piece uniformly should be used, and the piece turned frequently to insure good results. A mistake sometimes made in heating pieces of this description consists in using a fire too small to accomplish the desired result. One end and the center is heated, the end is reversed and the opposite end is heated. The first end, in the meantime, has cooled to a degree that makes it unsafe to quench the piece in the bath. So the second end is heated hotter than it should be, with the idea in view that the piece will again be reversed and the over-heated end will cool to the proper hardening heat, while the temperature of the opposite end is being raised to the desired heat. When it is taken from the fire, it is in the worst possible condition to harden; the center is too hot, one end is apparently about the right temperature, but the interior is not hot enough. The opposite end is possibly at about the right heat, but the interior is *too* hot. In this condition it is immersed in the bath and violent strains are set up, which result in the piece being cracked or sprung out of shape. Now, this is not at all right, yet it is so commonly practiced that the writer feels it necessary to caution the reader against a practice which is so radically wrong.

If obliged to use an ordinary forge, build a fire large and high enough so the piece may be uniformly heated; turn frequently; keep the piece well buried in the fire to prevent oxidation of the surface. When the steel reaches a low red heat, take it from the fire, sprinkle some pulverized cyanide of potassium on the surface. Place in the fire and bring to a uniform red heat, which must be a trifle higher than if there were teeth or projections on the surface, as, these being light,

would cool more quickly than a solid piece. If possible, use a bath having a jet of liquid coming up from the bottom. If it is a mandrel, it should be grasped by one of the ends with a pair of tongs of the description shown in Fig. 86. This insures hardening the body of the mandrel, and also allows the contents of the bath to have free access to the upper center, which would not be the case if a pair of tongs of the ordinary description were used.

It is essential that the *centers* of a mandrel be very hard. For this reason a method of quenching in the bath should be used that insures the centers in *both* ends hardening.

If it is considered best to draw the temper of the ends in order to avoid the corners chipping or the ends breaking, it is not advisable to make them as soft as the dead center of the lathe, which is usually drawn to very deep straw or brown color. The object attained in having the ends of a mandrel harder than the lathe center is that in case of wear, the center, being the softer of the two, will probably wear rather than the centers of the mandrel.

The piece should be worked up and down in the bath until it is of the same temperature as the contents of the bath, when it may be removed and heated somewhat to overcome the tendency to crack from internal strains. It should be held in a vertical position when dipping, in order to avoid springing.

Better results will follow if the piece is placed in a piece of pipe or tube when heating.

A very excellent method consists in placing the article in a piece of gas pipe, which is closed at one end. The hole in the pipe should be about one inch

larger in diameter than the piece to be hardened. Fill around it with granulated charred leather, having the mandrel in the center of the hole in the pipe, and the ends should not be within ½ inch of the ends of the pipe. Fill the pipe with the charred leather; place a loose-fitting piece of iron in the open end of pipe, and seal with fire-clay. When this is dry, the pipe may be placed in the fire and remain until the article is uniformly heated to the proper temperature, when it may be taken from the pipe and quenched, as described.

Still better results may be obtained if the piece is kept at a low red heat for a period of several hours, the time depending on the size of the piece. If ½ inch diameter or under, 1½ hours will be found sufficient. If larger, run correspondingly longer. When it has run sufficiently long, the piece may be removed from the tube, grasped by the tongs, as shown, and plunged in a bath of raw linseed oil, working up and down rapidly in the bath. This method receives further consideration in section on Pack Hardening.

Hardening Grooved Rolls.

When grooved rolls or similar articles are to be hardened, it is necessary to heat *very* uniformly. The projections, as shown in Fig. 105, have a tendency to heat faster than the balance of the roll. Should they become hotter, the projections will be very liable to crack or break off when quenched. As it is necessary to heat slowly in order to get uniform heats, the piece would be liable to oxidation on its outer surface, which is exposed to action of the products of combustion in

the fire and the air, if heated in an open fire. If small, it may be heated in a tube; if too large for this, it may be covered with the carbonaceous paste described in section on Methods of Heating. When the article has

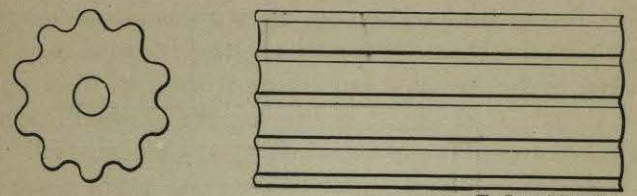

Figure 105. A grooved roll.

reached the desired uniform heat, it should be plunged in the bath in a *vertical* position. On account of the peculiar shape of the piece and the tendency of the steam generated, the contents of the bath should be agitated from the outside toward the center of the bath.

