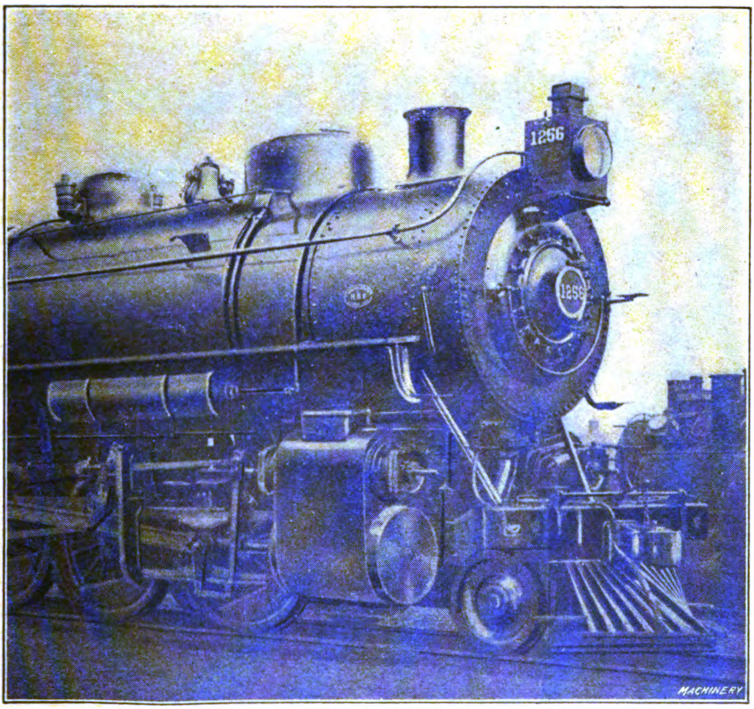
PRICE 25 CENTS

LOCOMOTIVE BUILDING

BY RALPH E. FLANDERS

WHEELS, AXLES AND DRIVING BOXES

SECOND EDITION



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NUMBER 80

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SECOND EDITION

PART II

WHEELS, AXLES AND DRIVING BOXES

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CHAPTER I

WHEEL AND AXLE WORK

In MACHINERY'S Reference Series No. 79, "Locomotive Building—Part I," were described, step by step, the operations followed in making the main and side rods of a consolidation freight locomotive. In the following the same consecutive method will be followed in describing the machine shop work on the axles, wheels, centers, tires and crankpins, in the Juniata Shops of the Pennsylvania Railroad at Altoona, Pa. The finished product resulting from these operations is shown in Fig. 33, which illustrates the main driving wheels and axle of a new design of exceedingly heavy passenger locomotive, recently built. These are 80-inch wheels, the largest now used in regular pas-

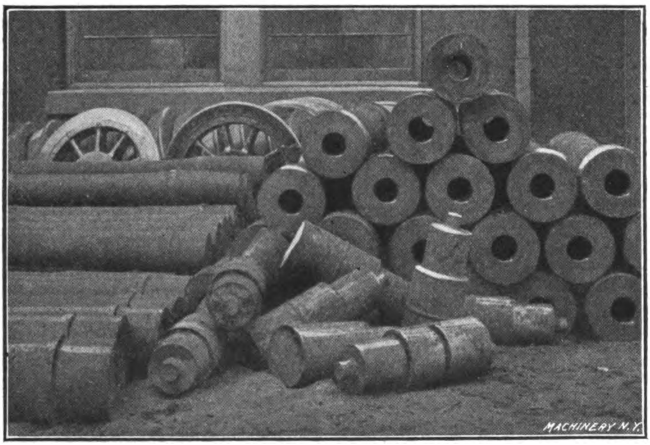

Fig. 1. Raw Material for the Wheel and Axle Work

senger service. The locomotive, being of the Pacific type, requires three driving axles in all.

In Fig. 1 is shown a stock pile of forgings and steel castings in the yard outside the shop, from which the finished work in Fig. 33 is built up. The axles and pins are forged from nickel steel. The tires are made by the circular rolling process, and are received at the shops rough. The wheel centers are steel castings.

The Main Axles—Drilling and Inspecting Holes

Fig. 2 is a drawing of the driving axles of the K-2 Pacific type locomotive, giving the principal dimensions. As shown and as seen also in the axles in the pile at the right of Fig. 1, holes are drilled clear through the axle centers, the diameter of the hole being 2 inches in this case. The purpose of this hole is simply to permit inspection of the interior of the forging. If there is a defect in an axle forging anywhere, it may be expected at the center, where seams due to piping and other troubles would surely be found if they were present at all. By examining the interior surface with an electric light mounted on a long rod and provided with a reflector, it is possible to be assured that each one of the thousands of driving axles used on the locomo-

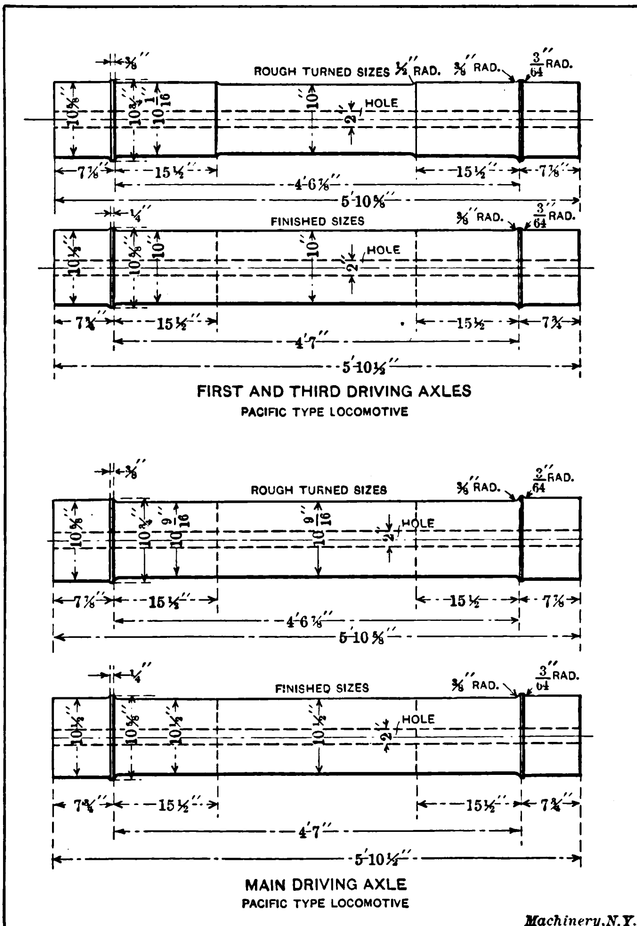

Fig. 2. Rough and Finished Turned Dimensions for Driving Axles

tives of the Pennsylvania system is flawless and homogeneous. This is a form of insurance which is rather expensive, but it is exceedingly effective.

Two forms of axle boring lathes are shown in Figs. 3 and 4, the first of these being the older design. In this machine, as shown, a hollow spindle is used, large enough to take the work in bodily. This is grasped by a chuck at the front end, and is centered and supported at the rear end on the points of three set-screws, so that it runs practically true. The drill itself is stationary, being grasped in a clamp bushing on a special carriage. The supporting bushing guides the drill close up to the work, starting it truly and keeping it in line until the end of the operation, thus assisting in keeping the hole concentric. The reason for revolving the work instead of the drill is, of course, that the hole can be kept concentric with the work when this is done. If the work were stationary while the drill only revolved, the chances are that the hole would run away out from the center line of the work, especially if it should meet a flaw or a hard spot in the metal.*

Now while it is necessary to revolve the work, it is evident that this involves constructional difficulties in the lathe itself. The spindle

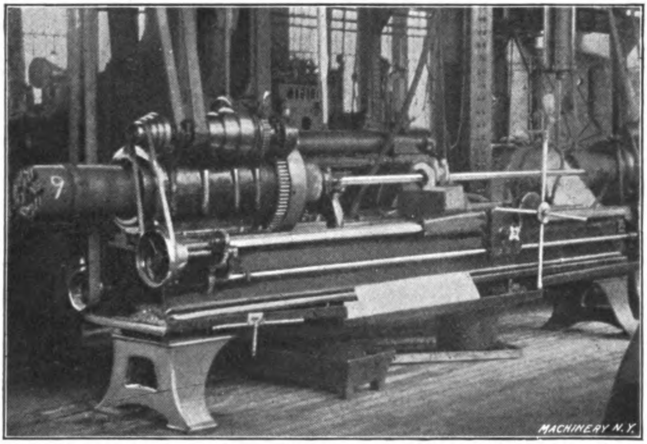

Fig. 3. Drilling the Test Holes in the Axle Forgings

shown in Fig. 3 has to be of a very large diameter, and must be run at very high speed if it is to allow a modern inserted blade drill to operate to the best advantage. To overcome the necessity for revolving a large spindle at high speed, the improved form of axle boring lathe shown in Fig. 4 was developed. Here the spindle is of ordinary proportions, the work being held at one end in the chuck while it is centered and grasped at the other in a revolving holder of the "cathead" type. This simplifies the problem by reducing the spindle diameter. Still further benefit is derived by revolving the drill itself at a high rate of speed instead of having it stationary as in Fig. 3. The work is also revolved, but all the beneficial results in the way of truing up the hole, can be obtained if the rate of revolution is quite slow. In the case shown, for a two-inch hole, the axle revolves at 15 revolutions per minute, and the drill in the opposite direction, of course, at 75 revolutions per minute.

*See MACHINERY'S Reference Book No. 25, "Deep Hole Drilling."

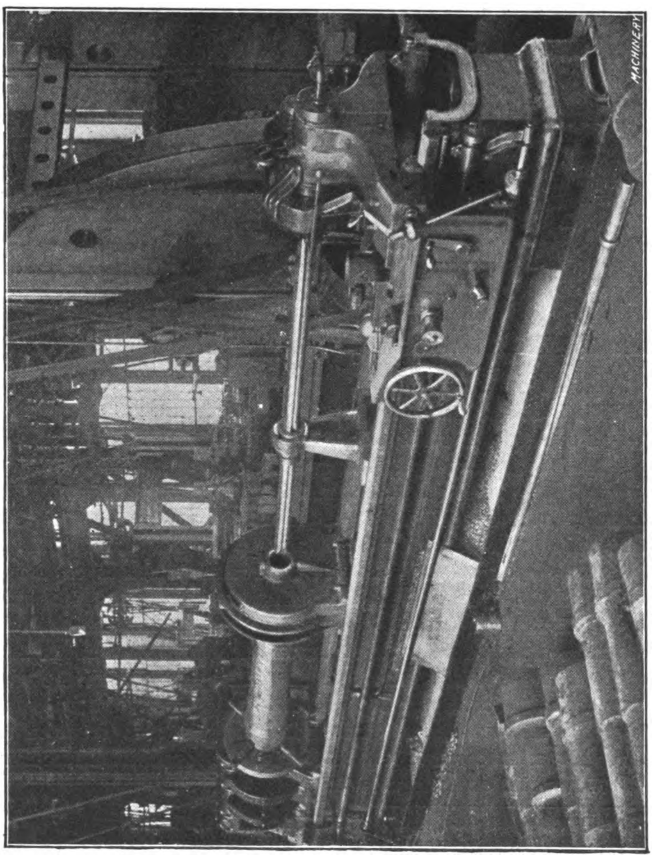

Fig. 4. An Improved Design of Boring Lathe for Drilling the Axles

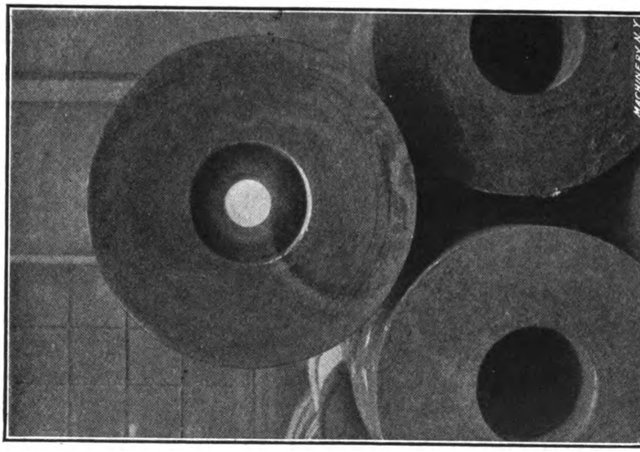

Fig. 5. Test Hole under Inspection

The drill head is clamped to a regular lathe carriage, and is connected for driving the drill with a special splined shaft at the back of the lathe. Unlike the machine shown in Fig. 3, this is practically a regular engine lathe, with only the addition of this splined driving shaft, the drill head on the carriage, the bushing support for the drill, and the revolving rest for the front end of the axle. Otherwise it is provided with lead-screw, change gears, and all the other requirements of the standard engine lathe. It may be used as an engine lathe when the attachments are removed. It is motor-driven, with a controller operated from the carriage.

