Dec. 14, 1937. L. D. SLADE 2,102,040

METHOD OF AND APPARATUS FOR HARDENING GEARS

Filed Aug. 4, 1934 3 Sheets-Sheet 1

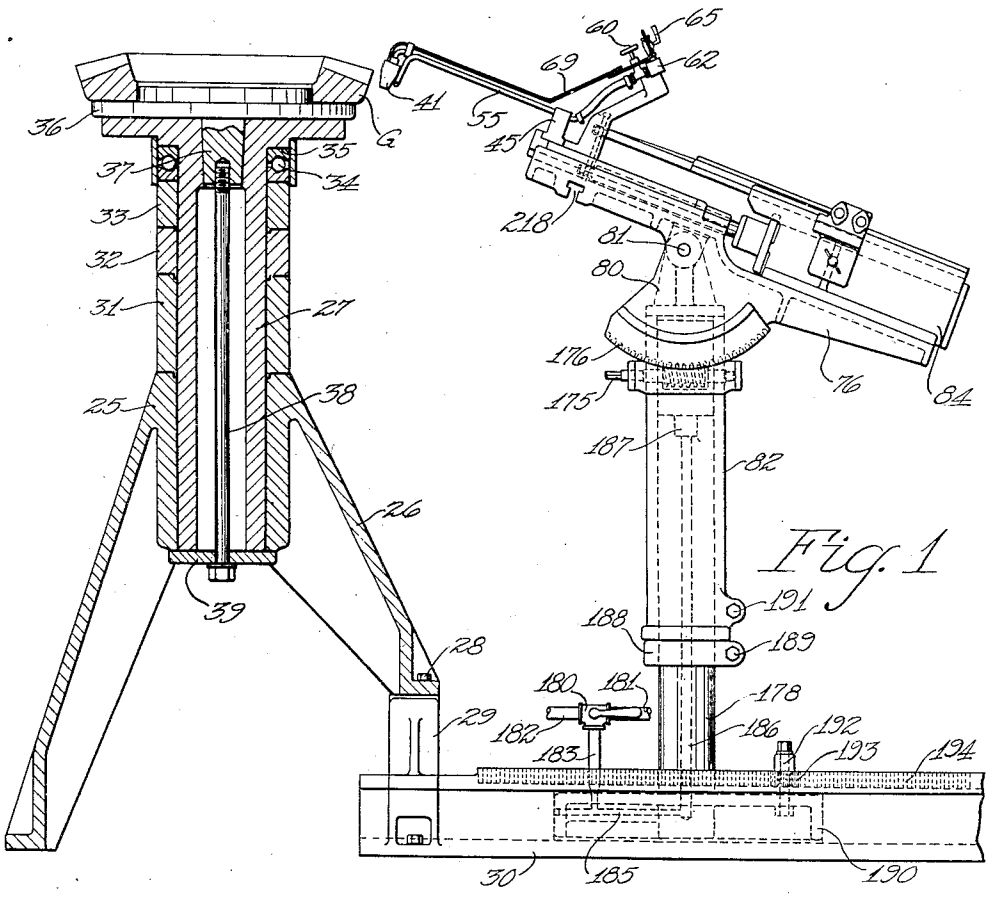


Fig. 1

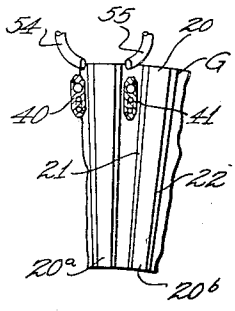


Fig. 9

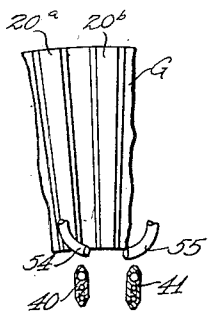


Fig. 10

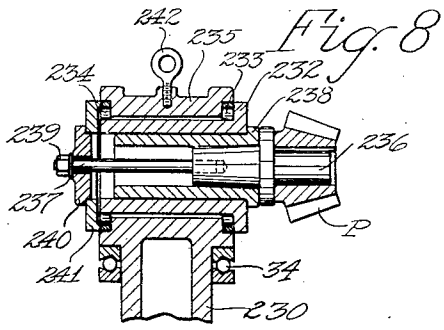


Fig. 8

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METHOD OF AND APPARATUS FOR HARDENING GEARS

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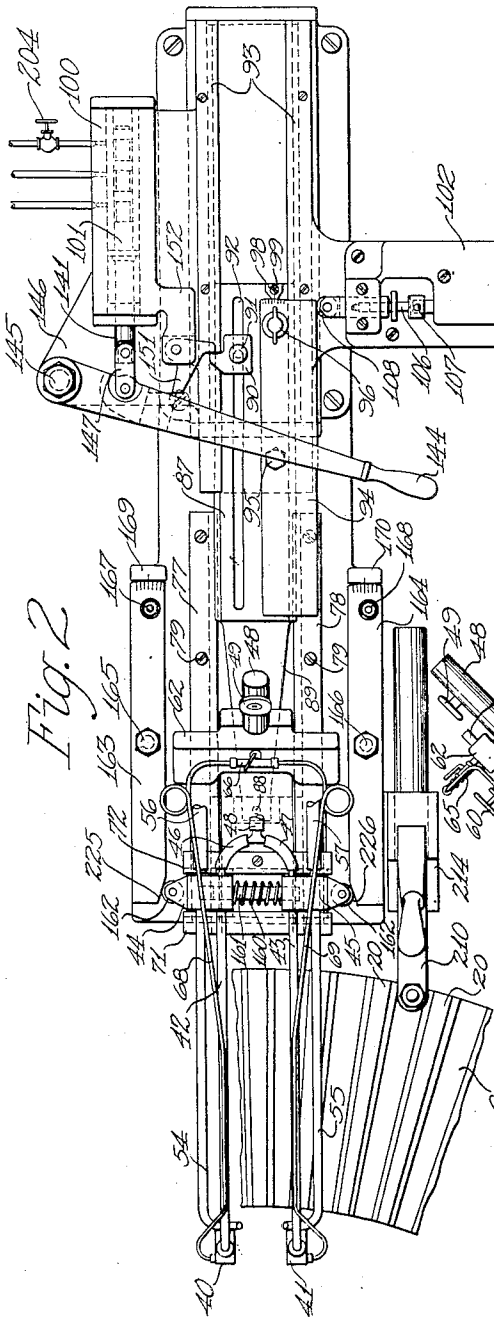