A method that gives very excellent results when hardening articles of this description is to use a bath having pipes coming up at the sides of the tank, as shown in Fig. 106. There should be a sufficient number of openings in these pipes to supply a generous quantity of water in order to produce the desired result. The water should be under sufficient pressure to project the contents of the bath against the piece being hardened, with enough force to drive the steam away, so the water can readily come in contact with the heated surface.

If the pieces are short and not too large, they may be heated in red-hot cyanide, dipping in a bath of the form described

If it is not necessary to harden very deeply, the

article may be removed from the bath when hardened sufficiently and placed in a tank of oil, leaving them in the oil until the steel is uniformly cooled to the tem-

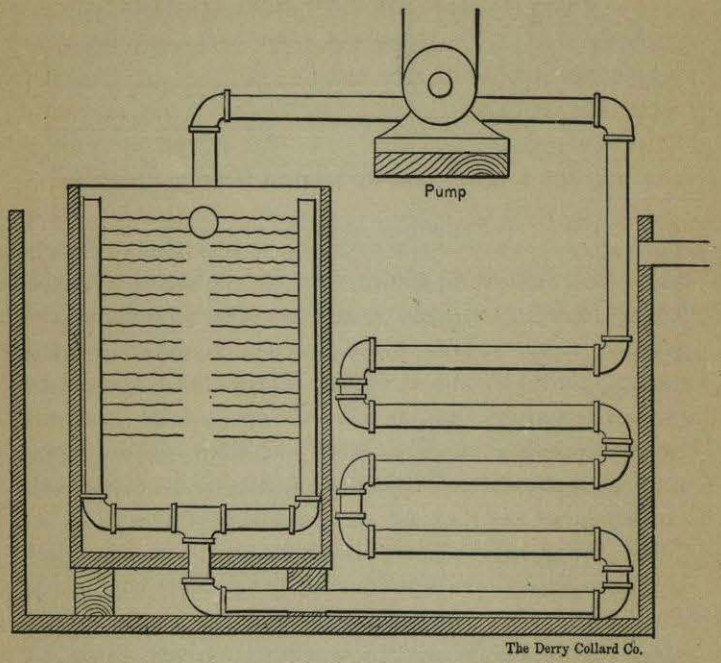

Figure 106. Bath for hardening grooved rolls.

perature of the oil. It is extremely important when hardening pieces of this description that they be reheated as soon as possible after removing from the bath to overcome the tendency to crack from internal strains. The longer they remain under strain, the

more likely they are to crack later without any apparent cause. Every mechanic can recall cases of this kind.

Hardening the Walls of Holes.

A peculiarity of a cylindrical piece of steel is that, when hardened, it is liable to become oval in shape. This is especially true of pieces having holes running through their centers, as shown in Fig. 107. When it is possible, or is considered advisable to grind the piece inside and outside after hardening, the amount it goes out of shape need not in any way interfere with the utility of the tool, provided there has been a sufficient allowance of stock made for grinding.

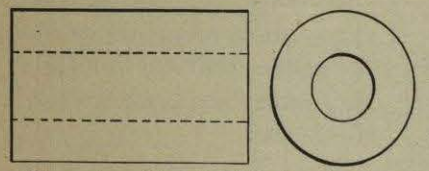

Figure 107. Piece with hole through center.

If, however, there is no means at hand for grinding the piece after hardening, it becomes necessary to harden in a manner that does away with the tendency of the piece going out of shape or the hole contracting very appreciably. This may be accomplished in the case of such articles as ring gauges, reducing

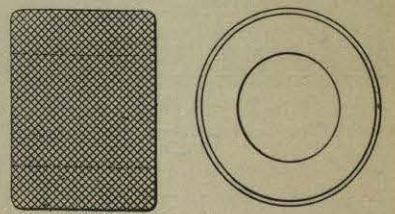

Figure 108. Gauge with hole through center.

dies, and any tools which do not require hardening on their outer circumference, if proper care is taken.

When gauges of this description (as shown in Fig. 108) are hardened by the ordinary methods, it is necessary to rough-grind them to within a few thousandths of an inch of finish size and lay them away to "season" or "age." After laying for a few months or a year, they are finished to size by grinding and lapping. It is not necessary to observe this precaution except in the case of gauges that are to be used in making *very accurate* measurements.

