No. 1279

FINISHING STAYBOLTS AND STRAIGHT AND TAPER BOLTS FOR LOCOMOTIVES

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Non-Member.

The locomotive boiler of average size contains about 1500 staybolts, the number varying from 1200 in the smaller sizes to 2000 or more in the heavier types. They vary in length from 4½ in. to 10½ in. for the water-space bolts, which constitute about 75 per cent of the total number, to about 28 in. for the radial and crown bolts.

2 Probably no part of the boiler is subject to more destructive conditions than these little staybolts. The most serious strains are those due to expansion and contraction of the inner sheet, which bend the bolts and cause them to break close to the outer sheet. This is especially true of the side or water-space stays, which are comparatively short and have very little flexibility.

3 The material used is a high grade of refined iron, close-grained and tough. The pitch being very important on account of entering the second sheet, these stays were formerly cut to length from the bar, drilled for centers, and threaded on engine lathes. The center-drilling was not always concentric and considerable time was required to center the rough bolt so that a good thread could be obtained. This method proving too expensive, bolt cutters were used for the work, but the results were not entirely satisfactory. It was difficult to cut the threads full and smooth with one passage of the chasers and the second passage was taken at the sacrifice of pitch, as well as of time, because there was not enough material to remove to carry the chasers along properly. The introduction of the lead screw in bolt cutters brought about a very considerable improvement in pitch, but still there was trouble in getting the thread smooth for the reason

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that the chasers were not always as accurate as the lead screw, under which conditions the threads would be rough or torn.

4 About thirty years ago the idea was conceived of concaving the bolts or reducing them in the center below the root of the thread, the object being to provide flexibility to compensate for the expansion between the inner and the outer sheets. Laboratory tests showed that a bolt reduced in the center would withstand about twice as many vibrations before breaking as one on which the threads were left straight for the full length. For many years it was the accepted practice to reduce a bolt in diameter on engine lathes after it was threaded in the bolt cutter and drilled for centers. (Figs. 1 and 2.)

5 In 1900, Alonzo Epright, an engineer in the employ of the Pennsylvania Railroad, designed machines which were fully auto-

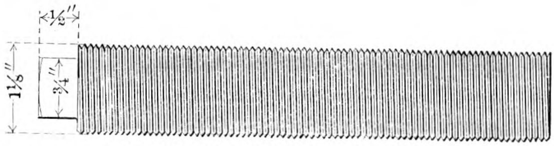

Fig. 1 Square End Water-Space Stay (Plain)

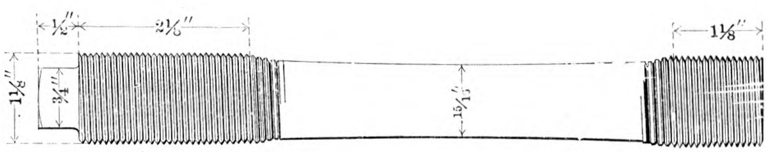

Fig. 2 Square End Water-Space Stay (Concave)

matic in that they made from the bar, threaded and concaved, all diameters of side stays up to 10 or 11 in. in length. The author has no knowledge of the production of these machines and therefore can make no comparison of costs.

6 The vertical type of machine for threading these bolts was used to some extent and it seemed that if the proper chaser could be made the best results would be obtained from this type of machine because the weight of the head would assist the chaser to give an accurate pitch. In the horizontal or bolt cutter type the chaser must carry along the vise and carriage to the detriment of accuracy in the lead. Also, the flow of oil would assist in washing away the chips, which were troublesome in the horizontal machine. Furthermore,

the vertical type of machine is more convenient to operate, one man attending six or eight spindles with ease.

7 After a great deal of experimenting a die head was developed in which, with chasers properly ground, the limit of accuracy of 0.01 in. in 8 in. can be maintained without the use of the lead screw, which is more nearly a perfect pitch than many staybolt taps in daily use. Where a proper lubricant is used a very fine, smooth thread can be obtained at a uniform cutting speed of 20 ft. per min.