Fig. 2

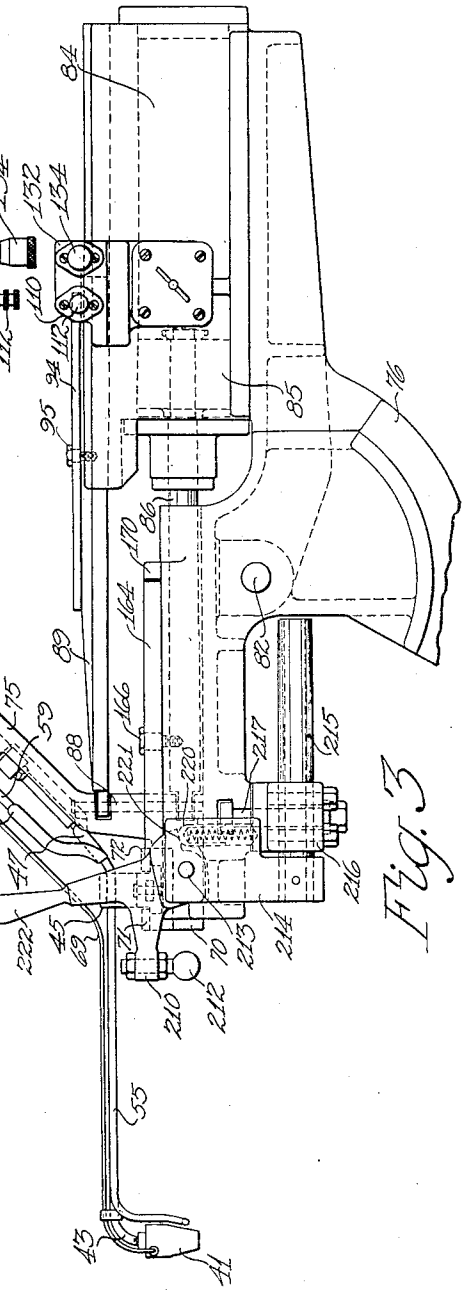


Fig. 3

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METHOD OF AND APPARATUS FOR HARDENING GEARS

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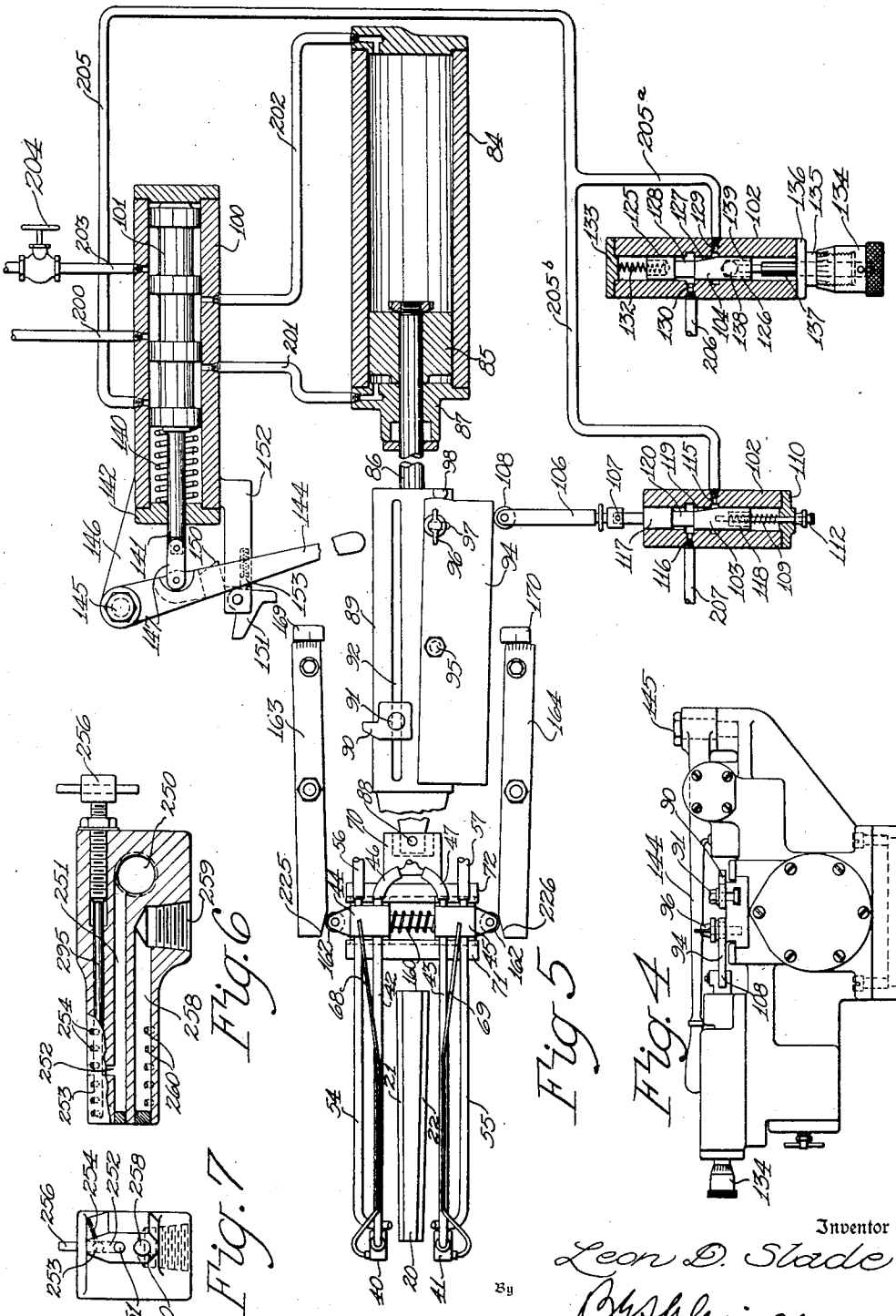


Fig. 6

Fig. 7

Fig. 5

Fig. 4

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UNITED STATES PATENT OFFICE

2,102,040

METHOD OF AND APPARATUS FOR HARDENING GEARS

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Application August 4, 1934, Serial No. 738,570

25 Claims. (Cl. 148—21)

The present invention relates to the surface hardening of metal articles and particularly to the surface hardening of gears and more especially of tapered gears such as bevel and hypoid gears. In a still more particular sense, this invention relates to a method and apparatus for surface-hardening gears in which a blow-torch for applying an intense heat is traversed along a gear tooth from one end to the other and the tooth is progressively quenched immediately after the intense heating by spraying it locally with some cooling medium such as water or oil. It is within the contemplation of the invention, however, to treat gears made of air-hardening steel also by simply bringing the teeth up to the desired heat by the blow-torch and then allowing the air to cool and harden them.