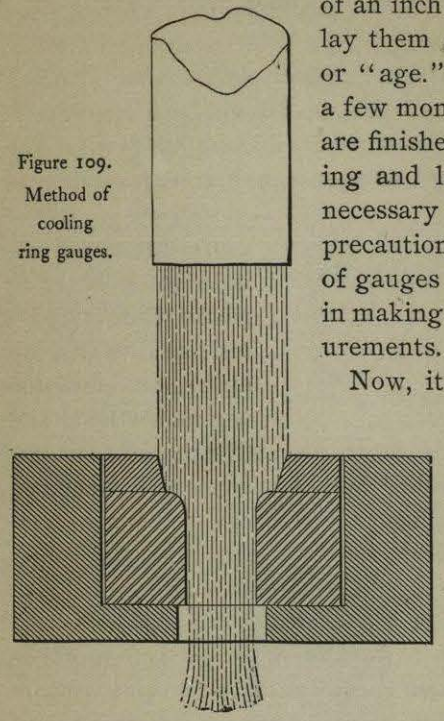

Figure 109. Method of cooling ring gauges.

Now, it is not always desirable to wait a year after a piece of work is hardened before grinding to size and using. In order to overcome the tendency of alteration of sizes and shapes as the piece ages, it may be hardened in a manner that gives the walls of the hole sufficient hardness to resist wear, yet leaving the circumference soft. This can be accomplished by heating the piece very carefully to the required heat and placing in a hole a trifle larger than the outside of the

piece. Now place a piece of metal having a hole somewhat larger than the hole in the gauge on top of the piece, as shown in Fig. 109. A stream of water may now be turned on in such a manner as to readily pass through the hole, thus cooling the walls and hardening them. The balance of the stock, being protected, does not harden. The walls of the hole being hard and inflexible do not yield as the piece grows cold. And as the outside portion of the piece is hot and yielding, it does not necessarily contract in the direction of the hole, thus reducing the tendency of alteration of size of the hole.

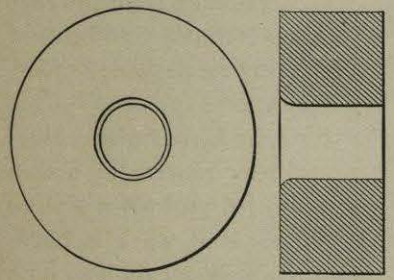

Figure 110. Die for reducing cartridges.

Dies used for reducing the size of gun cartridges, Fig. 110, and similar pieces, are hardened by this method, and give excellent results, because the outside, being soft, will have no tendency to break from the pressure exerted when the die is in use.

As there is very little tendency of alteration of size and shape of the hole, it can be lapped to size without grinding. In case it is not to be ground, there need be but a small allowance for lapping, provided the hole is smooth and straight.

As is customary when dies of this description become worn, they may be closed by heating red-hot and being driven into a taper hole. This diminishes the size of the hole in the die, which may then be reamed to size

and rehardened. In order to get good results, it is advisable to anneal the steel after closing in, or the molecules of steel will not assume their proper relations when hardened.

Articles with Holes Near One Edge.

When hardening articles having holes near the edge, extreme care must be observed, as the unequal contraction occasioned by the form of the piece will make it very liable to crack. A piece of the form shown in Fig. 111, represents an example of the form mentioned. While such a piece could be hardened by the pack-hardening process with no liability of its cracking if it were quenched in a bath of oil, it would not always be considered advisable to use this method, so it becomes necessary to heat the article in some form of fire, and quench in water.

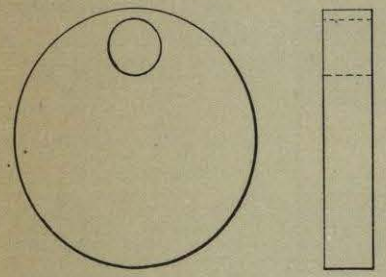

Figure 111. Piece with hole near edge.

The piece should be heated very carefully and no hotter than is necessary to accomplish the desired result. It will be necessary to use the utmost care in heating, because if the thin portion of stock between the hole and the circumference of the ring were heated any hotter than the balance of the piece, it would surely crack at this point.

When dipping in the bath, the heavy portion should

enter the bath first, the thin portion should be uppermost in order that it may enter last.

If it is not essential that the walls of the hole be hard, it may be filled with fire clay, previous to placing in the fire. If treated according to this method, the danger of cracking is reduced to the minimum.