A well-known type of deep-hole drill is used for this operation. It consists, as shown in Fig. 6, of a long bar *A* of steel, with a slot milled across its front end, in which an inserted blade *B* of high-speed steel is held by means of a taper pin *C*. Square grooves are provided on each side for the escape of the oil and chips. In circular grooves on

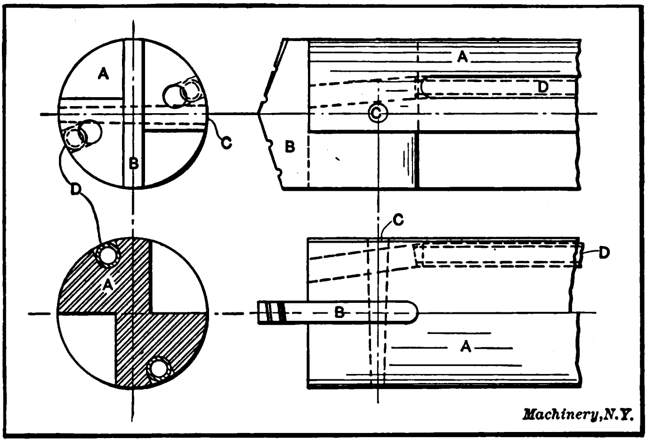

Fig. 6. The Drill used for Deep Boring in the Machines shown in Figs. 3 and 4

the side, tubes *D* are brazed, which lead the oil from the socket in the lathe carriage through to the cutting point. The only part of this drill subject to ordinary wear and replacement, as will be seen, is the steel blade *B*, which is very simple and inexpensive. These lathes, of course, are provided with power pumps, settling tanks, etc., for handling the lubricant, which in this case is a soda-water compound. This is delivered to the carriage by a "trombone pipe" arrangement in the case shown in Fig. 4.

Fig. 5 shows one of the holes drilled and under inspection. For this purpose an electric light is passed in at one end of the bore, provided with a reflector so mounted as to shade the eyes of the inspector from the direct glare of the filament, and still show clearly the walls of the bore, by the reflected light. As these holes have been drilled for inspection and insurance only and are of no further use, they are promptly plugged up again to provide centers for the subsequent machining operations on the axles. Various methods of plugging have been tried; but the one which has proved the most satisfactory in the long run at the Juniata Shops is the method which is also the simplest—namely, that of reaming out the ends of the bore with a taper reamer and forcing in corresponding taper plugs in the wheel press. The reamer and the plugs have a taper of ¾ inch per foot. In

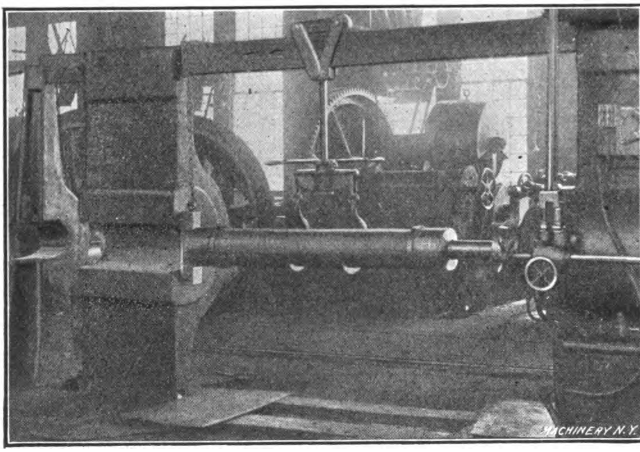

Fig. 7. Forcing Taper Plugs into the Ends of the Bore of the Axle

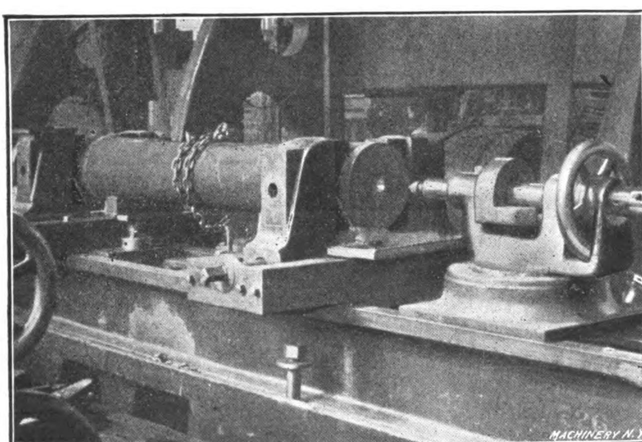

Fig. 8. Centering the Axle Preparatory to Turning

Fig. 7 the plugs are shown being pressed into place; a pressure of approximately 15 tons is used for this operation. The axles are now to all intents and purposes solid, and are treated as such throughout the remaining operations.

The axles are now ready for the turning operations, and the special machinery operations.

Finishing the Driving Axles

Fig. 8 shows the axle being centered. This is done in a special machine. The two ends are grasped in V-jaws tightened by right- and left-hand screws, which center the axle in front of two drill-spindle heads, one at each end. These heads are driven by bevel gearing from a splined shaft running through the center of the bed, and each is provided with a threaded quill and handwheel for feeding. As usual in centering, a leading hole is first drilled and this is then finished out to a center by the use of the countersink shown. The drift hole provides for rapid changes of drill and countersink.

From the centering machine the axles are taken to the lathe shown in Fig. 9, where the journals and wheel-fits are turned. Templets are used for the lengths of these cuts, one of these templets being shown laid on the wheel-fit at the near end of the axle. Fixed gages are also used for diameters. One of these is shown applied to the

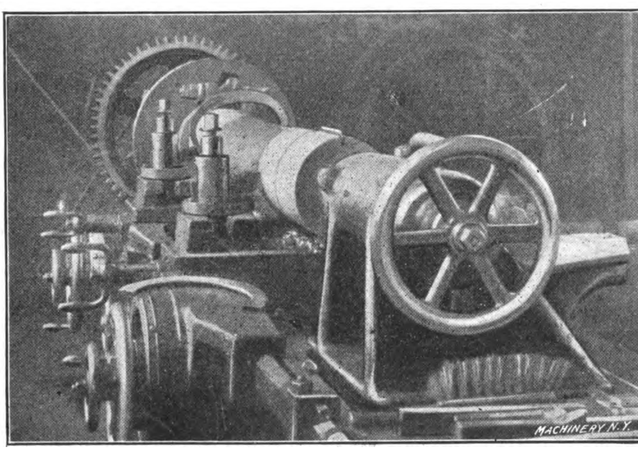

Fig. 9. Turning the Axles

journal, while the other is lying on the top of the carriage. The journals are finished by the rolling operation shown in Fig. 10. The roll is mounted in a forked holder in the tool-post, and fed back and forth across the work under a considerable pressure. There is an opportunity here for the display of judgment by the operator in the matter of the pressure applied. This must be heavy enough to roll down the tool marks and harden the surface. If too great a pressure is applied, however, these results are not obtained; instead, the surface is flaked and disintegrated, leaving it unfit for use in the bearing.

A little kink in estimating the smoothness of a surface is worth mentioning. The instinctive way of doing it is to run the tip of the finger across it to see how it feels. A more delicate test, however, consists of running the edge of the thumb-nail over the surface. For some reason this shows up ridges and irregularities of the surface much more sensitively than does the flesh of the finger tip.

The axle is now taken to a special milling machine, where the key-seats are cut 90 degrees apart on the ends, the two operations being simultaneous. This machine is shown in Fig. 11. The construction of the machine is plainly evident. The axle is mounted on its centers, and is supported on V-blocks which in connection with the weight of the axle, serve to keep it from moving under the cut. Two sliding

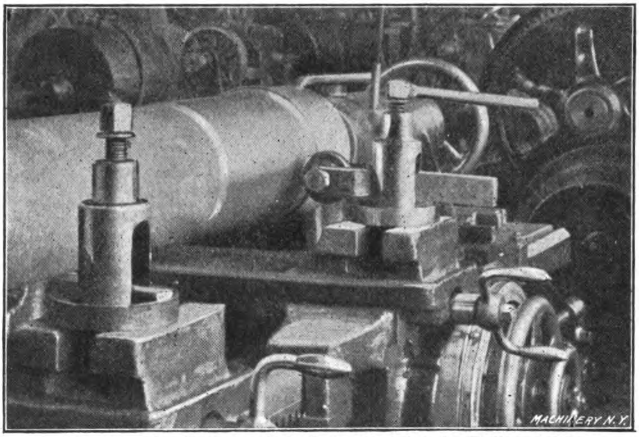

Fig. 10. Finishing the Axle Journals with the Rolling Tool

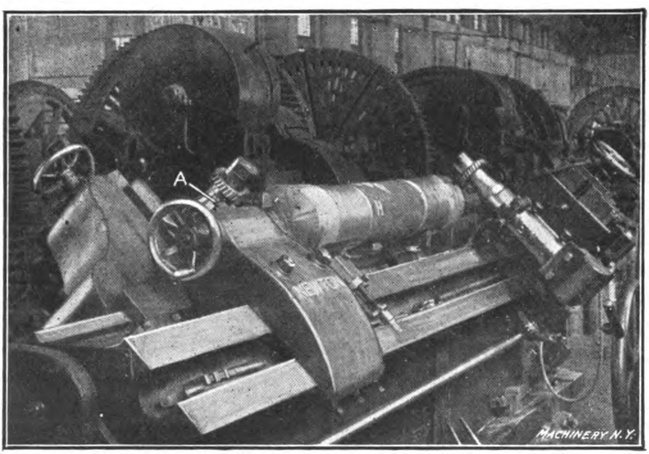

Fig. 11. Keyseating the Axles on a Special Quartering Milling Machine

cutter heads are provided, with axes at an angle of 90 degrees with each other. This brings the wheels on each side of the engine with the crankpins exactly 90 degrees apart; in other words, it "quarters" the wheels.

The cutters on these spindles have to be accurately centered, of course, if the quartering of the keyways is to be accurate. For this

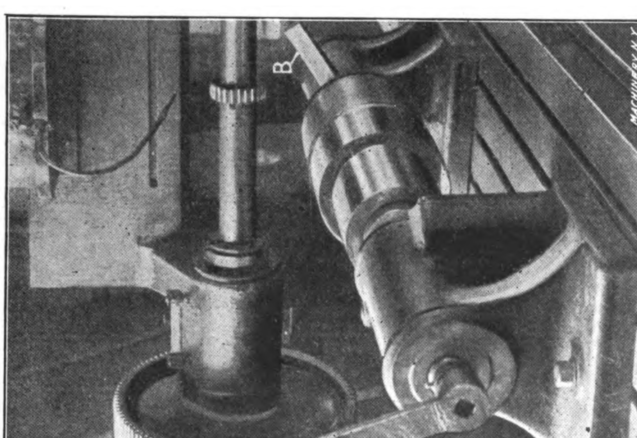

Fig. 12. Keyseating the Crankpin in the Horizontal Miller

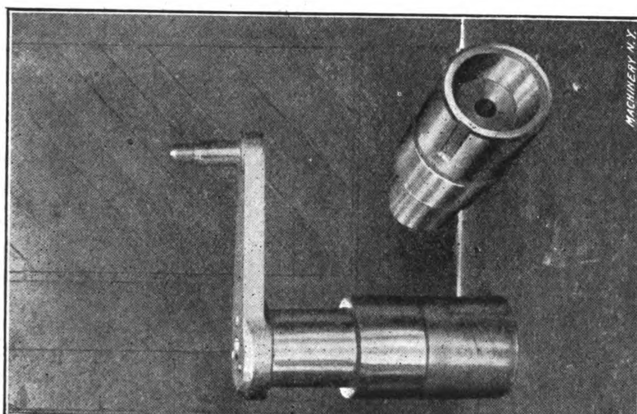

Fig. 13. Return Crank located in Proper Relation with the Keyseat

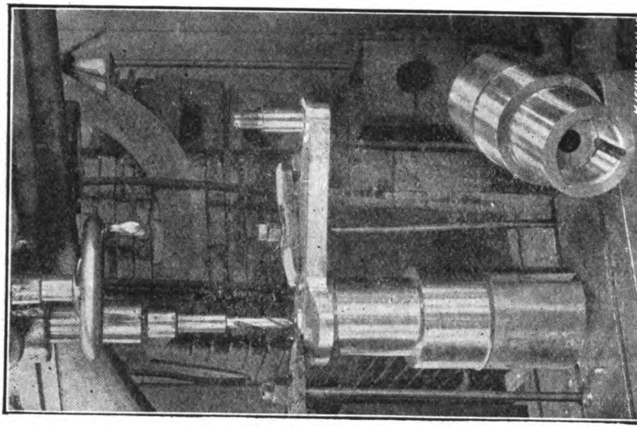

Fig. 14. Drilling the Dowel Holes for Locating the Return Crank

purpose a center line is provided on the back slope of the teeth, halfway between the sides of the cutter. This line on the cutter, in the original construction, was lined up with a pointer set in a stud in a bracket provided for the purpose on the cap of the cutter spindle bearing. The seat for the stud is shown, though the bracket is not in place. This method of centering has been changed somewhat in the practice of the shop. Instead of using this pointer, a reference surface shown at *A* in the engraving is used on the tailstock, and the measurements are made from this to the face of the cutter to set it central. This would seem to be a very satisfactory method, as it would not be affected by wear in the slides and changes in the tightness of the gibbing, owing to the fact that the reference point or surface is directly mounted on the member which supports and centers the work.