In the surface-hardening of gears, it has been the practice heretofore simply to traverse a flame along the tooth surface to be treated and progressively quench the tooth immediately after it has been treated.

Generally speaking, the surface-hardening apparatus heretofore built falls into two different classes. In one type of apparatus, the heating-flame is applied while the blow-torch is moving in one direction along a side of a tooth only and the flame is shut off at the end of the stroke and the gear is indexed while the blow-torch is being returned to original position preparatory to the hardening of another tooth. In the other type of apparatus the heating-flame is applied both on the forward and return strokes of the blow-torch, but the gear is indexed between strokes in opposite directions, one tooth being treated on a forward stroke and the next adjacent tooth being treated on the return stroke. In both forms of apparatus, a single torch only has been provided and only one side of a tooth has been hardened at a time. The second form of apparatus theoretically is more efficient than the first, but has not been used to any appreciable extent because in such apparatus as has heretofore been built the angular position of the blow-torch must be reversed between strokes in opposite directions and this involves complications. In the first form of apparatus, the return stroke is an idle stroke, and, therefore, wasteful of time.

In both forms of apparatus, the heating-flame is required to raise the temperature of a cold tooth up to the intense heat required for hardening and therefore the rate of traverse of the torch along the tooth is comparatively slow.

The primary purposes of the present invention are to provide a method and apparatus for surface-hardening gears which will be more efficient, faster, and more economical than surface-hardening methods and apparatus heretofore employed. To these ends, the heating-flame is first traversed in one direction along a tooth to preheat the tooth and then is immediately traversed back along the same tooth to harden it. Then the gear is indexed. The preheating stroke of the blow-torch raises the temperature of the tooth to a point close to the hardening temperature so that on the subsequent hardening-traverse of the torch over this tooth, the torch is required to raise the temperature of the tooth a very much less amount than if the tooth were cold and hence the torch can be moved more rapidly during the hardening traverse than has heretofore been possible and the hardening operation can therefore be accomplished in much less time and with much less cost than has heretofore been possible. Moreover, a preheated tooth will be hardened deeper than a tooth that is not preheated and this without applying excessive heat at the surface of the tooth. Further than this, by preheating there are less surface strains set up in the hardening process. This last feature is especially important if for any reason a tooth has to be hardened a second time. Without a preheating stroke cracks are very liable to develop. The preheating stroke is always made at a fast enough speed so that the surface of the tooth does not get to the hardening heat; otherwise it might crack on the hardening pass.

Still further, it is an object of the invention to provide apparatus for hardening both sides of a tooth simultaneously. This again is an improvement in efficiency and makes possible a further reduction in hardening time.

Another object of this invention is to provide apparatus having a simple adjustment for control of the speed of traverse of the torch on the hardening stroke so as to permit the speed of traverse of the torch to be varied to conform to the tooth thickness, tooth height, etc. of the gear to be hardened. This speed-control has a special application in the hardening of tapered gears, where the speed of traverse can be varied during the traverse in order to take care of the change in thickness and height of the tooth from end to end.

Another object of the invention is to provide simple means for controlling the path of traverse of the torch, which is interchangeable so as to permit the same apparatus to be used to harden gears of different lengthwise tooth-shapes.

A further object of the invention is to provide

simple and inexpensive, semi-automatic, fluid-pressure operated apparatus which with but slight modification can be used for surface-hardening various types of gears.

Still another object of the invention is to provide an improved form of blow-torch which will be equally effective in both directions of traverse and which can be readily adjusted to control the area of the flame to suit the height of tooth of the gear to be treated.

Other objects of the invention will be apparent hereinafter from the specification and from the recital of the appended claims.

A preferred embodiment of the invention is illustrated in the accompanying drawings in which:

Fig. 1 is a side elevation, with parts shown in section, of the surface-hardening apparatus as adjusted for hardening a bevel gear;

Fig. 2 is an enlarged plan view, showing the torches and spray pipes and the traversing and control mechanisms therefor;

Fig. 3 is an enlarged side elevation of the parts shown in Fig. 2;

Fig. 4 is an end view of the parts shown in Figs. 2 and 3, looking at the end opposite to that on which the torches are mounted;

Fig. 5 is a diagrammatic view illustrating the construction and principle of operation of the hydraulic control mechanism;

Fig. 6 is a sectional view through a preferred form of torch employed in practicing the present invention;

Fig. 7 is a bottom plan view of this torch;

Fig. 8 is a fragmentary sectional view, showing the work-head employed when hardening pinions; and

Figs. 9 and 10 are diagrammatic views illustrating, respectively, the positions of the torches and spray-jets at the beginning of a hardening stroke and at the beginning of the return preheat stroke.

The present invention has been illustrated in connection with apparatus set up for hardening the teeth of a straight bevel gear. Two blow-torches for burning oxy-acetylene gas are provided, and are so arranged that they heat opposite sides of a tooth of the gear simultaneously. There is a spray-jet provided in conjunction with each torch and arranged with relation to the torch so that the tooth is sprayed progressively with a cooling medium, such as water, immediately after it is heated up by the torch. The apparatus is provided with control bars or cams, which can be adjusted to cause the paths of the two torches to converge as they move from the large to the small end of a bevel gear tooth so that the torches will remain at a uniform distance from the sides of the tooth despite the lengthwise taper of the tooth itself. The two torches and their cooperating spray-jets are mounted upon a movable ram, which is hydraulically operated to reciprocate the torches over the tooth and control valves are provided to control the speed of movement of the torches on the hardening stroke to compensate for the change in tooth thickness and height of the tooth from end to end. A control valve is also provided to govern the speed of the return or preheating stroke in accordance with the thickness of the teeth to be hardened.

I shall first describe the apparatus as set up for hardening a bevel ring-gear.

The gear to be hardened is denoted at G in Figs. 1, 2, 9 and 10. It has straight teeth **20**, whose opposite sides **21** and **22** converge from their outer to their inner ends.

The work support comprises a tripod **25**, which has one short leg **26**. This tripod is provided with a central bore in which the work-spindle **27** is journaled. The two long legs of the tripod rest upon the floor and the short leg **26** is secured by bolts **28** to a cross-piece **29** that is fastened to or formed integral with a base-plate **30** which forms a support for the ram that carries the torches. This base-plate **30** rests upon the floor.

The distance of the work above the floor can be varied, as is required for gears of different sizes and for different types of gears, by use of a set of nesting interchangeable rings, of which three are shown in Fig. 1 and designated **31**, **32** and **33**, respectively. These rings are provided with bores that align with one another and with the bore of the tripod **25**. The spindle **27** is, therefore, journaled in the rings and the tripod.