8 The turning or reducing tools are shown in Fig. 3, the cutting points being visible at the center, back of the chasers. To these tools

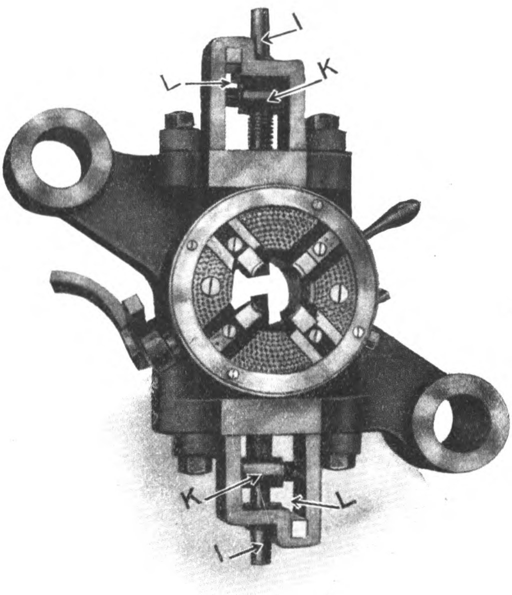

FIG. 3 DIE HEAD FOR THREADING STAYBOLTS

are attached the crossheads *KK*, which are actuated by profilers or formers passing through the spaces *LL*, over which the head is drawn by the chaser, the staybolt acting as a lead screw.

9 The staybolt-threading machine is shown in Fig. 4. The several die heads are attached by small rods to straps passing over the pulleys on a shaft at the top of the machine. The operator grasps one of the strap handles with his right hand and, by the aid of the rotating

pulley over which the strap passes, raises the die head until it comes in contact with the bracket which closes the die. With his left hand he places the squared end of a staybolt in a holder underneath the die and allows the head to drop until the chasers begin to cut, when he moves to the next die head and repeats the operation. By the time he has placed all the heads in operation, the first bolt is finished, the die having dropped automatically when the threading was completed.

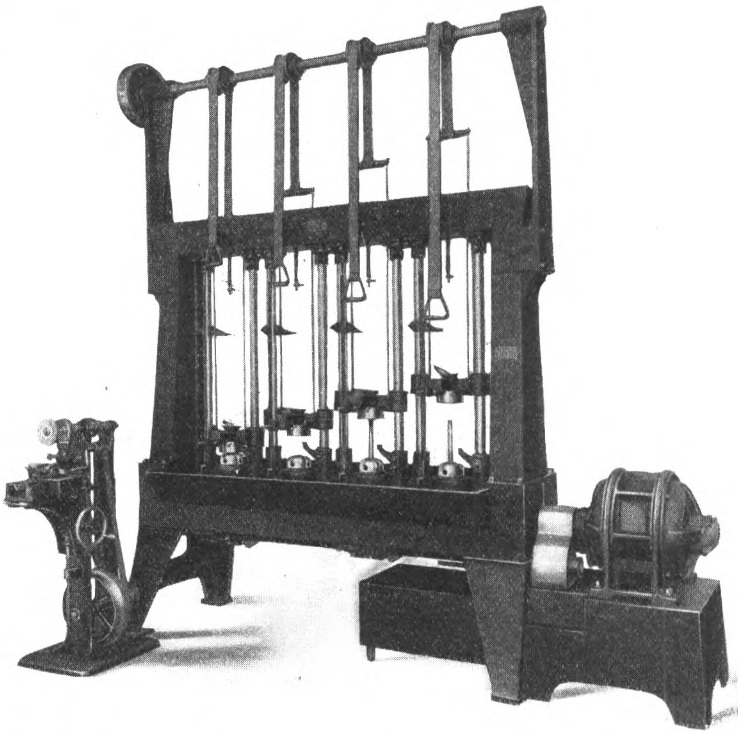

FIG. 4 STAYBOLT-THREADING AND REDUCING MACHINE, WITH SPECIAL GRINDER FOR CUTTING TOOLS

10 In Fig. 4, the die head at the right is shown raised sufficiently to insert the staybolt in place; the next at the left is just beginning to thread the bolt and the two other die heads are in still lower positions.

11 A comparison of costs by the two methods, taking a $7\frac{1}{2}$-in. side stay as an average length, would be about as follows:

FORMER PRACTICE

Threading-in bolt cutter, usually taking two cuts at $0.20	$0.40
Drilling for centers	0.22
Concaving or reducing on engine lathe	0.75
Cost per hundred	$1.37

PRESENT PRACTICE

Present cost, threaded the entire length or threaded and concaved for all sizes and lengths, per hundred	$0.13

Using the average number of stays, a saving of labor cost of $18.60 per boiler is obtained with a minimum of rejected stays.

METHODS OF DRILLING STAYBOLTS

12 The telltale holes which are drilled in the staybolts have been the cause of considerable expense and annoyance. Some railroads drill them after the stays are placed in the boiler, with pneumatic hand drills. Under these conditions there is danger that the hole may not be central. It often happens that the drill runs through into the water space or is broken off in the hole. In either case it is necessary to remove the bolts and put in others. Sometimes the holes are drilled on a vertical drilling machine before being placed in the boiler. Even then the breakage of drills is very large, averaging about sixteen to the boiler, and each broken drill means a staybolt thrown away.