After the keyways have been cut on this machine the axle is ready for assembling with the wheel-centers.

Finishing Operations on the Crankpins

The crankpins are machined from the rough forgings by obvious chucking and lathe operations which do not need to be described in detail. With the Walschaerts valve gear, these pins are of two kinds, depending on whether the Walschaerts crank is to be screwed and doweled into a counterbore, as in the case shown in Fig. 14, or is to be keyed and bolted with a split hub, onto a seat turned on the outer end of the pin, as for the case of the K-2 wheel shown in Fig. 33.

The pins shown in Figs. 12, 13, and 14 are of the former sort. Fig. 12 shows the operation of milling the keyseat for the fit of the pin in the main driving wheel center. This keyseat is, of course, required for the main pin only, as this is the pin from which the valve gear connections are made. The other crankpins are forced into place without keying. In Fig. 12 the work is simply held between centers in an ordinary horizontal milling machine, and the keyway is cut with a mill properly centered. At *B* is a key, set into the keyway of a templet mounted just back of the pin; it is used merely to indicate the existence of the templet, which is out of sight. The latter has on it a line corresponding with one scribed on the pin, with which the Walschaerts return crank must match. This templet is used, therefore, in locating the keyway with reference to the line of the crank.

In Fig. 13 the crank has thus been properly located. In Fig. 14 it is shown on the drill press while the three dowel holes which locate it with reference to the pin are being drilled. These holes, as shown, after passing through the flange of the crank, are drilled half into the hub of the crank and half into the counterbore of the pin, locking them firmly together. The crank itself is, of course, held in place by a bolt passing through the center of the pin, and fastened by a nut on the inner face of the wheel.

Boring the Tires

In Fig. 15 is shown a section through the driving wheel rim and tire. The method used on the Pennsylvania R. R. for holding the tire in place is clearly shown. The usual lip or shoulder is provided on

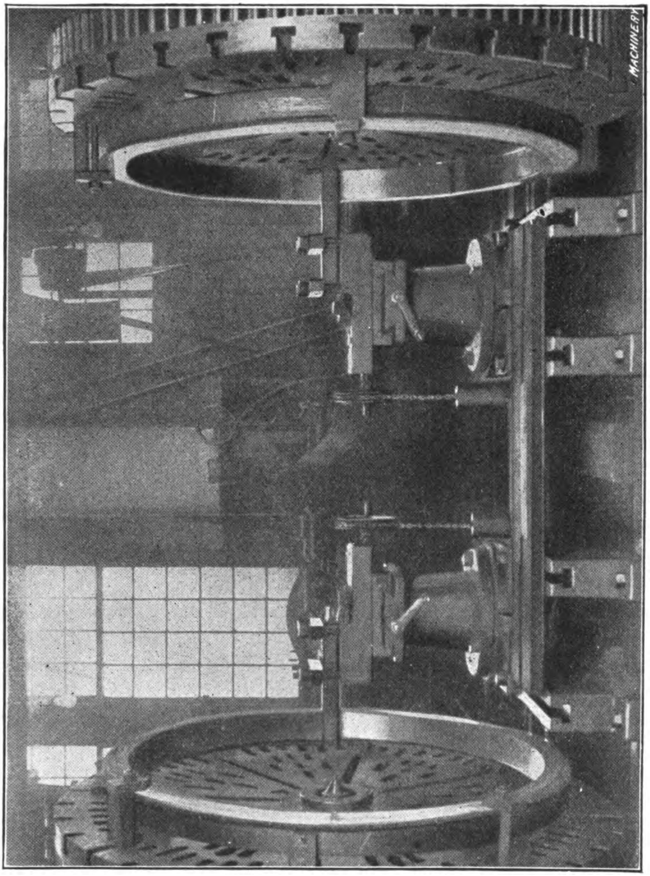

Fig. 16. Boring the Tires Two at a Time in the Wheel Lathe

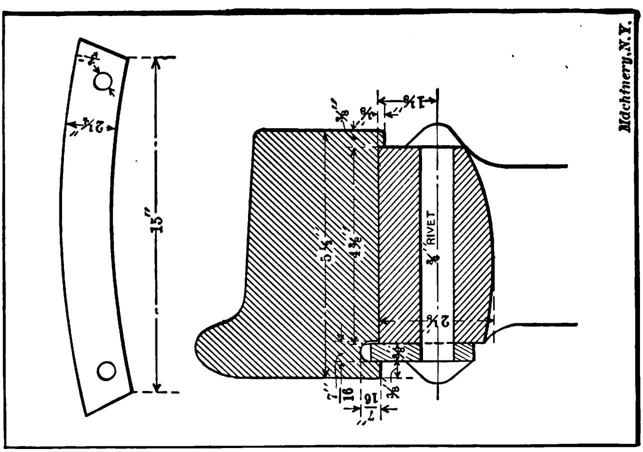

Fig. 15. The Tire and its Retaining Ring

the outer edge of the tire for taking the heavy thrust of the rail against the flange of the tire in rounding curves, taking switches at high speed, etc. In addition to this, a groove is turned in the bore of the tire and into this is set a series of plates about 2¼ inches wide and 15 inches long, as shown, held to the inner face of the wheel rim by ¾-inch rivets. Six of these plates are ordinarily used, spaced equally around the rim.

This provision for locking the tire in place is made necessary by the tendency which tires have to loosen from the centers under certain conditions. It is a common occurrence to have a tire so heated by the slipping of the wheels on the track in starting at heavy loads, that it will loosen from the center and start to slide off. It cannot, of course, come clear off, as it is retained in place by the flange striking against the rail. The tire is shifted from its position, however, and when it cools again the gage of the engine has been widened, necessitating a cautious trip to the shop for reheating and replacing the tires. By the use of various methods of locking, of which the clip arrangement here shown is one of the most satisfactory, this difficulty is avoided.

The tires are received from the rolling mills rough all over. The finish rolling is, however, accurately and smoothly done. The first operation consists in boring the tire for its fit on the wheel center, and also for forming the retaining lip or shoulder. This operation may be done in either the wheel lathe or the boring mill. In Fig. 16 the tires are being bored in the lathe. They are held on the faceplate by clamps and blocking, and are mounted on parallels to provide clearance for the boring tools when working at the extreme inner edge. The tire is located in place for clamping and is accurately centered by a set of stops with adjustable screw-points, located between each of the four clamps shown. The operations of boring, and of forming the lip, are all of an obvious kind and do not need to be described in detail. An interchangeable blade boring tool is used. The inside diameter is accurately turned to a standard length gage.

Operations on the Wheel Centers

The wheel centers shown in Fig. 17 are of cast steel. Two forms of counterweights are used. One style shown in this figure is cast solid with the wheel centers. This is the style commonly used on passenger wheels of large diameter, where it is possible to get a large enough weight and one far enough from the center to produce the required balancing effect. On freight engines, in general, where the wheel is very much smaller in diameter, it is not usually possible to get into the required space enough weight in cast iron. On this account such counterweights are ordinarily cored hollow, and poured full of lead so as to get the required weight in the required space.

Instead of pouring this into an enclosed space, the Pennsylvania practice is to pour it into open chambers, as shown plainly in the freight wheel in Fig. 20. After these have been poured full, a plate of steel is bolted on for a cover, preventing any possibility of the

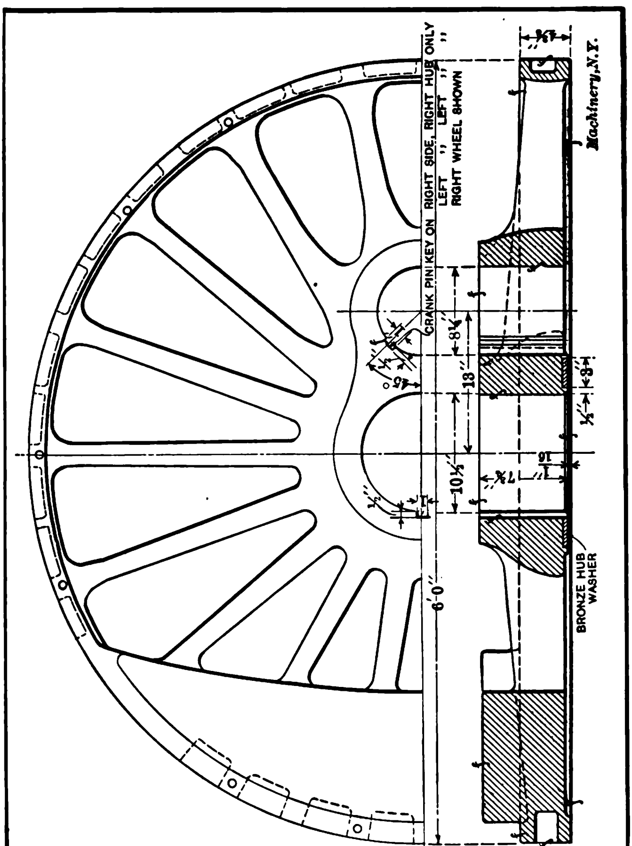

Fig. 17. Center for 80-inch Main Driving Wheel of Pacific Type Locomotive

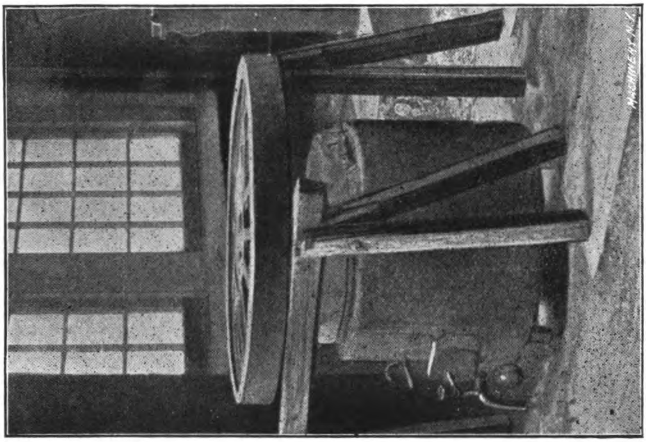

Fig. 18. Pre-heating the Wheel Center while Melting the Bronze for the Hub Liner

lead being lost out. The advantage over the closed chamber lies in the fact that in the latter case, the interior is difficult to clean properly and difficult to fill properly; it is common for the lead filling to shake loose and to rattle around as the wheels revolve.

The first operation, if the wheel is to have a hub liner or washer, is the turning of the seat for this with dovetailed grooves to hold

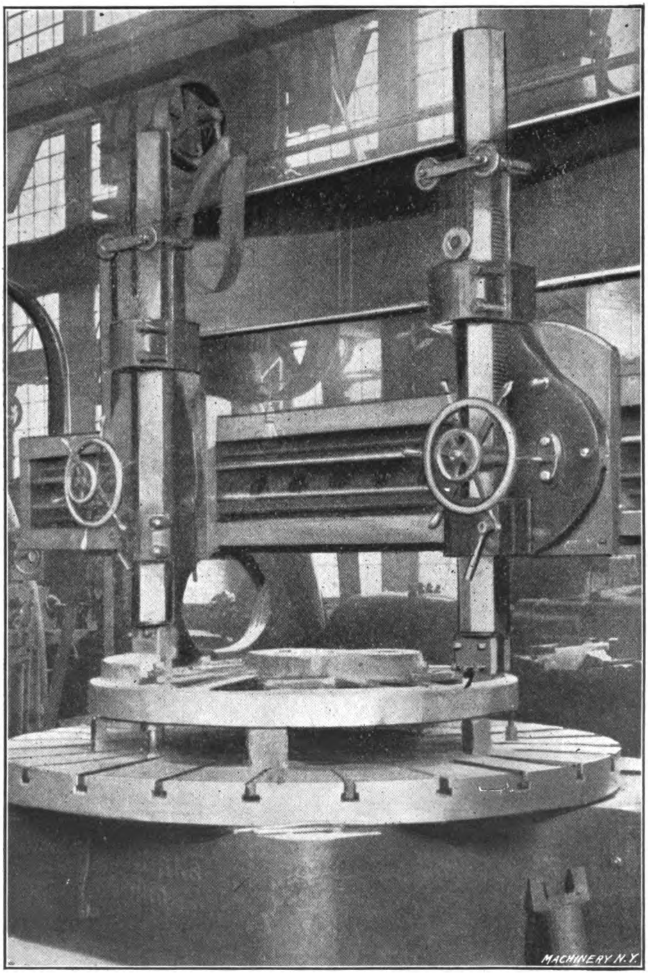

Fig. 19. Boring and Turning the Wheel-center

it in place. This is done on the boring mill. The pouring of a bronze liner that will not crack while it is cooling is an operation that many railroad shops have difficulty with. The method here followed, however, obviates this trouble entirely. The secret of success is shown in Fig. 18, where the wheel-center is seen mounted on horses directly over the crucible oil furnace in which the bronze is being melted. The hub of the wheel is not merely warmed, but is heated to a high degree, being somewhere near the point where it would begin to show redness. When the bronze is poured into the heated hub, the liner and the hub shrink together, so that the cracking of the former is entirely obviated. It may be said that the cracking of the liners does no particular harm, it being, in fact, common custom to use them in this condition; but certainly the cracking does them no good, and when it can be avoided by a simple process like this the little extra trouble is worth while.