One or all of the rings **31**, **32** and **33** can be removed to vary the height of the work above the floor or additional rings can be added if required. A ball bearing **35** is provided to be interposed between the shoulder of the work-spindle and the upper face of the uppermost ring or the upper face of the tripod in case all of the rings are removed. This ball-bearing allows of free turning movement of the work-spindle.

The gear G is mounted on the centering-plate or arbor **36**. This seats against the upper face of the work-spindle and is provided with a tapered projection **37** that fits into a correspondingly tapered portion of the bore of the work-spindle. The arbor is secured to the work-spindle by the draw-bar **38**. The head of this draw-bar engages a plate **39** which is adapted to seat against the lower face of the bearing portion of the tripod.

There are a pair of torches provided with the apparatus illustrated. These are designated **40** and **41**, respectively. Preferably water-cooled torches are employed, as shown.

The torches are secured to oxy-acetylene feed-pipes **42** and **43**, respectively. These pipes are secured in blocks **44** and **45**, respectively (Figs. 2, 3 and 5) and are connected by flexible tubing **46** and **47**, respectively, with a pipe **48**. The gas-mixture is supplied to this pipe in any suitable way. There is a manually operable control valve **49** in this pipe to turn on or shut off the gas.

To quench the sides of the teeth immediately after they are heated and as the torches move progressively along the teeth from one end to the other, they are preferably sprayed with jets of water. To this end, a pair of spray-pipes **54** and **55** are provided. These operate, respectively, in conjunction with the blow-torches **40** and **41**. The spray-pipes are preferably made of a flexible copper tubing so that they can be readily bent to direct the liquid used as the quenching medium on the tooth surfaces at points immediately behind the torches.

The pipes **54** and **55** are also secured in the blocks **44** and **45**, respectively. They are connected by flexible hose **56** and **57**, respectively, with a single Y-pipe **59** and this is, in turn, connected through a hand-operated valve **60** with a casing **62** to which is connected the water-supply pipe **63** through which water is pumped to the casing from any suitable source.

In the apparatus shown, water is employed for cooling the torches. It is supplied to the two torches from the casing **62** through a valve **65**, the T **66**, and the flexible tubing **68** and **69**, respectively.

The blocks **44** and **45** are slidable transversely

in ways formed in the reciprocal head or ram 70. The blocks are held in the ways by gibs 71 and 72.

The casing 62 and gas-supply pipe 48 are mounted upon a bracket 75 which is integral with the head 70.

The head 70 reciprocates in ways formed in a supporting bracket 76 and is held in these ways by gibs 77 and 78 which are secured to this bracket by screws 79.

The bracket 76 is trunnioned on the head 80 of a cylinder 82 to which further reference will be made later, the pin 81 serving as a journal on which the bracket 76 is angularly adjustable.

The bracket 76 carries a cylinder 84 in which the piston 85 is reciprocal. There is a piston-rod 86 secured to this piston 85. This piston-rod projects through the front end wall 87 of the cylinder 84 and is connected by the pin 88 with the bracket 75 and its integral head 70. The pin 88 serves also to connect a plate 89 with the bracket and head.

The plate 89 reciprocates with the head 75. It slides in ways 93 provided on the top wall of the cylinder 84. The plate 89 carries a trip-lug 90, the purpose of which will be described hereinafter. This trip-lug is longitudinally adjustable along a longitudinal slot 92 formed in the plate 89 and is held in any adjusted position by means of the bolt 91 which engages in this slot.

The plate 89 also carries an angularly adjustable cam-bar or plate 94. This is pivotally mounted on a bolt 95 that threads into the plate 89 and is held in any position of its angular adjustment by the butterfly nut 96 which threads upon a bolt that is secured in the plate 89 and passes through an arcuate slot 97 in the cam-bar that is concentric with the pivot-bolt 95. The cam-bar 94 is graduated at one end to read against a zero mark on a lug 98 that is secured by the screw 99 to the upper face of the plate 89.

At one side of the cylinder 84 there is mounted a housing 100 for a reverse valve 101. At the other side of the cylinder there is mounted a housing 102 which contains a pair of throttle-valves 103 and 104, which are shown in section in Fig. 5. The reverse-valve controls the directions of movement of the head 70 under actuation of the piston 85. The throttle valves control the speed of this movement in one direction, namely, during the hardening stroke.

There is a rod 106 secured to the stem of the valve 103 by a pin 107. This rod slides in a guide-bore provided on the valve-casing 102 and at its free end, the rod 106 carries a roller 108 which is adapted to engage and ride on the side surface of the cam-bar 94. The roller 108 is held against the bar 94 by a coil-spring 109 which is interposed between the valve-stem 103 and the plate 110 that closes the bore of the casing 102 in which the valve 103 slides. The spring 109 surrounds a pull-rod 112 which is secured to the valve-stem 103 and which extends through an opening in the plate 110 and has a knob 112 at its outside end to permit manipulation of the valve 103.

The valve-casing 102 is provided with an inlet port 115 and an outlet port 116. The valve 103 is provided with cylindrical guide surfaces or lands 117 and 118, respectively, adjacent its two ends. The valve has a beveled portion 119 merging with the cylindrical portion 118 and controlling the area of the port-opening 115. The cylindrical land 117 is connected with the beveled portion 119 by a portion 120 of reduced diameter. The area of opening of the port 115 controls the rate of movement of the piston 85 and is controlled in turn by the setting and shape of the cam-bar 94, as will hereinafter be described more particularly.

The valve 104 provides a basic control over the speed of movement of the piston 85 during the hardening stroke which is independent of the position of the valve 103. The valve 104 is of the same general construction as the valve 103 having cylindrical guide portions 125 and 126 at its opposite ends with a beveled portion 127 merging into the cylindrical portion 126 and with the beveled portion 127 connected to the guide portion 125 by a cylindrical portion 128 of reduced diameter. The beveled portion 127 controls the area of opening of the inlet port 129. The exhaust port is indicated at 130.

The valve 104 is pressed toward full-open position by a coil-spring 132 which is interposed between the inner end of the valve and the end-plate 133 of the valve-casing 102. The area of opening of the port 129 can be adjusted by rotation of a knurled-nut 134, which threads onto a collar 135 that is formed integral with the plate 136 that closes the outside end of the bore in which the valve 104 reciprocates. The nut 134 is pinned to a rod 137 which passes through the end-plate 136. Its inner end is of reduced diameter and engages a ball 138 that is seated in a recess 139 formed in the valve-stem 104. The sleeve of the knurled-nut 134 is beveled at its inner end and the beveled portion is graduated to read against a zero mark on the sleeve 135 to permit accurate adjustment of the valve-opening.