13 An automatic machine has been devised for drilling these holes before the stays are placed in the boiler. They are fed from a hopper and automatically centered in position for the drill. When the hole is bored about one-third of the depth, the drill is withdrawn and the bolt is carried forward in the turret mechanism which holds it to a second and a third drill, completing the hole. Each drill is 0.01 in. smaller than the preceding one, providing for a minimum of friction and a maximum of clearance of chips. The holes are of uniform depth and in the center of the bolt. The average breakage is about three or four drills to the boiler.

COMPARISON OF COSTS

Drilling in the boiler, per hundred (to which should be added the cost of replacements)	$0.90
Drilling under drill press, per hundred (to which should be added cost of drills and waste of material and labor)	0.45
Drilling in the automatic machine, per hundred (with the minimum number of broken drills and bolts destroyed)	0.12

METHODS OF FINISHING STRAIGHT AND TAPER BOLTS

14 The usual method of finishing straight and taper bolts for locomotives was to drill for centers, place in engine lathes, face under the head, turn the body taper, turn the part to be threaded straight and to proper size, face down the thread end to length and shape, leaving the center intact, test and file to accuracy, and cut off center point, after which the bolt is ready to be threaded in the bolt cutter and to have the hexagon head changed to any special shape desired.

15 About 1889, S. M. Vauclain, Mem.Am.Soc.M.E., designed and used a turning head in connection with a vertical machine for bolts up to 12 in. long. Under rights obtained from him the Pennsylvania Railroad placed an equipment of this kind in its Altoona shops and that is the only railroad known to the author using other than engine lathe methods in finishing bolts.

16 As a great many straight and taper bolts used in locomotives are 12 in. to 20 in. in length and even longer, it became necessary to design for this work a turning head which would handle taper bolts up to 18 or 20 in. in length and up to $1\frac{3}{4}$ in. diameter of thread, and straight bolts in any length up to 27 in. and up to $2\frac{1}{2}$ in. in diameter. It may be quite possible to go beyond these dimensions should the specifications require. These requirements have been met by a special machine of the vertical, multiple-spindle drill type, with which is used a special cutter head shown in Fig. 5. This head is the real or essential means of producing these bolts, either straight or taper and cylindrically true to the axis, the machine being simply a proper means of driving and feeding the bolt during the turning operation.

17 The cutter head consists of a retaining shell of cast iron, the bore of which must be round and straight; six segments, three of which are rigidly fastened to the shell, the other three having a limited amount of freedom and being fastened in place by a taper key with an adjusting screw located in the center of the radius with a bearing on the shell; and three blades, alternating with three guides, placed between the segments and backed up with taper keys and adjusting screws. The taper keys, in connection with a certain amount of taper on the blades and guides, have sufficient movement to provide for about one-eighth inch adjustment for re-grinding of the blades, or with the same amount on the guides, one-quarter inch in diameter of bolts. It will readily be seen that when an accurately ground plug gage of the size that it is desired to turn the bolt is placed centrally in the head, the blades and guides can be adjusted to their proper position. The three

loose segments are then forced forward by the taper key, clamping the blades and guides rigidly in their proper working position.

18 The economical use of this method of turning bolts, particularly in the railroad shops and locomotive works where taper bolts are largely used, necessitates a change of system. The usual practice, especially on repair work, has been to carry in stock only standard sizes of forgings, though in some cases the more common sizes were placed in stock finished. With the engine lathe located near the loco-

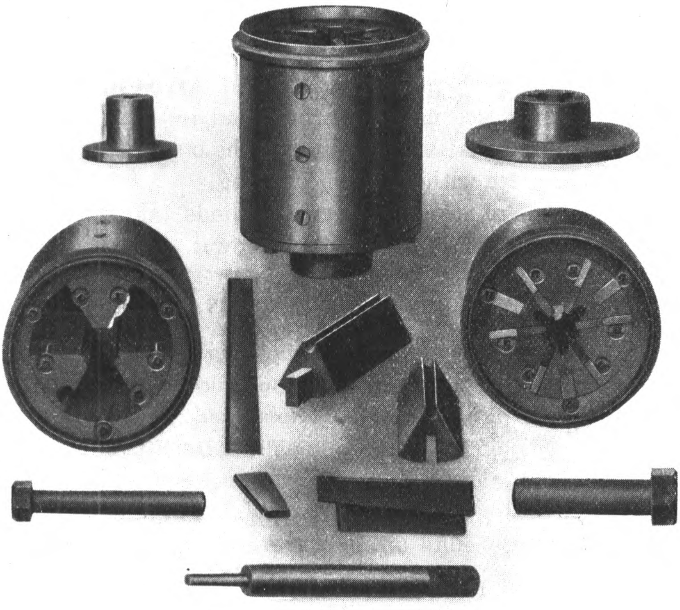

FIG. 5 CUTTER HEAD AND ATTACHMENTS

motive being repaired, the bolts were fitted to the hole after the least possible amount of reaming had been done that would clean up the hole.