The wheel-center is now taken to the boring mill, and is first mounted with the inside surface uppermost. Here the periphery and the inside edge of the rim are faced and the hub bored and faced. The wheel is then turned over and mounted as shown in Fig. 19. Here the outside edge of the rim is faced, as is also the hub and its extension for the crankpin. The center is shown between the two operations in Fig. 20, which also shows very plainly the open form of chambers provided for receiving the counterweight lead in freight locomotive practice.

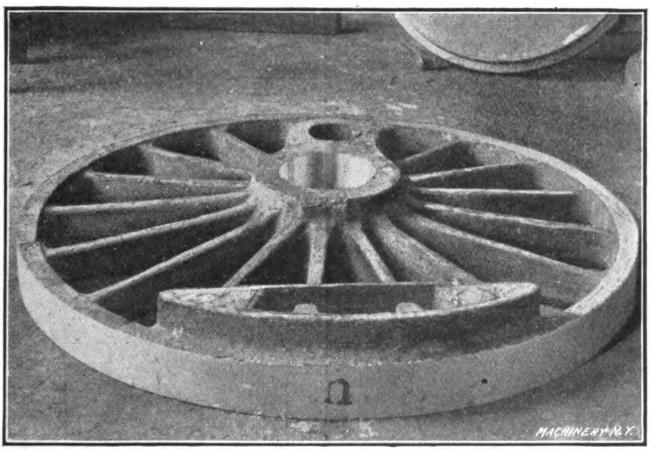

Fig. 20. The Counterweight Poured into Open Chambers

The particular wheel here illustrated is intended for the electric locomotive on the New York Tunnel service. It will be noted that only the two outside chambers are filled with lead. This particular casting is intended for the rear wheel, in which only the weight of the side-rod is to be balanced. If the same casting were to be used for the main driving wheel, the weight of the connecting-rod from the jack-shaft would also have to be balanced, requiring all the chambers to be filled with lead. This construction permits the use of one casting for both styles of wheels, thus simplifying the question of patterns, and making the castings, in a way, interchangeable.

The hub surface of the axle and crankpin is next marked with chalk, as shown in Fig. 21, for scribing the keyways for the axle and the pin. A templet is used for this operation, two forms of which are shown in the engraving. The one in place is for the K-2 or Pacific type locomotive, in which the return crank for the valve gear is located at the proper angle by the keyway of the crankpin. The templet consists of a cross made of rectangular steel, provided with

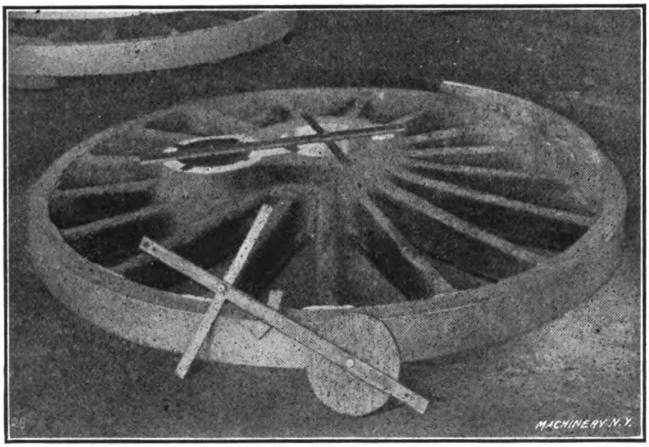

Fig. 21. Laying out the Keyseat for the Crankpin with Special Templet

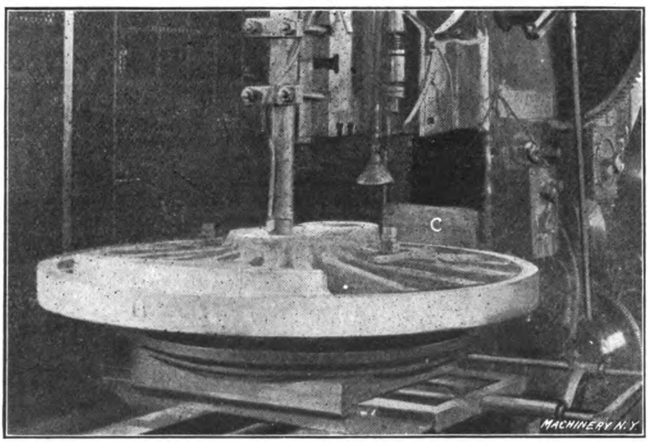

Fig. 22. Keyseating in the Slotting Machine with Special Squaring Plate for Setting the Work

gage marks and a circular segment for locating it on the axle bore, and with a disk templet, as shown, for scribing the crankpin bore and marking the keyway. Of the four projections on this disk the two shown nearer the axle are for the keyways, that on one side being used for the right-hand wheel, and the one on the other side for the left-hand wheel.

For lighter types of locomotives, the crankpin keyway is put directly in line with the axle keyway, both being on the connecting center line. For this condition the templet shown lying against the wheel is used. This is located in the axle bore in the same way, and the crankpin bore is scribed. The long steel bar to which the other members are fastened is the width of the key used in both bores, so this is used for scribing their location. For locomotives using the Stevenson gear, no keyway is required for the crankpin, of course; so only the axle keyway and the crankpin hole are scribed, to insure proper quartering.

When the keyways have been thus laid out, the wheel center is taken to the slotting machine, as shown in Fig. 22, where the keyways are cut to the lines scribed in the previous operation.

For those centers where the keyways are in line with each other and on the center line of the axle and crankpin, great assistance is given in the matter of setting up by the plate shown at *C*. This is

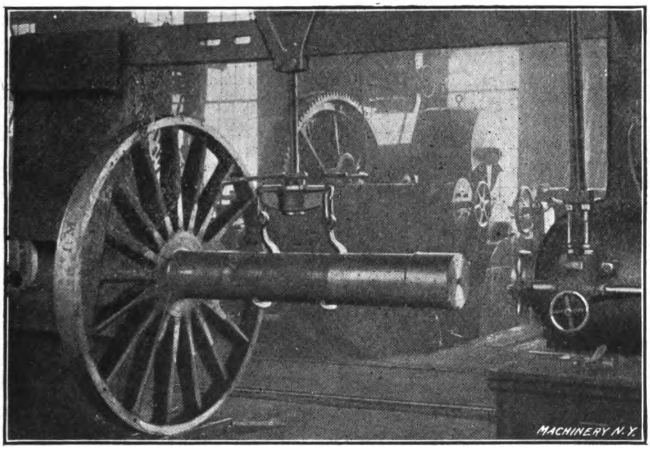

Fig. 23. Pressing the Axle into the First Wheel

fastened to the face of the column of the machine by studs, and is carefully set so that its surface is exactly at right angles to the ways on the bed, on which the work-table is adjusted in and out. By setting a square against this accurate surface, the wheel-center to be machined may be set so that the two keyways exactly square up, and are thus in line with the ways of the machine. When the tool is right for cutting one keyway, the work may be shifted over to cut the other without further setting.

The next operation, not illustrated, is the drilling of the various holes required for the tire retaining plates, the counterweight cover-plate, etc. After this operation, and the pouring of the counterweights, the center is ready to be forced on the axle.

Assembling the Wheels, Axles and Tires

The wheel-press is shown in use in Figs. 23 and 24. The first operation shows the press immediately after the forcing of the axle into the first center. The axle is supported from the tie-bar in the usual sling, accurately set for height by means of the screw adjustment shown. The wheel center rests on a roller support, by means of which it may be turned until the keyway exactly lines with the key fitted in the axle.

Fig. 24 shows the second center being forced on. This is also mounted on a roller support for bringing the keyway in line with the key. Blocking is used, as shown, so that the ram applies its pressure to each side of the hub, forcing it down to its seat on the axle, and allowing the end of the latter to project through it slightly if its length is such as to require this.

For a 10-inch wheel-fit like this, the axle is turned approximately 0.010 inch larger than the bore of the hole in the center, the usual rule being about one-thousandth inch allowance per inch diameter of fit. An axle of this size would require anywhere from 120 to 145 tons

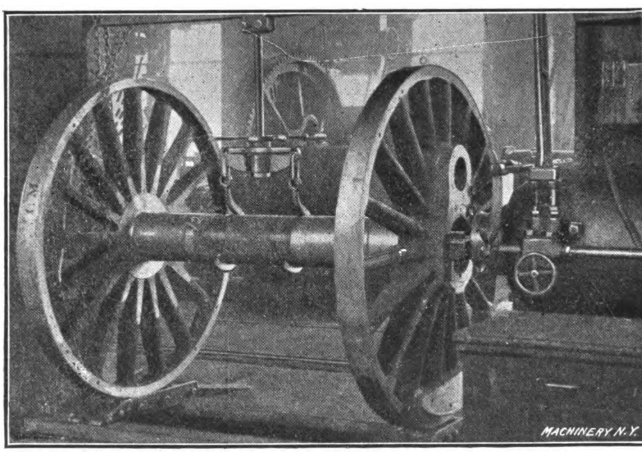

Fig. 24. Pressing the Second Wheel onto the Axle

pressure to force it home, this pressure varying with the character of the machining on the surface fitted and with the exact dimensions to which the parts are finished.

The wheels are now ready to have the tires shrunk on them. Where this tire-shrinking job is done on the wholesale as it is, for instance, at the Altoona repair shops, a heating furnace is used into which the tire is set bodily. In continuous operation this arrangement heats a great number of tires per day. For establishments where the operation is only occasional, the favorite arrangement is to provide a pipe slightly larger in diameter than the tire, and provided with a series of jets through which a gas flame is directed on the tire around its circumference. For the number of tires per day, however, which have to be attended to at the Juniata shops (one locomotive per day is the regular capacity) the arrangement shown in Fig. 25 has been found entirely satisfactory. It provides for heating the tire uniformly around its circumference with a single flame, this flame being so arranged as to be capable of accurate control and to give an economical and efficient flame.

As shown in the engraving, the arrangement consists of a turntable on which the tires are mounted, a combustion chamber of sheet iron lined with fire-clay, and a burner in which crude oil is atomized by compressed air at the regular shop service pressure. The combustion chamber is swung on a swivel, as shown, so that it may be directed properly against the work. The burner is supported by it, and is supplied by flexible pipes. The tires are mounted two at a time on the turntable, which is slowly revolved by a push from the operator every once in a while. To determine when the tires have reached the proper heat, an inside solid gage is used, similar to the one used for boring

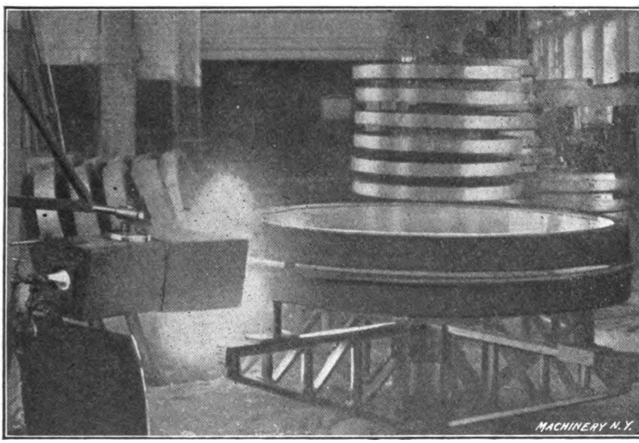

Fig. 25. Heating the Tires on a Turntable for Shrinking onto the Centers

the tires in Fig. 16, but larger, of course, by the amount of expansion the tire must possess before it can stretch over the wheel-center.

When it has expanded to the point where the gage will enter the bore of the tire in any direction, the tire is picked up by the crane and dropped on the floor of the shop. The crane then picks up the axle with the two centers and drops one of the centers into the tire. The second tire is then picked up and dropped onto the upper wheel-center, the combination being left in the position shown in Fig. 26 until the tires shrink on. The centers and tires rest against the lip on the latter, of course, so that they shrink squarely into position. The chalk mark "H" on the lower tire means that the tire is hot. The correctness of this statement could, without doubt, be determined by experiment.

