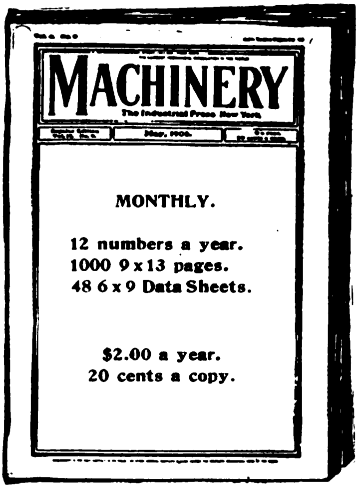

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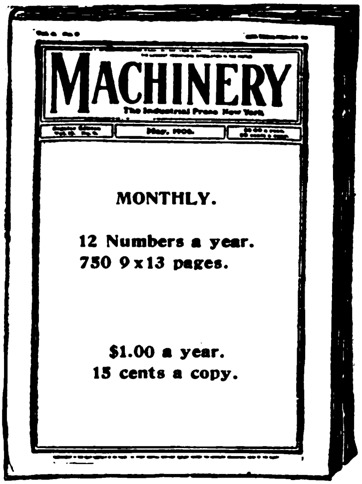

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No. 9. Springs, Slides and Machine Details.—Formulas and Tables for Spring Calculations; Machine Slides; Machine Handles and Levers; Collars; Hand Wheels; Pins and Cotters; Turn-buckles, etc.

No. 10. Motor Drive, Speeds and Feeds, Change Gearing, and Boring Bars.—Power required for Machine Tools; Cutting Speeds and Feeds for Carbon and High-speed Steel; Screw Machine Speeds and Feeds; Heat Treatment of High-speed Steel Tools; Taper Turning; Change Gearing for the Lathe; Boring Bars and Tools, etc.

No. 11. Milling Machine Indexing, Clamping Devices and Planer Jacks.—Tables for Milling Machine Indexing; Change Gears for Milling Spirals; Angles for setting Indexing Head when Milling Clutches; Jig Clamping Devices; Straps and Clamps; Planer Jacks.

No. 12. Pipe and Pipe Fittings.—Pipe Threads and Gages; Cast-iron Fittings; Bronze Fittings; Pipe Flanges; Pipe Bends; Pipe Clamps and Hangers; Dimensions of Pipe for Various Services, etc.

No. 13. Boilers and Chimneys.—Flue Spacing and Bracing for Boilers; Strength of Boiler Joints; Riveting; Boiler Setting; Chimneys.

No. 14. Locomotive and Railway Data.—Locomotive Boilers; Bearing Pressures for Locomotive Journals; Locomotive Classifications; Rail Sections; Frogs, Switches and Cross-overs; Tires; Tractive Force; Inertia of Trains; Brake Levers; Brake Rods, etc.

No. 15. Steam and Gas Engines.—Saturated Steam; Steam Pipe Sizes; Steam Engine Design; Volume of Cylinders; Stuffiing Boxes; Setting Corliss Engine Valve Gears; Condenser and Air Pump Data; Horsepower of Gasoline Engines; Automobile Engine Crankshafts, etc.

No. 16. Mathematical Tables.—Squares of Mixed Numbers; Functions of Fractions; Circumference and Diameters of Circles; Tables for Spacing off Circles; Solution of Triangles; Formulas for Solving Regular Polygons; Geometrical Progression, etc.

No. 17. Mechanics and Strength of Materials.—Work; Energy; Centrifugal Force; Center of Gravity; Motion; Friction; Pendulum; Falling Bodies; Strength of Materials; Strength of Flat Plates; Ratio of Outside and Inside Radii of Thick Cylinders, etc.

No. 18. Beam Formulas and Structural Design.—Beam Formulas; Sectional Moduli of Structural Shapes; Beam Charts; Net Areas of Structural Angles; Rivet Spacing; Splices for Channels and I-beams; Stresses in Roof Trusses, etc.

No. 19. Belt, Rope and Chain Drives.—Dimensions of Pulleys; Weights of Pulleys; Horsepower of Belting; Belt Velocity; Angular Belt Drives; Horsepower transmitted by Ropes; Sheaves for Rope Drive; Bending Stresses in Wire Ropes; Sprockets for Link Chains; Formulas and Tables for Various Classes of Driving Chain.

No. 20. Wiring Diagrams, Heating and Ventilation, and Miscellaneous Tables.—Typical Motor Wiring Diagrams; Resistance of Round Copper Wire; Rubber Covered Cables; Current Densities for Various Contacts and Materials; Centrifugal Fan and Blower Capacities; Hot Water Main Capacities; Miscellaneous Tables: Decimal Equivalents, Metric Conversion Tables, Weights and Specific Gravity of Metals, Weights of Fillets, Drafting-room Conventions, etc.