19 The improved system contemplates the turning, facing under the head, and placing in stock of standard sizes in lengths of 6, 9, 12, 15, and 18 in. and varying in diameter under the head by thirty-seconds of an inch. Stock may be kept in sixty-fourths of an inch if desired, but very few holes will be found which require less than thirty-

seconds of an inch to clean up. In fact, the chief reason for carrying the intermediate sizes would be to save the hole when it cannot be cleaned up within the next thirty-second. Standard reamers are used, with collars or marks to indicate when they have been driven to the required depth. All bolts have standard hexagon heads conforming to the thread diameter. The sizes of stock are given in Table 1.

20 Bolts are specified with relation to the length and the diameter under the head, and the stock size next longest is used. Under these conditions not more than 3 in. must be cut off to bring the bolt to the proper length. The stock bolts are then taken to the bolt-altering machine, which is a quick-acting hand machine equipped with collet chucks and split bushings for the various diameters of the bolts. The end may be cut off to the proper length and turned for cotter pins, and the head changed to counter sink, box head, button head, or whatever may be required. After threading on the bolt cutter, the bolt is ready to drive in place without further fitting.

21 A comparison of costs by the two methods, taking a $1\frac{1}{8}$ in. by 9 in. bolt as an average would be about as follows:

ENGINE LATHE PRACTICE

	Cost per hundred
Drilling for centers	$0.22
Turning in lathe	2.50
Altering in lathe	$2.50 to 3.50
Threading in bolt cutter	0.22
Cutting off center points	0.10

PRESENT PRACTICE

Pointing the blank	$0.12
Turning by the method described	0.45
Cutting off and changing points and heads where necessary on the bolt-altering machine	$0.40 to 0.60
Threading in the bolt cutter	0.22

22 A device is now being perfected by which the threading can be done automatically at the same time the turning is done. This not only eliminates the bolt cutter charge of $0.22 per hundred, but assures a full, uniform thread absolutely in line with the body of the bolt and square with the facing under the head. When used in connection with a nut faced squarely with its thread, the most satisfactory bolt is obtained.

23 A combined turning and threading device implies a modified form of the cutter head previously described, underneath which is

TABLE 1 STOCK SIZES

Showing 8 Threaded Diameters of Bolts and 32 Diameters Under the Head

Thread Diameter	3/4				7/8				1				1 1/8			
Diameters under head	25/32	13/16	27/32	7/8	29/32	15/16	31/32	1	1 1/32	1 1/16	1 3/32	1 1/8	1 5/32	1 3/16	1 7/32	1 1/4
Length under head	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	....	....	....	....	9	9	9	9	9	9	9	9	9	9	9	9
	....	....	....	....	....	....	....	....	....	12	12	12	12	12	12	12
	....	....	....	....	....	....	....	....	....	....	....	....	15	15	15	15
	....	....	....	....	....	....	....	....	....	....	....	....	....	....	18	18

Thread diameter	1 1/4				1 3/8				1 1/2				1 5/8			
Diameter under head	1 9/32	1 5/16	1 11/32	1 3/8	1 13/32	1 7/16	1 15/32	1 1/2	1 17/32	1 9/16	1 19/32	1 5/8	1 21/32	1 11/16	1 23/32	1 3/4
Length under head	6	6	6	6	6	6	6	6	....	....	....	....	....	....	....	....
	9	9	9	9	9	9	9	9	....	....	....	....	....	....	....	....
	12	12	12	12	12	12	12	12	12	12	12	12	....	....	....	....
	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18

attached a die head of special construction. This die head is carried on four or more vertical rods or guides which are attached to a ring to which the cutter head is fastened. Provision is made for squaring the die head with the cutter head at the time it begins cutting the thread, and at the same time automatically placing the die head in a position where it is free to move in a vertical plane up or down in exact proportion to the difference between the feed and the pitch of the thread to be cut. An automatic knock-out is provided which opens the die head and passes to one side, allowing the threaded bolt to go through to any length within the feed of the machine Under these conditions it will be seen that so long as the length of the thread to be cut is the same, the length of bolt to be turned is immaterial. The device is very simple in its construction and does not call for a skilled mechanic to adjust or operate it.