After the tires have cooled down so that they are firmly shrunk into place, the wheels are taken to the quartering machine shown in Fig. 28, where the crankpin holes are bored. This well-known tool bores the crankpin holes exactly 90 degrees from each other. This is, of

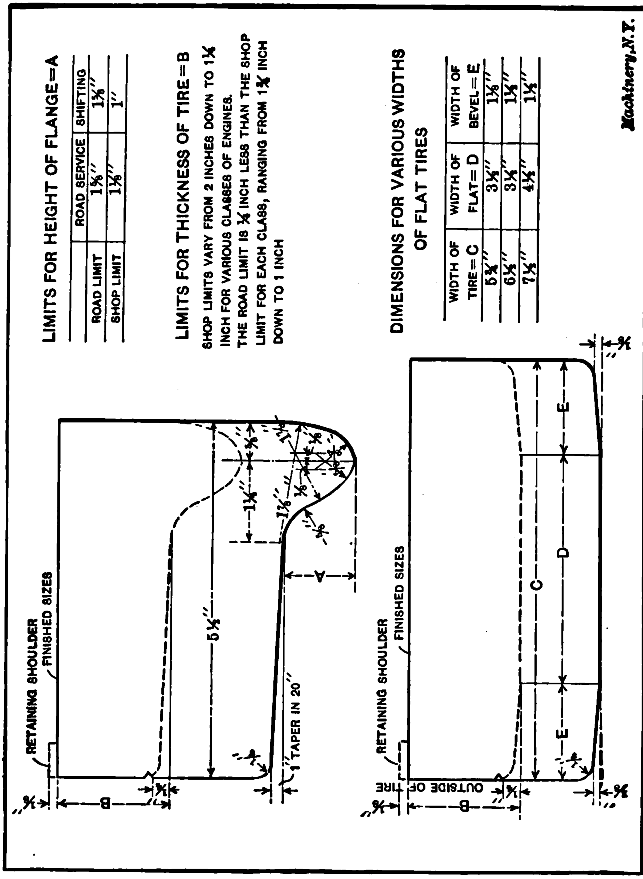

Fig. 27. Contour of Finished Tire, showing Road and Shop Limits

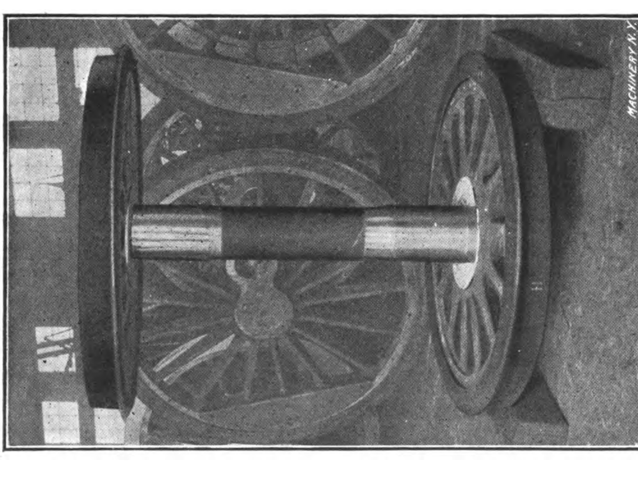

Fig. 26. Shrinking the Tires onto the Centers

course, a matter of great importance, for if the various pairs of driving wheels are not all accurately quartered, with crankpins at exactly the same radius, they will cramp and bind in the connecting-rod brasses, until these are distorted or worn loose enough to allow for the inaccuracy. If the quartering machine is accurately made, the wheels may have their crankpin holes bored in them with perfect confidence that they will run properly under the locomotive.

The axle is located by its centers, as in the case of the axle keyseat milling machine shown in Fig. 11. On each end of the bed two heads are mounted, one on one side and one on the other, adjustable for the throw of the crank; each carries a boring spindle as shown. Between the wheels are furnished outboard bearings for the boring-bars, permitting heavy cuts to be taken without vibration or chatter, and without danger of inaccuracy. The rims of the wheels are clamped to this support, as shown, to hold them firmly in position. If the quartering of the keyways in the axle, and the slotting of the keyways in the hubs of the driving wheel, are properly done, the outlines scribed on the crankpin hub at each end can be accurately finished out by this boring operation.

If the wheel cannot be set so that the crankpin holes, as bored by the machine, will finish out to the line on each wheel, it is evident that the keyway on the hole that does not finish out will be out of place, throwing the pin around, and therefore disturbing the relation of the return crank which operates the Walschaerts valve gear. A check is thus furnished for all preceding operations, so far as they refer to the valve gear. It is not expected, and indeed is not found, except in rare cases, that the preceding operations have been at fault, but wherever they have been, notice is served of the difficulty in time to make such corrections as may be required before the engine is assembled. It should be noted that the keyway is filled with a dummy key, approximately flush with the cored hole, before boring the crankpin seat. The operation is not so hard on the tool as it would be for the blade to pass through the open keyway at every revolution.

It will be seen that the quartering machine is arranged so that the boring slides can be mounted on the opposite sides of the heads from that shown, if desired. This makes it possible to quarter wheels in which the right side leads, as well as those in which the left side leads. Engines are now made with the left side leading as standard practice, but some of the older designs, which have to be reckoned with in repair work, call for the right side leading. Provision also has to be made for this in the axle keyseating machine shown in Fig. 11. Here it is not so much trouble to change the machine over, as the milling heads are simply fed along the slides until they have passed each other and are working on the opposite ends of the axle. The feed-screws are long enough to permit this.

Turning the Tires

Another operation, shown already performed in Fig. 30, is the turning of the tires, which is done in the wheel lathe in which the

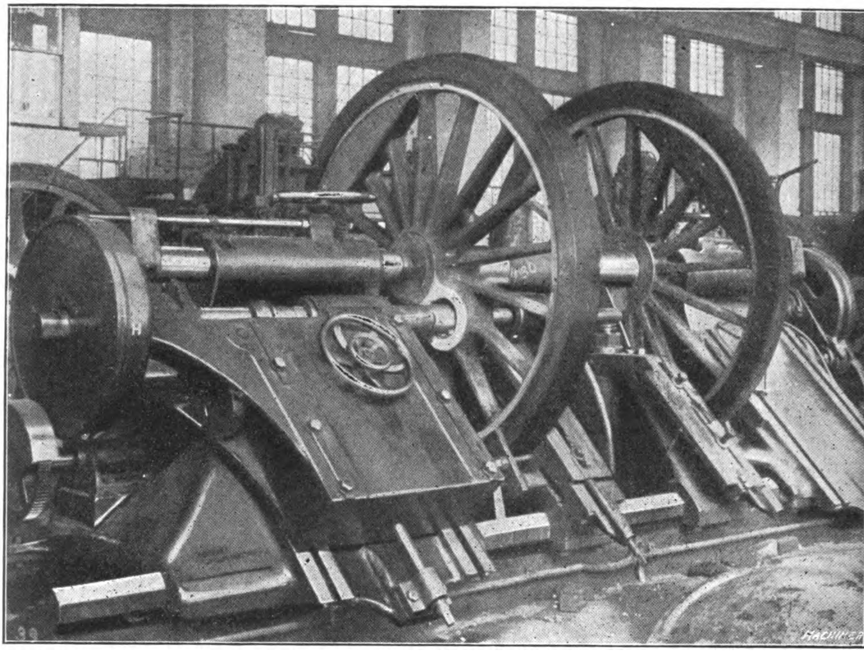

Fig. 28. Boring the Crankpin Holes in the Quartering Machine

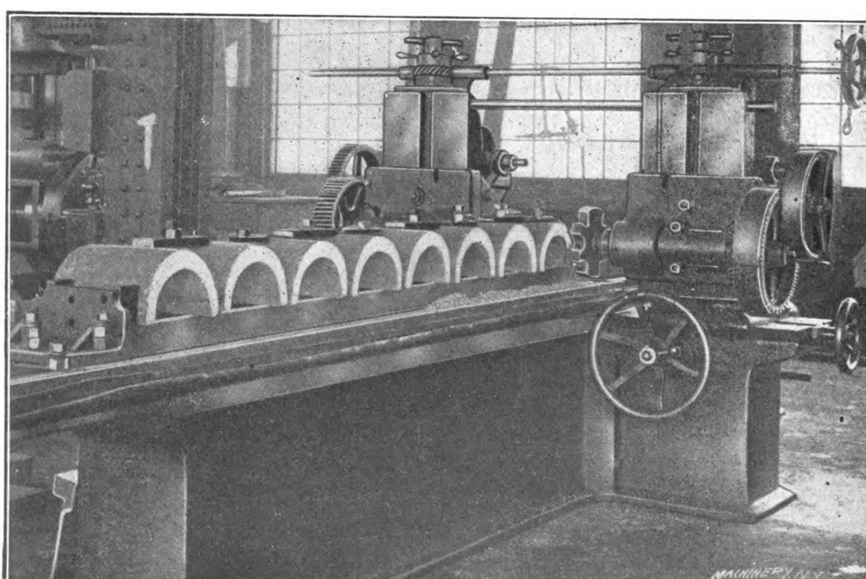

Fig. 29. Finishing the Ends of a Gang of Crown Brasses in a Double-spindle Milling Machine

tires were bored, in Fig. 16. All passenger locomotive tires are turned on centers the last thing before the crankpins are forced in place, before the wheels are sent to the erecting floor. On freight locomotives, which do not run at so high a speed and are not so hard on the track, the tires are simply centered very carefully for the boring, finish turning not being required.

The standard contour for driving wheels on the Pennsylvania

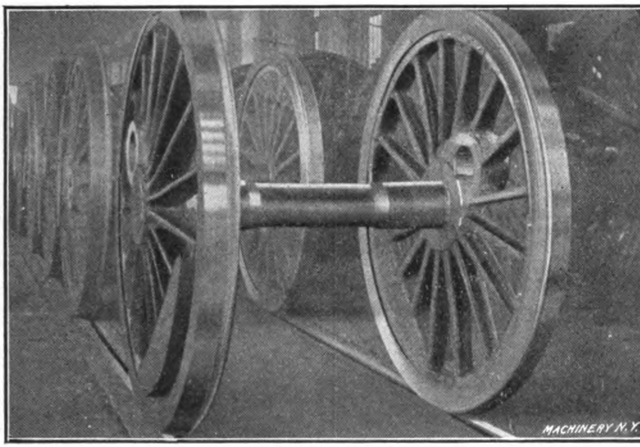

Fig. 30. The Wheels ready for the Crankpins

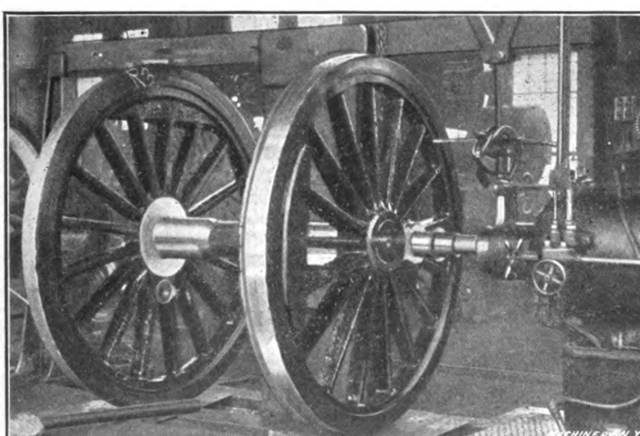

Fig. 31. Forcing in the Crankpins

system is shown in Fig. 27, which also gives details as to the road and shop limits for the height of the flange and the thickness of the rim. Whenever one of the flanges wears down below the road limit given for dimension *A*, the wheels are brought into the shop to be turned off again. When this has been done so often that another turning would reduce dimension *B* below that given for the shop limit, the tires are scrapped. Whenever dimension *B*, in service, wears below the road limit given for that dimension, the tire is scrapped. The measurements for determining dimension *B* are taken from the V-groove shown turned in the outer face of the tire, which is ¼ inch below the minimum limit. This groove is cut into the tire in the wheel lathe during the turning operation. Dimensions for flat tires with the various limits are also given in Fig. 27.

Driving the Crankpins and Finishing

Fig. 31 shows the operation of forcing the crankpins into place. In this operation the thrust of the ram against the wheel is taken care of by backing the latter against the "post," which is adjustable to the proper position on the top and bottom tie bars. This gives a solid backing for the pressure required to force the pin in place. About 0.008 inch allowance for driving is made on a crankpin fit

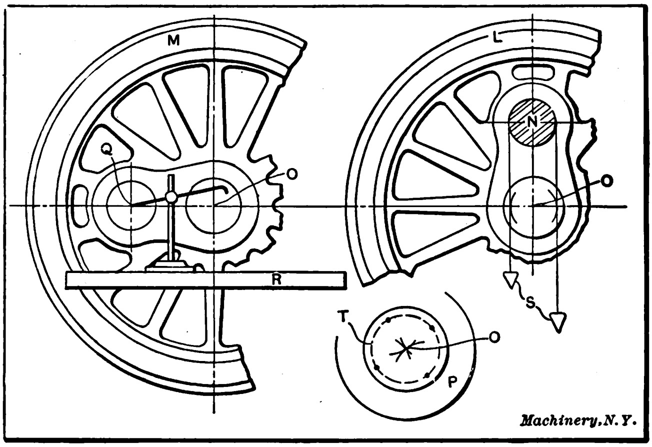

Fig. 32. Method of Testing and Quartering

of 8 inches in diameter, the pressure required ranging from 75 to 100 tons. It may be mentioned in this connection that the driving pressures for all axle and crankpin fits are recorded at the shops, and put on permanent record for use in case of any question arising as to the service of the engine on the road. The engraving shows the second pin being driven, the first having already been forced into place by an identical operation.

It was stated that an accurate quartering machine will take care of the proper boring of the crankpin holes without requiring any anxious thought in this matter on the part of the workman. It is, however, well to know how to test the quartering, so as to make sure that the machine is right in the first place, or to make sure that it does not for any reason wear out of line as time goes on. Fig. 32 shows how this testing is best done. The two wheels on the same axle are shown at *L* and *M*.