The reverse valve 101 is of usual construction. It is moved in one direction by a coil spring 140 which surrounds the valve-stem 141 and is interposed between one end of the valve and the plate 142 which closes the adjoining end of the valve-casing 100. The valve is moved in the opposite direction by hand-lever 144. This lever is pivoted at 145 on a lug 146 formed integral with a side wall of the cylinder 80. This lever 144 is connected to the valve-stem 141 by a link 147.

The reverse valve is adapted to be releasably locked in the position to which it is moved manually. To this end, the lever 144 is formed with a lug 150. This is adapted to be engaged by the lock-dog 151. The lock-dog 151 is pivotally mounted on a lug 152 extending from the casing 100 of the reverse-valve. The lock-dog is constantly pressed toward locking position by a spring-pressed plunger 153 which is housed in the lug 152.

To produce a return or preheating movement of the piston 85, the lever 144 is swung from the position shown in Fig. 5 to the position shown in Fig. 2. The lock-dog 151 engages and holds the lever in this latter position until at the end of the return movement of the piston 82, the trip-dog 90 engages the tail of the lock-dog, disengaging the lock-dog from the lug 150 and releasing the lever. Then the spring 140 acts to reverse the valve 101 and effect automatically a forward movement of the piston.

The blocks 44 and 45 previously described are pressed apart by a coil-spring 160 which is interposed between their opposed inner faces. This spring is mounted on a rod 161 whose opposite ends enter holes in the opposed faces of the two blocks. At its outer end, each of the blocks 44 and 45 carries a roller 162.

These rollers 162 are arranged to ride on cam-bars 163 and 164, respectively, which are pivotally

mounted for adjustment upon the upper face of the bracket 76. The cam-bars 163 and 164 adjust about studs 165 and 166, respectively, that thread into the bracket 76. The bars are secured in adjusted positions by bolts 167 and 168, respectively, which pass through arcuate slots in the bars and thread into the upper face of the bracket 76. The bars are graduated at one end to read against zero marks inscribed on lugs 169 and 170, respectively, which are integral with the bracket 76.

From the preceding description it will be seen that as the ram 70 is moved longitudinally under actuation of the piston 85, the blocks 44 and 45 will be moved transversely toward or from one another depending upon the shape and setting of the cam-bars 163 and 164. Thus as the torches and jets move longitudinally along a tooth, they may also be moved transversely to maintain them at a uniform or at varying distances from the sides of the tooth.

The bracket 76, as above mentioned, is trunnioned on the head 80 of a cylinder 82. To adjust the bracket 76 angularly about its pivot point a worm shaft 175 is provided. This worm shaft is suitably journaled externally on the cylinder 82 and the worm which it carries, meshes with a worm-wheel segment 176 which is secured to or integral with the bracket 76.

The cylinder 82 is vertically movable upon a relatively stationary piston 178. The movement of the cylinder 82 upon the piston 178, which is for adjustment of the height of the blow-torches, is controlled by a hand-operated three-way valve 180. This valve controls the connection of a supply-line 181 or an exhaust-line 182 with the pipe 183. The supply and exhaust lines are suitably connected to a pump and sump (not shown), respectively. This pipe 183 is connected to a duct 185 that is drilled in the foot or base 190 of the piston 178, and this duct 185 is connected with a vertical duct 186 that leads through the piston 178 and has a port-opening 187 to the space in the cylinder above the top of the piston. It will readily be seen that when the valve 180 is turned so as to connect the supply-line 181 with the pipe 183, the cylinder 82 will move vertically upwards on the piston 178 and that when the valve is turned so as to connect the exhaust line 182 with the pipe 183, oil above the piston 178 will be exhausted from the cylinder and the cylinder can be lowered on the piston.

The cylinder 82 is rotatable on the piston 178 to align the torches with a tooth of the gear to be hardened. To hold the cylinder in the vertical position to which it has been adjusted while it is being rotated for angular position, a split clamping-collar 188 is provided. By releasing the clamping-bolt 189, this collar can be slid along the piston until it engages under the cylinder and then by tightening up the clamping bolt 189 again, the collar can be clamped to the piston to secure the cylinder against downward movement on the piston.

The cylinder itself is formed to provide a split-clamp at its lower end and after it has been adjusted to the correct angular position, it can be clamped in this position by tightening up the bolt 191 to tighten this split-clamp.

The foot or base 190 of the piston 178 is mounted for horizontal adjustment on ways cut into the base-plate 30 to which reference has already been made. Horizontal adjustment of the piston base 190 on the base-plate is effected by rotation of the stub-shaft 192 which is rotatably mounted in the base 190 of the piston and which carries a spur-pinion 193 that meshes with the teeth of a rack 194 which is secured to the base-plate 30. The horizontal adjustment described permits of moving the torches toward or from the work-spindle to accommodate gears of different diameters.

I shall now describe the operation of hardening a straight bevel gear such as the gear G shown.

The gear is positioned on the arbor 36 and the gear and blow-torches are brought into operative relation by horizontal adjustment of the piston-base 190 on the base-plate 30, by vertical adjustment of the cylinder 82 on the piston 178, by angular adjustment of the cylinder 82 on the piston 178, by angular adjustment of the bracket 176 on the cylinder 82 and by vertical adjustment of the work-spindle 27 on the tripod 26 through use of the interchangeable, nesting rings which are provided with the apparatus. The interchangeable rings allow of a rough adjustment of the vertical positions of the torches and gear relative to one another, while a finer vertical adjustment of the relative positions of the torches and gear is permitted by movement of the cylinder 82 on the stationary piston 178.

For a straight bevel gear, cam-bars 163 and 164 having straight guide-surfaces, such as shown, are used. These bars are adjusted angularly on the bracket 76 so that the guide-surfaces of the bars are inclined to one another at an angle equal to the angle of convergence of opposite sides of the teeth of the bevel gear to be hardened and so that the guide surfaces are parallel to the opposite sides of a tooth of the gear. The graduations permit of setting these bars accurately.

The throttle-valve 104 is adjusted by the knurled nut 134 to determine the basic speed of movement of the blow-torches on the hardening stroke. This adjustment is determined by experience and can be made very fine because of the graduations on the sleeve of the nut. The cam-bar 94 is adjusted angularly on the plate 87 to determine the variation in speed of traverse of the blow-torches as they move along a tooth of the gear in the hardening stroke. There are a number of factors which enter into the setting of the cam-bar. Among these are the pitch of the gear, the change in thickness of the teeth of the gear from end to end and the change in height of the teeth from end to end.