The first thing to do is to set the wheel so that crankpin *N* is exactly vertical over the center of the axle. This is done, as shown, by hanging a double plumb-line over the crankpin and rolling the wheel slightly one way or the other until it is located in position so that the center of the axle *O* is exactly equidistant between the two lines, or until the crankpin circle, struck with the dividers from center *O*, just touches the two plumb-lines equally on each side. Of course, in locating the center *O*, the axle sould be prepared the same as is customary for tramming in setting the valves. For this purpose, the center hole should be pounded full of lead and a new fine center accurately located on it. At the Altoona shops this center is located from a proof circle *T* turned with a sharp pointed tool on each end of the axle, while it is still in the axle lathe as shown in Fig. 9. By striking with the dividers from this proof circle as shown in the

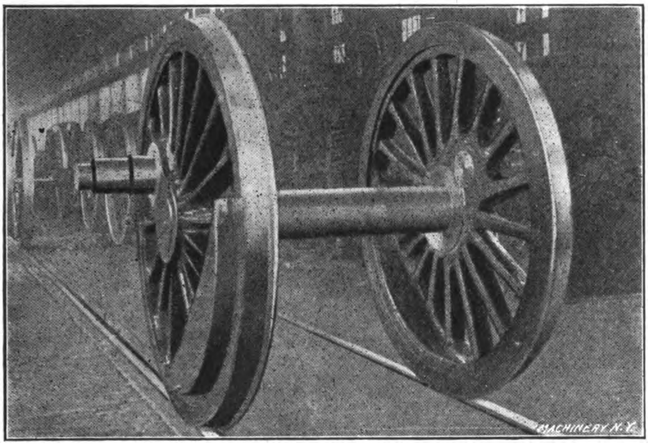

Fig. 33. Completed Driving Axle and Drivers for Heavy Pennsylvania K-2 Type Pacific Passenger Locomotive

detail *P*, the center may be accurately located. Where it is not customary to turn a proof circle on the axle end, a ball point divider is used to scribe the proof line before the center is plugged up. Arcs are struck as shown from this proof circle until they intersect at the center, which is then marked with a prick punch. It is more accurate, however, to turn the proof circle *T* at the time the journals are turned.

Having set one side with the pin exactly vertical over the axle this way, the other side, shown at *M*, should be exactly horizontal with the center. To prove this, first set up a table having a surface-plate *R* mounted on it. With a precision spirit level, the best obtainable, bring this surface-plate to an accurate horizontal position. Then by means of a surface gage, test the center *Q* of the crankpin and *O* of the axle to see if they are the same height. The centers of both the pin and axle on this side should, of course, have been filled with lead and accurately centered in the same way as previously described, and as shown at *P*. If the lines on the vertical and horizontal sides have been proved to be correct by this method the wheels are properly quartered and the machine has done its work properly.

It is of great importance that the man in charge of the wheel work should know that the quartering machine is in good condition. If he is sure of this, he can meet with confidence the various reports of inaccuracies and difficulties in this particular that are sure to come to him from engines in actual use. He can meet such "kicks" with calm assurance, knowing that while something is doubtless the matter, it is not the quartering that is at fault.

The wheel, after being painted, is now ready for the assembling floor. The method of construction here described, it will be seen, makes use of the ordinary tools of the railroad shop and represents "good practice." Attention should be called particularly to the fact that fixed gages are used for all the important operations. This relates to the diameters of journals and axle fits, the boring of the tires, the turning of the wheel centers, etc., and besides this, as was explained, the use of the templet method of marking the keyseat and the bore of the crankpin furnishes an automatic check on all of the most important operations of the series.

CHAPTER II

DRIVING BOX MANUFACTURE

Among the great variety of manufacturing operations to be found in a locomotive building shop, the making of the main bearing boxes is one of those worthy of detailed illustration and description. The operations as laid out in the Juniata shops have proved to be efficient and accurate, but at the same time inexpensive in the matter of the

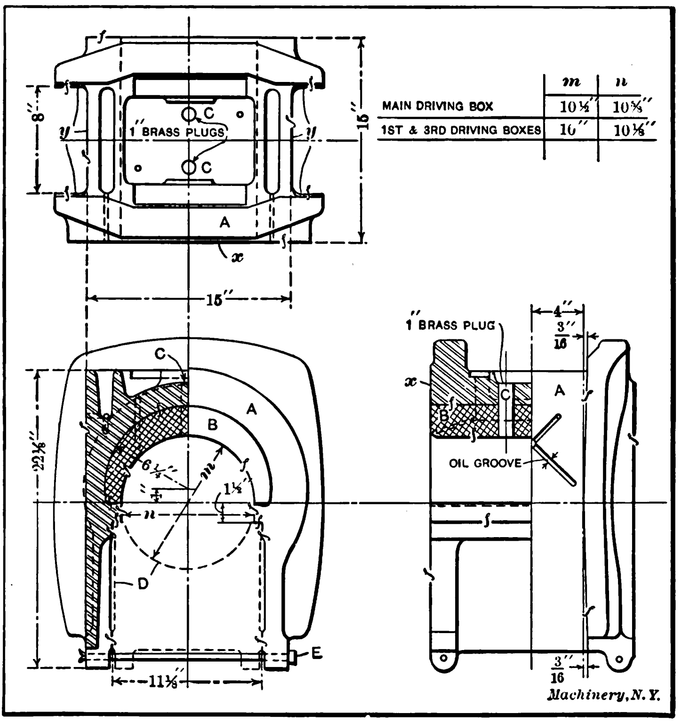

Fig. 34. The Main Driving Boxes for a Heavy Pacific-type Passenger Locomotive

outlay for special tools and special machinery. Only standard machine tools are used on this job, such as find a large range of usefulness in the railroad shop. The number of special appliances is reduced to a minimum. For this reason the lay-out of the operations requires as high a grade of ingenuity as is needed for devising expensive special appliances for rapid manufacturing. In the description, we will begin with the machining of the various separate parts, proceeding therefrom to the assembling and machining of the finished product.

The Design of the Driving Box

A typical locomotive driving box is shown in Fig. 34. This design is used on an exceedingly heavy Pacific type locomotive. The box is of simple construction, consisting of but two parts, the driving box casting itself, *A*, and the crown brass *B*, which is driven into place in a machined seat where it is pinned by the two brass plugs shown at *CC*. These effectually prevent its loosening under any conditions. The cellar *D*, is indicated by the dotted lines only. The cellar used is a patented device of special construction, whose manufacture is a separate matter from that of the remainder of the box. It is held in place by two pins *E*.

This design of driving box has a plain finished face at *x* for the wheel thrust. The wheel itself has a bronze liner, which forms a suitable surface for contact with the steel casting face at *x*. Some

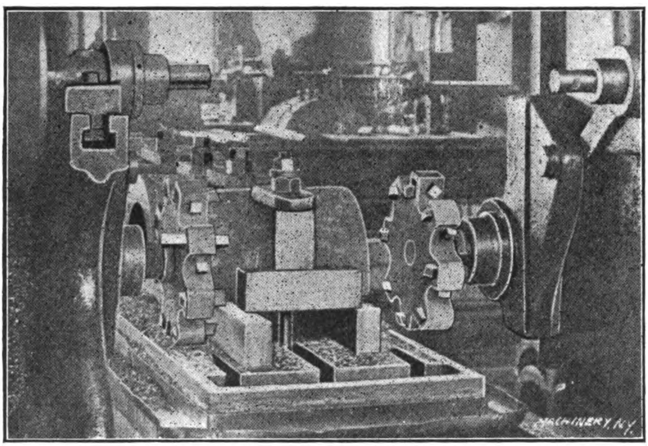

Fig. 35. Enlarged View showing the Two Inserted Tooth Mills

of the boxes shown in the following engravings, however, have a bronze liner inserted in surface *x*. Some of these liners are shown in Figs. 39 to 42. These are used when the hub of the driving wheel is not lined, but is simply faced up true on the steel surface. Still another method of treating surface *x* is to groove it out and pour a babbitt lining, on which a true bearing surface is faced. The standard practice here is to put bronze liners on the boxes, for the reason that it is more difficult to replace a liner on a wheel than on a box. Furthermore, when mounted on the wheel, the liner detracts from the length of the fit between the wheel and axle. This should be noted in connection with Figs. 49 and 50.

Machining the Crown Brasses

The first operation on the crown brasses or bearings, which are made of phosphor-bronze, is shown in Figs. 29 and 35. They are mounted, eight at a time, on long parallels on the bed of a duplex milling machine. An ordinary angle-iron serves to take the thrust of the feeding at the end as shown. The castings are held down on the parallels by simple bolts and straps in the central T-slot of the table, each strap spanning the distance from the top surface of one brass to that of the next. The strap of the first brass has, of course, as shown in Fig. 35, to be blocked at the outer end. In setting these up, the parallels are first lined up with the T-slot of the table, to serve as a gage. Then the separate brasses are put in place with the bolts between them, and packed solidly up against one another and against the angle-iron at the end, and set so that all of them project over the parallel the same distance; this leaves about the same amount of metal to be removed from all of them in finishing the ends. As each brass is put in place, care is taken to see that it is at right angles with the face of the parallels, a square being used for the purpose.

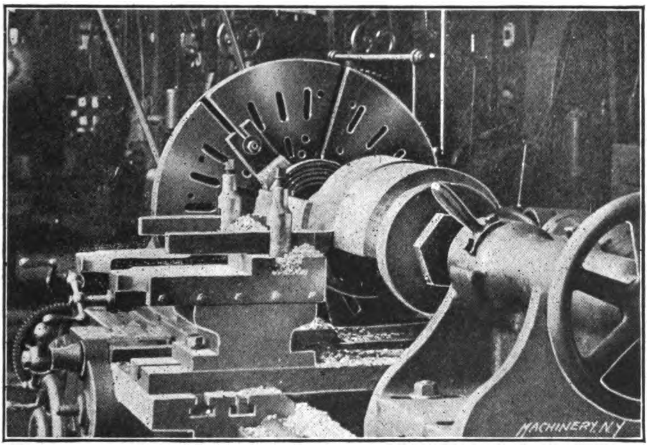

Fig. 36. Turning Two Crown Brasses at once on a Special Arbor

After being properly set and tightened down in this position, the cutter-heads are adjusted to the required distance apart, dividing the chip equally between each end of the work. The cut is then taken across as shown.

The next operation is that of turning the outside diameter of the brasses for the fit in the seat on the main bearing casting. This is done in the engine lathe, as shown in Fig. 36, on a special arbor whose details are shown in Fig. 37, and which permits turning two at a time. The special advantage of this arrangement is that the two brasses are set halfway round from each other on the arbor so that the lathe is cutting all the time. This is not so hard on the lathe as is the case when only one is being turned so that the single tool is "cutting wind" half the time. It also gives more rapid production, as two pieces are cut in practically the same time as one with former appliances.

In Fig. 37, which shows details of the device, the arbor carries a fixed flange in the center. The two brasses to be machined are clamped against the opposite faces of this flange by nuts and washers. Each, it will be seen, is thus clamped in place separately, and either member can be loosened without loosening the other. This construction is imperative in the matter of handling these heavy parts and clamping them in place in the lathe without the help of a laborer. The brasses are clamped on their faced ends, and are supported and lined up by means of "cat heads." There are two of these for each brass, and each has three bearing points for the inner surface of the work, set to line up the periphery properly, so that it will finish out when it is bored in place in the main casting.

Originally it was proposed that a special double carriage lathe be provided for this work. All that was found necessary, however, was to mount a supplementary slide on the carriage of an old lathe, and provide this with a second toolpost, as shown in Fig. 36. For this

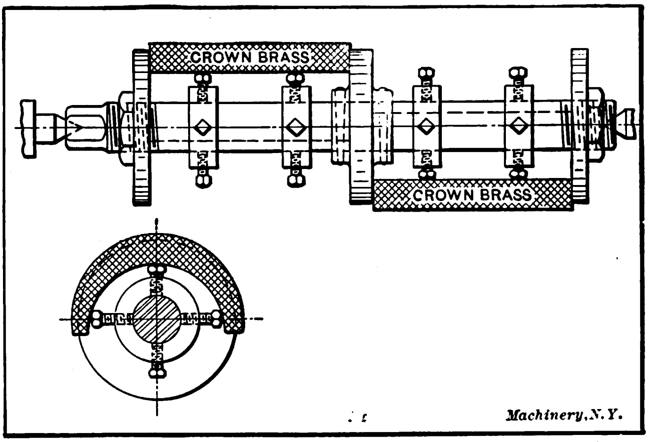

Fig. 37. Details of Special Arbor and Supports used for Turning Crown Brasses

work the arrangement is as satisfactory as a more expensive two-carriage lathe would be. The total time required for taking roughing and finishing cuts on two of these crown brasses is twenty-two minutes.

The final finishing operation on the brasses, before forcing them into the bearings, is that of milling the edges to fit the retaining lips in the bearings. The form is given these edges by means of two formed and relieved milling cutters, as shown in Fig. 38. These are both mounted on the arbor, at the same time, with an overhead support between them to reduce the chattering. A knee-brace is also used, as shown. The work is clamped down to V-blocks, each of which is provided with a hole for the passage of the bolt for clamping them in place, there being a bolt between each adjoining pair of brasses. A gage is provided of the exact contour of the outside and edge of the work, to which the brasses must fit after this cut has been taken.

Allowance is made in this gage for the extra stock required for the force fit for assembling them in the bearings. The time required for each brass on this milling operation is seven minutes.

Operations on the Bronze Thrust Liner

As previously explained, most driving boxes are provided with bronze thrust liners. The first operation required on these liners

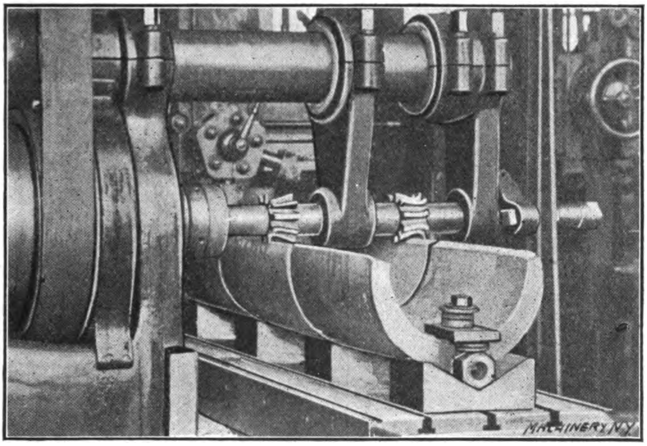

Fig. 38. Milling the Edge of the Crown Brasses for the Fit in the Main Bearing Casting

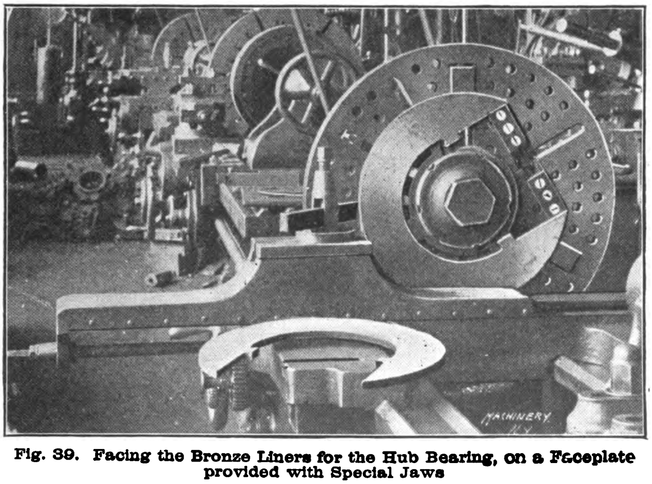

Fig. 39. Facing the Bronze Liners for the Hub Bearing, on a Faceplate provided with Special Jaws

is shown in Fig. 39. This consists in facing the two sides of the phosphor-bronze liner casting. For this work the faceplate of an old lathe was equipped with the simple appliance shown. These appliances consist of three chuck jaws for gripping the outside of

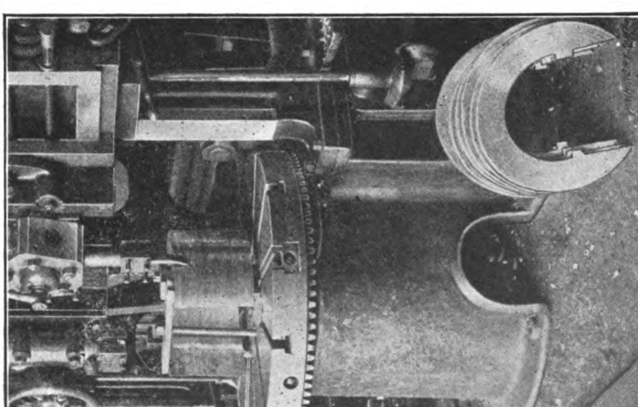

Fig. 40. Turning a Stack of Liners on the Boring Mill, after Facing

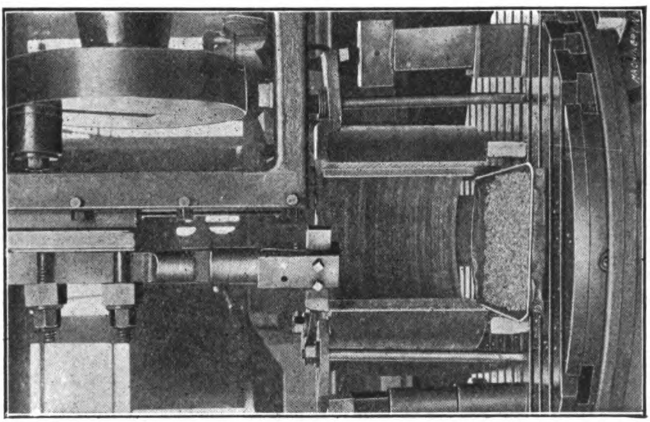

Fig. 41. Slotting out the Cellar-fit in a Stack of Liners

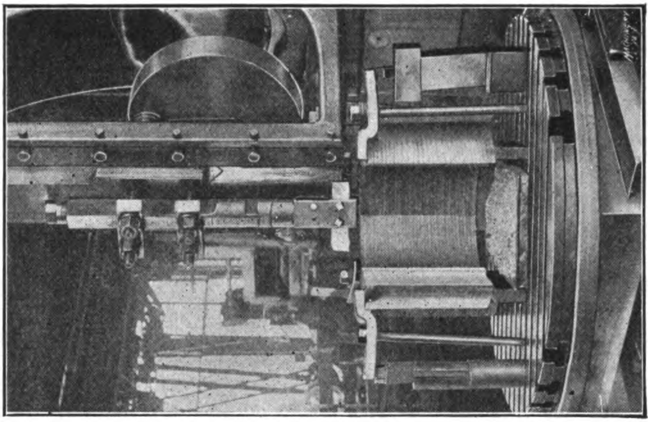

Fig. 42. Machining the Bore of a Stack of Liners on the Slotter

the casting, an adjustable support or spreader for keeping the ends from springing together (as shown, this is operated by a right- and left-hand screw), and a three-bearing centering support in the inside of the casting, clamped in place by the central nut and washer. These simple devices hold the liner firmly in place for facing off front and back. One chip only is taken on the back side, with one roughing and one finishing chip for the bearing side of the liner.

In Fig. 40, the next operation on the liners (that of turning the outside) is shown. This is done on the table of the boring mill without special fixtures. The boring mill has a great advantage over the lathe, where work is to be done in stacks, as in this case. It is possible to locate the work and clamp it in place without difficulty, as there is no tendency for it to fall off the faceplate onto the floor while it is being set and clamped.

The top liner of this pile has been scribed with a templet to the outline desired. This outline is set so as to run concentric with the tool point, and the pile is squared up on its outside edges to match it, so that they all finish out alike. This operation includes two cuts, one roughing and one finishing.

The next operation consists in machining out the interior outline of the liner. This is also done in multiple, a stack of thirty-two being machined at once in the case shown in Fig. 41. As before, the upper liner has had the desired outline scribed upon it, and the circular interior surface or edge has been centered with the axis of rotation of the work-table, the whole pile being carefully lined up with this upper piece by means of a square, set on the table. The work being thus clamped in place, the jaws and lip are first finished out to the required outline (see Fig. 41), and then, as shown in Fig. 42, the rotary feed is applied, and the inner circle is cut out to the desired radius.

First Operations on the Driving Box

The first operation on the main driving box itself consist in machining out the fit for the crown brass. This operation is done on the circular table of the slotting machine, as shown in Fig. 43. The table having been set so that the tool point gives the proper radius, the work is mounted square with the table, and in a position which permits the interior to be machined out, allowing stock all around as well, as determined by a templet laid on the upper surface. The diameter of the crown brass fit, and the depth of cut at the retaining lips are made to match a templet having the exact contour of the crown brass, with suitable allowance for the force fit.

While set up in the slotter for the operation shown in Fig. 43, the workman scribes a line with the surface gage on the face of the casting on each side, at the same height all around. This line is used for the next operation, shown in Fig. 44, which is that of facing the back of the casting in the boring mill. This is being done in the nearest of the three mills shown. By setting the casting up to the scribed lines, the squareness of the facing with the seat for the crown brass is assured. The bearing is then turned over onto this faced

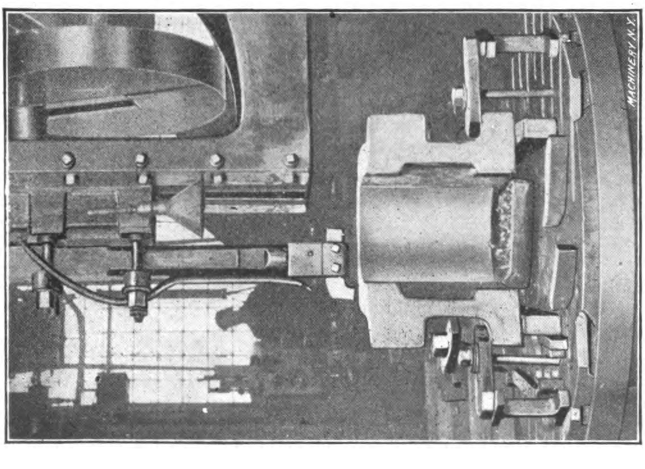

Fig. 43. Machining the Crown Brass Fit

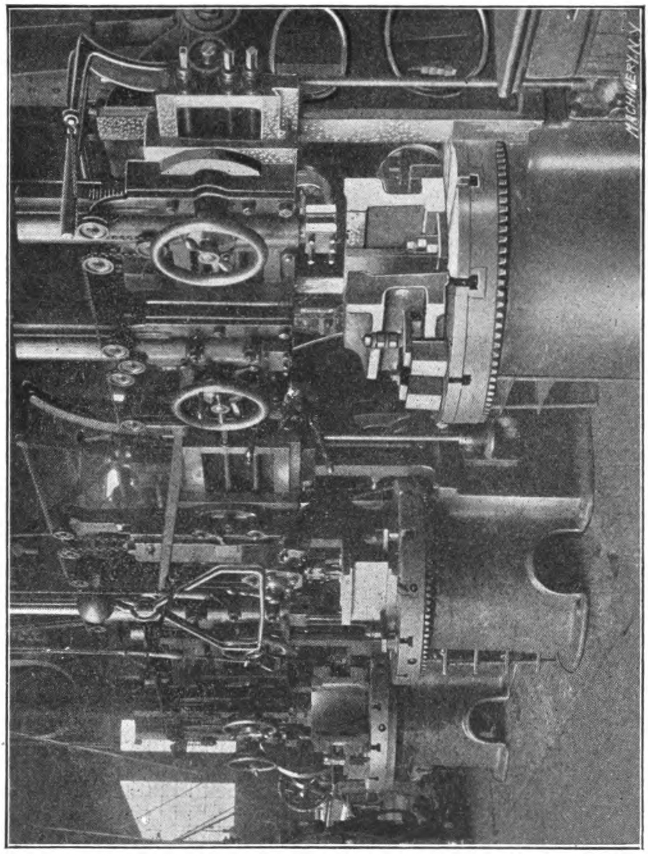

Fig. 44. Facing Operations on the Main Bearing

seat and the outer face with the recess for the liner is machined. Where babbitted thrust surfaces are to be used, this surface is grooved for retaining the babbitt. The total time required for facing both sides, including counterboring and grooving, is two hours.

The work is slotted in this manner before facing, for the reason that the slotting is the vital operation, and the one where there is the greatest liability of not having stock enough to finish out. At the same time the facing, when it is to be counterbored for a bronze liner, must be concentric with the crown brass fit. For this reason it is safest to slot out the fit as the first operation.

Laying-off and Planing the Bearings

The first assembling operation is that of forcing the crown brass into the bearing. This is done under the hydraulic press as shown in Fig. 45. The crown brass is driven in at this time, before the planing operations, for the reason that the pressure of forcing the brass into place springs the bearing casting somewhat, so that it would not be safe to machine it beforehand. The workman consumes about nine minutes per piece in this operation. The castings with the brasses in place are now taken to the laying-off table, where, by means of a templet located by the projecting outside edge of the crown brasses, a line is scribed across the front face of the bearing. This is used in setting up in the operation of planing out the shoe and wedge fits for the frame pedestal.

For this operation, the work is set up on the planer table, as shown in Fig. 46. A large rectangular box casting forming a sort of angle-plate is clamped to the middle of the planer table, with its sides parallel to the ways. To each face of this casting are bolted and strapped six bearing castings as shown. Each of these is shimmed up from the table so that the line scribed in the laying-out operation just mentioned, is parallel with the platen, and at the same distance from the top of the table on all the castings, as shown by the surface gage. When the bearing castings have been set up on each side of the double angle-plate in this way, the grooves for the shoe and wedge fits on each side are planed to the proper width and distance from the front face, and to the proper height from the reference lines scribed by the templet.