The trip-dog 90 is adjusted along the slot 92 to govern the length of stroke of the ram 70. This depends upon the length of face of the gear to be hardened.

The normal inoperative position of the parts of the apparatus is shown in Fig. 5. To harden a tooth of the gear, the operator throws the hand-lever 144 from the position shown in Fig. 5 over to the position shown in Fig. 2. The locking-dog 151 automatically locks the lever 144 in this latter position, the dog being automatically engaged with the lug 150 of the hand-lever under actuation of the spring-plunger 153. The spring 140 is, of course, compressed in the movement of the hand-lever from right to left.

With the hand-lever in the position of Fig. 2, the hydraulic motive fluid flows from the supply-line 200 (Fig. 5), which is connected in any suitable manner to a pump (not shown), through the duct 201 into the left-hand end of the cylinder 84 and exhausts from the right-hand end of the cylinder 84 through the duct 202 and the exhaust

line 203, the latter flowing back to the sump (not shown). This causes the piston 85 to move to the right carrying with it the blow-torches 40 and 41 and the spray-jets 54 and 55 and the torches will preheat the tooth surfaces. The spray-jets 54 and 55 are ahead of the torches in the rightward direction of travel, and the water has no appreciable effect.

There is a manually adjustable throttle valve 204 in the exhaust line 203. This may be a globe valve of any usual or suitable construction. It permits of adjusting the rate of the preheating movement to conform to the size of the teeth of the gear to be hardened. It is adjusted in each case so that the preheating movement will be quite rapid and the surface of the tooth will not be heated to the hardening temperature.

As the piston moves to the right it will be noted that the two torches and the respective spray-jets associated with each are spread further and further apart due to the setting of the cam-bars 163 and 164 and the action of the spring 160 on the blocks 44 and 45 which carry the jets and torches.

Toward the end of the rightward or preheating traverse of the piston, the trip-dog 90 engages the tail of the locking-dog 151 and swings this locking-dog about its pivot to release the hand-lever 144. The spring 140 then immediately moves the valve 101 and with it the hand-lever over to the right to the position shown in Fig. 5. This reverses the valve 101. The motive fluid now flows from the supply-line 200 through the duct 202 into the right-hand end of the cylinder 84 and the left-hand end of the cylinder is on exhaust. This causes the piston 85 to move back to the left.

The exhaust is through the duct 201 and the line 205. This line divides and has two branches, designated 205*a* and 205*b*, respectively. The exhaust-fluid flowing through the line 205*a* passes through the throttle-valve 104 and flows back to the sump through the line 206. The rate of exhaust from the line 205*a* is determined by the setting of the nut 134, as described. The fluid exhausts from the line 205*b* through the throttle-valve 203 and the line 207 which flows back to the sump. The rate of exhaust from the line 205*b* is determined by the setting of the cam-bar 94.

The movement of the piston 85 to the left is comparatively slow because the motive fluid from the left-hand end of the cylinder 84 must exhaust through the valves 104 and 103. It will be noted that with the setting of the cam-bar shown in Fig. 5, the speed of travel of the blow-torches will accelerate as the piston 85 moves from the right to the left. The section of the gear teeth grows thinner from the large to the small end of the teeth and the accelerated travel of the blow-torches in this direction allows of properly heating the teeth at all points along their length and at the same time prevents burning of the teeth at their thin sections.

As the piston 85 moves from the right to the left, the blow-torches are also brought closer and closer together. This is because the cam-bars 163 and 164 acting through the rollers 162 force the blocks 44 and 45 together against the resistance of the spring 160. The blow-torches are, therefore, maintained at a uniform distance from the sides of a tooth as they move along the tooth.

In this movement of the piston 85 from right to left, the blow-torches precede the spray-jets. The torches progressively heat up the side of a tooth to a high intensity. The spray-jets following immediately quench the heated portions of the tooth and thus the sides of the tooth are progressively hardened.

The forward or hardening traverse of the torches stops when the piston 85 bottoms in the left-hand end of the cylinder 84. The operator then indexes the gear G to bring the next tooth of the gear in line between the blow-torches and then he throws the lever 144 from the position shown in Fig. 5 over to the position shown in Fig. 2 again, so as to start the return travel of the piston 85. In this return travel of the piston the torches will preheat the new tooth of the gear, as already described.

Any suitable type of indexing mechanism may be provided, but in the apparatus shown the indexing is intended to be effected by hand by simply rotating the gear manually. This requires no effort because the work-spindle is mounted on anti-friction bearings. The gear is held in its indexed position by a detent that is adapted to be engaged in the tooth spaces of the gear.

This detent is shown in Figs. 2 and 3. It comprises a hand-lever 210 that carries a ball-tipped pin 212. The lever is pivotally mounted at 213 on a block 214 which is pinned to a bar 215. The bar 215 is slidably mounted in a bracket 216, which is secured by means of a T-bolt 217 to the underside of the bracket 76. The head of the T-bolt engages in a T-slot 218 (see Fig. 1) formed in the under side of the bracket 76.

The ball-pin 212 is constantly urged toward locking position by a spring-pressed plunger 220 (Fig. 3) which is housed in the block 214 and which engages a lug 221 formed on the hand-lever 210.

To index the gear G, the operator simply grasps the handle 222 of the hand-lever and moves the ball 212 upwardly out of engagement with the gear. He then rotates the gear to bring a new tooth into operative position. When the operator releases the hand-lever the spring-plunger 220 holds the ball 212 in engagement with a tooth space of the gear, preventing rotation of the gear during the hardening operation.

It will be noted from Figs. 2 and 5 that at their left-hand ends, the cam-bars 163 and 164 are sharply beveled off, as denoted at 225 and 226 respectively, providing guide-surfaces that diverge sharply from one another. The purpose of these outwardly beveled portions is to move the torches 40 and 41 quickly away from one another after they pass beyond the inner end of the gear tooth so as to prevent the intensity of the flame from one torch melting the opposite torch.

Figs. 9 and 10 illustrate diagrammatically two successive steps in the hardening of a bevel gear. In Fig. 9, the torches 40 and 41 and the spray-jets 54 and 55 are shown in position as they move along the sides of the tooth 20 of the gear G on a hardening stroke. As they move toward the small end of the tooth their paths converge as long as they are in operative relation with the tooth. When the torches pass beyond the end of the tooth, however, they are quickly spread apart through operation of the spring 160 causing the rollers 162 to follow the diverging portions 225 and 226 of the guide-surfaces of the cam-bars 163 and 164. The operator then indexes the gear, bringing the tooth 20*b* into operative position. Then he reverses

the lever 144 to cause the torches to make the return preheating traverse along the sides of the tooth 20b. In Fig. 10, the torches and jets are shown still spread apart just prior to the return preheating movement. At the end of the return movement, the piston is automatically reversed, as described, and the torches again traverse the tooth 20b but in the opposite direction and the tooth is hardened.