The groove for the shoe and wedge fit, of course, is tapered 3/16 inch from each side as shown in Fig. 34, to allow the locomotive frames to rock on the springs without cramping the boxes. To obtain this double taper, each of the bearings is next loosened from position while a parallel shim of the proper thickness is inserted between it and the face of the angle-plate, at what will be the lower end when it is in place on the locomotive. They are then all clamped down again in this position while the planer tools rough out one-half the taper on each side of the slot of each casting. Then the castings are again loosened up while the shim is removed and changed so as to block out the work at what will be the top end of the casting. The work being again clamped down into place, the reverse taper on

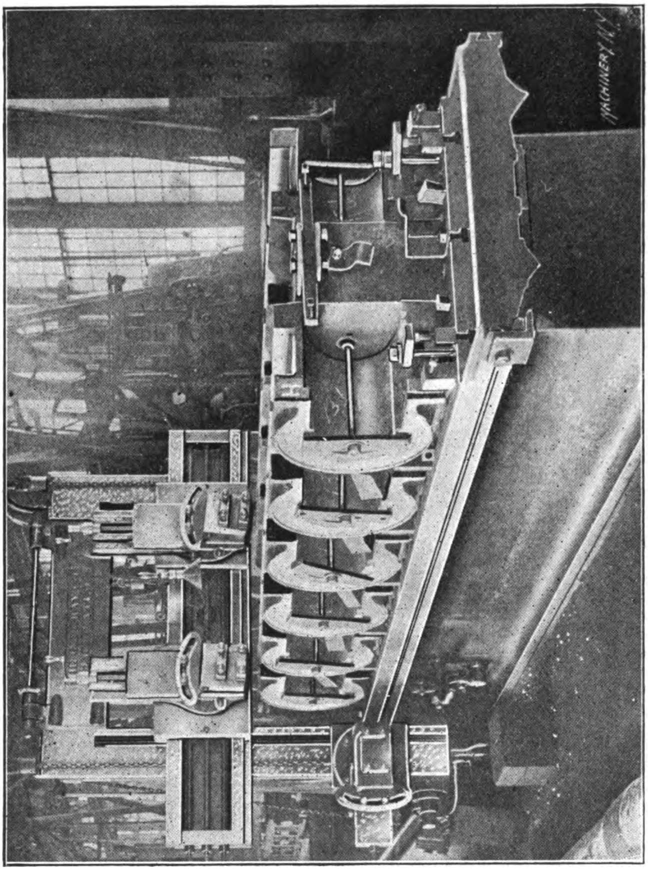

Fig. 46. Planing the Shoe and Wedge Fits in the Main Bearing

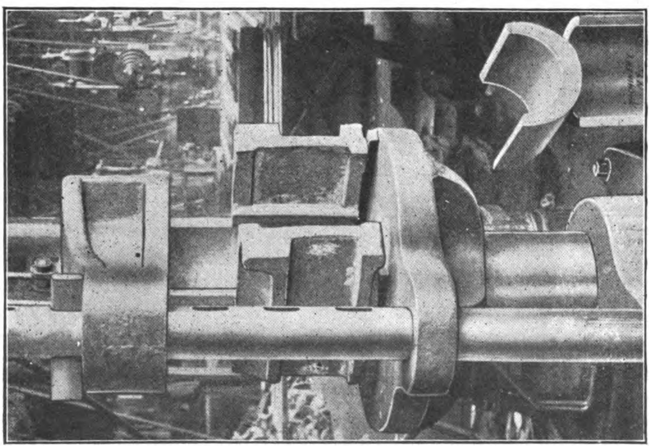

Fig. 45. Forcing the Crown Brass into the Bearing

each side of each slot is worked out. This finishes the slots on one side.

In the next operation the bearings are all turned over and the shoe and wedge fit slots planed on the other side. In this case there is no packing underneath them, nor elaborate setting to be done, as they are simply clamped against the face of the double angle-plate and are squared up by resting on parallels placed between the finished shoe and wedge fit and the top of the table. As before, the double taper to permit the rocking of the engine on the axles and the springs is effected by shimming out first one edge of the box and then the other, on the double angle-plate. The total time on each bearing casting for planing the shoe and wedge fits, with the tapers for the rocking motion, is about three hours.

Miscellaneous Operations

Each box has now to be laid out accurately for the cellar fit, and for boring the crown brasses. This is done by the use of the templet

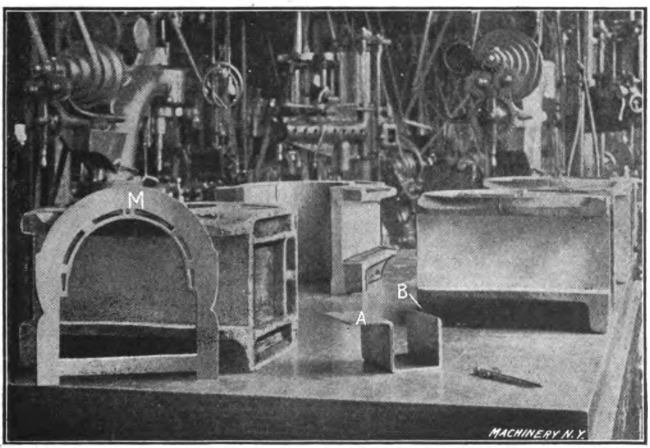

Fig. 47. Laying out the Cellar-fit and Bore on the Bearings

and scratching gage shown in Fig. 47. The face of the scratching gage, shown at *A*, is laid against the bottom of the finished surface of the shoe and wedge fit, while a line is scratched with the scriber along the knife edge *B* on the face of the box liner. Templet *M* is then laid on the face of the casting, and lined up by the mark just scribed. The scriber is again brought into play, and the lines for the bore and for the cellar fit are drawn on the face of the bearing.

In Fig. 48 one of the bearing castings is shown mounted on the table of the slotter for machining the cellar fit. It is mounted on parallels, of course, to allow clearance for the slotting tool. This machining operation simply consists in slotting to the lines scribed by the templet, and to the proper width to fit the cellars. This operaion, on a large bearing, takes about one and one-half hour.

The next operation consists of facing the thrust surface, if babbitt is to be used, or in driving the liner into place if a phosphor-bronze surface is desired. This having been done, the face of the bearing is finished off in the boring mill. This is being done in the middle machine of the three shown in Fig. 44, which happens to be at work on an engine truck bearing instead of a main bearing. The time required for this operation is about nine minutes per piece.

A variety of holes for different purposes have to be drilled in the bearing, with its liner, crown brasses and cellar, which is now fitted into place. These various holes (oil holes, bolt holes, dowel holes for retaining lining, etc.), require about three and one-half hours complete. This varies somewhat, depending on whether hard grease or oil lubrication is to be used.

Boring the Boxes

The next and final operation is that of boring out the bearings. This is done in a double-table boring machine, as shown in Figs. 49

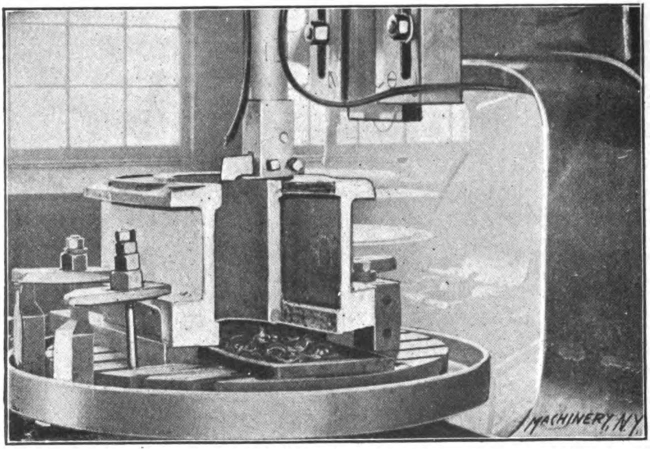

Fig. 48. Machining the Cellar-fit in the Slotter

and 50. It might be asserted, in connection with the opening remarks of this chapter, that this is a special machine. It is so in a sense, as it has a number of special features, consisting principally in the extended length of table used, and in providing two tables instead of one, with an intermediate bushing support. But these features are as applicable and useful in everyday boring practice, where a number of small or medium sized parts have to be handled, as for this particular work; so it is hardly fair to call this a special boring machine for this particular work.

As shown in Fig. 49, four bearings are bored at once, with a multiple blade boring-bar. The tables are long enough so that while this operation is in progress the workman can be removing and replacing four other pieces of work at the other end of the tables. There is thus little or no lost time in the operation of the machine. The workman is kept busy.

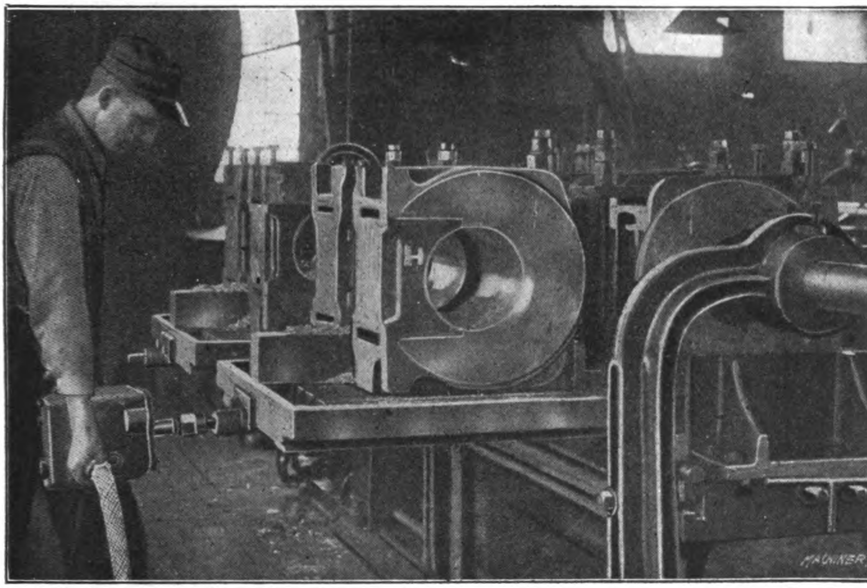

Fig. 49. The Last Operation. Finishing the Bearings on the Boring Machine. Note use of Air Drill for Traversing Double Table

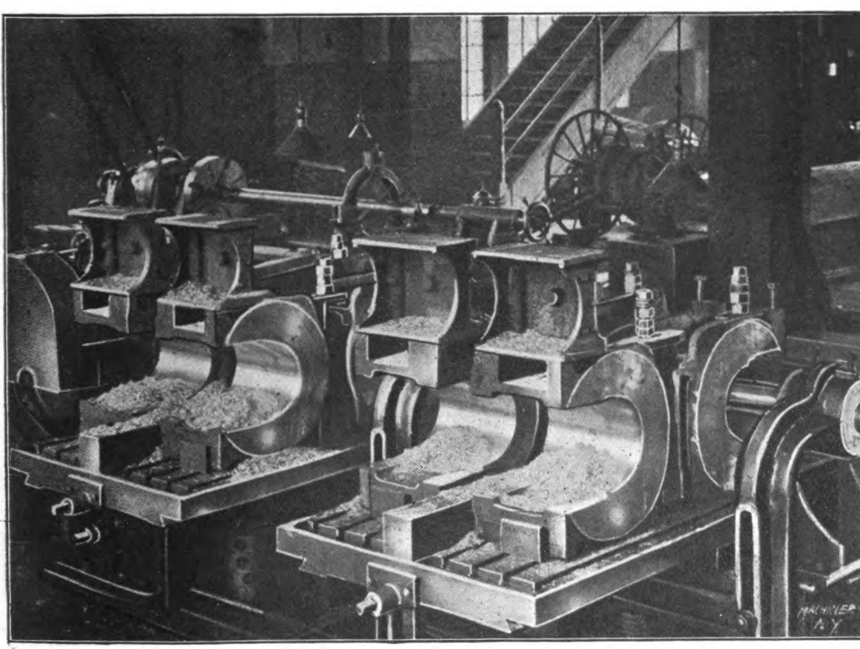

Fig. 50. The Work Completed. Finished Bearings ready for Removal from Boring Machine

As is also shown in Fig. 50, the work is clamped down onto parallels in the shoe and wedge slots, and it is located as well against parallels extending lengthwise of the tables for squaring up the work with the spindle of the machine. The lines scribed by templet *M* in Fig. 47 are relied on for setting the table of the machine to the proper height in beginning a lot of bearings, and also in adjusting each particular bearing to the proper position on the table. For this, measurements are taken from the end of the table to the scribed line on the face of each bearing, and all are made uniform.

Fig. 49 also shows another ingenious feature—namely, the use of an air drill in traversing the table from one extreme to the other, when changing from a finished to a rough set of castings. This distance is so long as to be tedious, when a change is made by hand. By hitching an air drill to the cross-feed, however, it is shifted very rapidly and easily.

This operation of boring the boxes is performed at the rate of fifty-five minutes per box. This includes rounding the corners of the bearing, as shown, and also the boring out of the cellar to the same radius and the same round. The completed work is shown in the foreground of Fig. 50. This is the last operation. At its conclusion the bearings are ready for assembling in the finished locomotive.

The time given on the various operations takes account of setting up the machine, taking measurements, and all other necessary but "non-productive" periods.

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