The first operation on a tooth is the preheating traverse and then follows the hardening traverse. At the end of the hardening traverse, the gear is indexed.

For different types of gears, different work-supports may be provided. Fig. 8 shows a work-support for a bevel pinion. In this case a spindle 230 is provided to take the place of the spindle 27. This spindle 230 is constructed so as to be substituted directly for the spindle 27 on the work-support and take its bearing on the anti-friction bearing 34. The spindle 230 is formed with a head 235 which is bored at right angles to the axis of the spindle. The bore in the head 235 is adapted to receive a second spindle 232 which is mounted on anti-friction bearings 233 and 234 in the bore of the head.

The pinion P to be hardened is mounted upon an arbor 236 which is secured by the draw-bar 237 in a sleeve 238 that has a pressed fit in the spindle 232. The draw-bar is tightened by threading up on the nut 239. This nut through its cooperating washer engages a circular plate 240 which has a portion of reduced diameter that fits into a second circular plate 241 that engages the outer race of the anti-friction bearing 234. Therefore, by tightening up the nut 239, the arbor 237, sleeve 238, and spindle 232 are all held in place. An eye-bolt 242 is threaded into the head 235 so that the head can be lifted readily out of the tripod and ring when it is desired to change work spindles.

It will be noted that when a work spindle is used, such as has just been described, that the teeth of the pinion will have a reverse relation to the torches as compared with the teeth of a ring gear such as shown in G, that is, the narrow ends of the teeth of the pinion will be at the right end of the travel of the torches and the wide ends of the teeth at the left end of travel of the torches. To harden the pinion, therefore, the cam-bars 163 and 164 will be adjusted angularly in the reversed relation from that shown in Figs. 2 and 5 so that the torches may converge as they travel from left to right and diverge as they travel from right to left.

While the invention has been described particularly in connection with the hardening of straight tooth bevel gears, it will be readily understood that the invention is applicable to the hardening of all types of gears and further that with but slight change, the apparatus illustrated can be used for hardening various types of gears. Thus, in order to harden straight tooth spur gears, a suitable work-spindle may be provided and the torches can be caused to travel in parallel paths, as required to harden opposite sides of the teeth of such gears, by simply setting the cam-bars 163 and 164 to zero positions so that their guide-surfaces are parallel.

For the hardening of helical spur gears the cam-bars 163 and 164 will be adjusted so that their guide-surfaces are parallel but are inclined angularly in accordance with the helix angle of the teeth of the gear to be hardened.

For longitudinally curved tooth gears, such as spiral bevel and hypoid gears, cam-bars having curved guide-surfaces will be used instead of the cam-bars 163 and 164. The guide-surfaces of the bars will be of a curvature to correspond to the lengthwise curvature of the teeth of the gear to be hardened and the bars will be adjusted angularly in correspondence with the spiral angle of the teeth of the gear so that the two torches may travel, respectively, in paths substantially parallel to the opposite sides of the teeth.

To harden herringbone gears, cam-bars may be employed having V-shaped guide surfaces parallel to the sides of the teeth of the gear.

Any suitable type of blow-torch may be used for the hardening of gears according to the present invention. A preferred form of blow-torch is illustrated, however, in Figs. 6 and 7. The oxy-acetylene gas mixture enters the torch through the bore 250 and flows through the ducts 251 and 252 into the duct 253 which is parallel to the duct 251. The flame-openings 254 connect with the duct 253 and extend diagonally from one side of this duct, as clearly shown in Fig. 7. This is a very important feature as can be seen from Fig. 10, for when the torches have moved clear of the tooth at the small end thereof, the flames from the two torches are not directed against one another but diagonally and forwardly. With this torch-construction and with the separation of the torches at the small end of the tooth, the possibility of the flame from one torch melting the other torch is obviated. Each torch is so arranged that the flame-openings extend up the sides of the tooth. When a gear of considerable tooth height is to be hardened, all of the flame-openings will be in use, but provision is made for the closing off of one or more of these openings when gears of smaller tooth height are to be hardened. The means for closing off the upper flame-openings comprises a valve-rod 255 which is threaded at its upper end into the duct 253 and which is manipulated by the knob or handle 256. The torch is cooled by water which enters the duct 258 through the opening 259 to which one of the tubes 68 or 69 is connected. The water exhausts through the openings 260.

The invention has been described in connection with an apparatus which is semi-automatic in operation. It is within the contemplation of the invention, however, to provide fully automatic apparatus if desired.

In general it may be said that while the invention has been described in connection with certain particular embodiments, it is capable of still further modification and this application is intended to cover any variations, uses, or adaptations of the invention, following, in general, the principles of the invention and including such departures from the present disclosure as come within known or customary practice in the art to which the invention pertains and as may be applied to the essential features hereinbefore set forth and as fall within the scope of the invention or the limits of the appended claims.

Having thus described my invention, what I claim is:

1. The method of surface-hardening which comprises traversing a flame in one direction at a relatively high speed across the surface to be treated to pre-heat the surface, and then immediately traversing the flame across the same surface at a relatively slow speed in the opposite direction to bring the surface up to the temperature required for hardening.

2. The method of surface-hardening a gear which comprises traversing a flame along a tooth in one direction from end to end to pre-heat the tooth and then immediately traversing the flame in the opposite direction along the tooth from end to end at such a rate as to raise the successively exposed portions of the tooth to the temperature required for hardening, and then indexing the gear.

3. The method of surface-hardening gears which comprises traversing a flame along a tooth in one direction from end to end at a relatively fast speed to pre-heat the tooth, immediately traversing the flame along the tooth from end to end in the opposite direction at a relatively slow speed to raise the tooth to the temperature required for hardening, and then indexing the gear.

4. The method of surface-hardening gears which comprises traversing a flame along a tooth in one direction from end to end to pre-heat the tooth, immediately traversing the flame along the tooth from end to end in the opposite direction to raise the tooth to the temperature required for hardening, quenching the tooth progressively immediately after it is raised to the hardening temperature, and then indexing the gear.

5. In apparatus for hardening gears, a pair of torches arranged, respectively, to direct intense flames simultaneously at opposite sides of a gear-tooth, means for traversing the torches along the sides of the tooth, and means for quickly moving the torches apart when they pass beyond one end of the tooth.

6. In apparatus for hardening tapered gears, a pair of torches arranged, respectively, to direct intense flames simultaneously against opposite sides of a gear-tooth, means for traversing the torches along the tooth from end to end, and means for causing said torches to converge as they traverse the tooth from the large to the small ends thereof.

7. In an apparatus for surface hardening gears, a torch for directing an intense flame against a side of a gear tooth, a support on which the torch is mounted and means for moving the support in the direction of the tooth length to move the flame along the tooth surface, and means operable upon movement of the support for varying the velocity of movement of said support.

8. In apparatus for surface-hardening gears, a longitudinally reciprocable support, a pair of torches mounted on said support and movable thereon transversely of the direction of movement of said support, means for reciprocating said support to move the torches longitudinally of a gear tooth, and means adapted to control the transverse movement of the torches during the reciprocatory movement of the support.

9. In apparatus for hardening gears, a movable support, a torch mounted upon said support and arranged thereon to direct an intense flame against one side of a gear-tooth, means for actuating said support to traverse the torch along the tooth from one end thereof to the other successively first in one direction and then in the other, and means controlling the rate of movement of said support so that it is moved at a relatively high speed in one direction to cause the torch to preheat the tooth and at a relatively slow speed in the opposite direction to cause the torch to raise successive portions of the tooth to hardening temperature.

10. In apparatus for hardening gears, a torch arranged to direct an intense flame against one side of a gear-tooth, means for traversing the torch along the tooth in one direction at a relatively high speed, means for automatically reversing the direction of movement of the torch at the end of said movement, means for moving the torch in the opposite direction along the tooth at a relatively slow speed, and means operable during movement of the torch in the latter direction to progressively quench the tooth immediately after it is heated.

11. In apparatus for hardening gears, a reciprocable support, a blow-torch carried by the support and adapted to direct an intense flame against one side of a gear-tooth, means for reciprocating the support, and means operable by the support in its movement in one direction for varying the speed of its movement.

12. In apparatus for hardening gears, a reciprocable support, a blow-torch carried by the support and adapted to direct an intense flame against one side of a gear-tooth, fluid-pressure operated means for reciprocating said support, and an adjustable throttle valve operable by the support in its movement in one direction for controlling the speed of movement of the support in one direction.

13. In apparatus for hardening gears, a reciprocable support, a pair of blow-torches carried by the support and adapted to direct intense flames against opposite sides of a gear-tooth simultaneously, means for reciprocating the support, and means operable by the support in its movement for varying the distance between said torches as they move along the tooth.

14. In apparatus for hardening tapered gears, a pair of torches arranged, respectively, to direct intense flames simultaneously against opposite sides of a gear-tooth, means for traversing the torches along the tooth from end to end thereof, means for causing said torches to converge as they approach the small end of the tooth, and means for accelerating the rate of movement of the torches as they approach the small end of the tooth.

15. In apparatus for hardening gears, a torch, a work support, a reciprocable slide upon which one of the aforesaid parts is mounted, means for moving the slide to move the torch relatively along the length of the gear tooth, and a cam for guiding said torch as it moves lengthwise of the tooth to maintain the torch at a uniform distance from the side of the tooth being treated.

16. In apparatus for hardening gears, a torch, a work support, a reciprocable slide, a block upon which one of the first two parts is mounted, said block being mounted on said part and being reciprocable thereon in a direction transverse to the direction of movement of the slide, a relatively fixed cam having an operating surface parallel to the side surface of a tooth of the gear, and means operatively connecting said block to said cam.

17. In apparatus for hardening gears, a work support, a pair of torches, means for producing relative longitudinal movement between the torches and the work support to move the torches from one end of a gear tooth to the other, and means for producing relative movement between the torches and the work support in a direction transverse to said longitudinal movement to cause said torches to remain at uniform distances, respectively, from opposite sides of a tooth of the

gear as they move from one end of the tooth to the other.

18. In apparatus for hardening gears, a work support, a pair of torches, a slide, a pair of blocks, in which the torches are mounted, movable transversely on the slide, and means for moving the blocks transversely as the slide moves longitudinally of a gear tooth to maintain the torches at uniform distances, respectively, from the sides of the gear tooth.

19. In apparatus for hardening gears, a work support, a pair of torches, a slide, a pair of blocks, in which the torches are mounted, transversely movable on the slide, and means operable on movement of the slide for moving the blocks transversely of the slide.

20. In apparatus for hardening gears, a work support, a pair of torches, a slide, a pair of blocks mounted on the slide for movement transversely thereof, a pair of fixed cams extending longitudinally of the slide and having operating surfaces, respectively, in parallelism with opposite sides of a tooth of the gear, and means operatively connecting said blocks, respectively, to said cams to move the blocks transversely on the slide on movement of the slide.

21. In apparatus for hardening tapered gears, a work support, a pair of torches, a slide, a pair of blocks mounted on the slide for movement transversely thereof, a pair of cams having straight guide surfaces adjustable into converging relation to be parallel to opposite sides of a tooth of the gear, and means operatively connecting said blocks, respectively, to said cam-guides.

22. In apparatus for hardening gears, a work support, a torch, a slide on which one of said parts is mounted, fluid-pressure operated means for reciprocating said slide, a frame on which the slide is reciprocable, a cam and a throttle valve, one of which is mounted on the slide and the other on the frame, said cam having an operating surface extending longitudinally of the slide, and means operatively connecting the cam to the throttle valve to control the opening of the throttle valve as the slide moves longitudinally.

23. In apparatus for hardening gears, a work support, a torch, a slide on which one of said parts is mounted, fluid-pressure operated means for reciprocating said slide in opposite directions to effect preheating and hardening strokes of the torch, means for controlling the movement of said slide so that it moves at a faster rate on the preheating stroke than on the hardening stroke, a reverse valve controlling the direction of movement of the slide, and means carried by the slide for automatically tripping the reverse valve at the end of each preheating stroke.

24. In apparatus for hardening gears, a work support, a pair of torches for heating opposite sides of a tooth of the gear simultaneously, a slide on which the torches are mounted, means for reciprocating the slide to effect preheating and hardening movements of the torches, and means for moving the torches apart at the end of each hardening stroke.

25. In apparatus for hardening gears, a work support, a reciprocable slide, a pair of blocks mounted on the slide for movements transversely of the direction of movement of the slide, a pair of torches mounted in the blocks and arranged to operate simultaneously on opposite sides of a tooth of the gear, said torches having flame openings directed diagonally at the sides of the gear tooth and toward one end of the tooth, relatively fixed cams extending in the direction of movement of the slide, and means operatively connecting the blocks with said cams, said cams being so formed as to cause separation of the torches when they pass beyond the described end of the tooth.

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