A method employed very successfully in some shops when hardening articles of this description, consists in

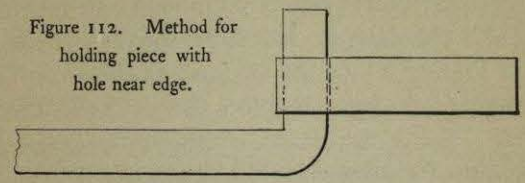

Figure 112. Method for holding piece with hole near edge.

bending a piece of wire in the form of a hook. This hook is heated red hot on the bent end, and when the article is at a uniform heat, the red hot end of the hook is inserted in the hole near the edge, as shown in Fig. 112, and the article immersed in the bath. The heavy portion will, of course, enter the bath first, the wire being red-hot will prevent the thin portion cooling as rapidly as it otherwise would. The size of the wire must be determined experimentally; that is, if many pieces are to be hardened, the size of wire that gives best results should be used, but in no case should it fill the hole when the pieces are cold.

The bath should be warmed somewhat in order to reduce liability of cracking.

Wood-Working Tools.

There are many methods used in hardening tools used for cutting wood, the different methods varying

according to the nature of the steel used and the use to which the tool is to be put when finished. The more common method is to heat in an open fire and plunge in water, drawing the temper until the brittleness is reduced to a point that makes it possible for the tool to stand up when in use. By this method, it is necessary to draw the temper quite low in order to get a degree of toughness that enables the tool to stand up well.

A method that is practiced in many shops is to heat in a muffle furnace or in a tube, hardening in a bath of water having oil on its surface, as shown in Fig. 82, the depth of oil depending on the desired amount of hardness. Some hardeners claim to be able to gauge the amount of hardness by the depth of oil to a nicety, that makes it unnecessary to draw the temper after hardening. The writer cannot vouch for this claim, as he has never seen it done when hardening wood-working tools, but has been able to accomplish it when certain kinds of iron-working tools were hardened.

Another method consists in heating the tool in a crucible of red-hot lead, or in a crucible of red-hot cyanide of potassium, dipping in a bath of oil, to which has been added a quantity of alum. The exact amount cannot be stated, as he has found it to vary when applied to hardening steels of various percentages of carbon. The use to which the tool is to be put when hardened, has a great deal to do with the composition of the bath.

As brittleness is *not* a desirable quality in wood-working tools, it is necessary to harden in a manner that insures toughness in the hardened product. For this reason it is not advisable to use a bath of cold liquid of any kind.

If the cutters are light on the cutting portions, the bath may be heated considerably, the temperature depending on the shape and size of the tool and the steel used in its construction.

Various animal or vegetable oils are used for quenching tools of this description, either separately or mixed with varying proportions of tallow. Melted tallow is many times used with success, heated to a temperature that gives good results when applied to the individual piece of work. The amount necessary to draw the temper depends on circumstances and can not be arbitrarily stated, but it is generally found to be between a brown and a dark blue color.

A method employed in some shops when hardening wood cutting tools consists in heating to a low red and plunging in a mixture of molten lead and tin in the following proportions: Lead, 7 parts; tin, 4 parts, which melts at about 440° Fahr.

The cutters are heated to a low red and plunged in this mixture at the temperature mentioned, allowed to cool for a short time, then removed and cooled in water. They will be found to be exceedingly tough, and capable of holding their edge in a satisfactory manner.

Unless this method is used in a painstaking manner, it had better not be tried, as anything but satisfactory results will follow.

If many cutters are to be hardened, it will be found necessary to gauge the heat of the bath by use of a thermometer.

Fixtures for Use in Hardening.

In order to attain certain results, it is necessary at times to make fixtures for holding the work. These

fixtures are designed to protect certain portions of the piece of work from the action of the contents of the bath.

The writer was at one time in charge of work in a

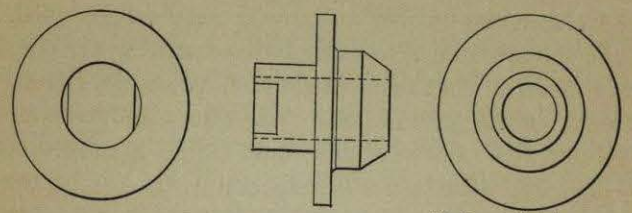

Figure 113. A hard piece to harden.

shop manufacturing bicycles. In order to accomplish a desired object, the axle cones, which had formerly been made of machinery steel, were made from a high grade of tool steel. The front axle cone was of the

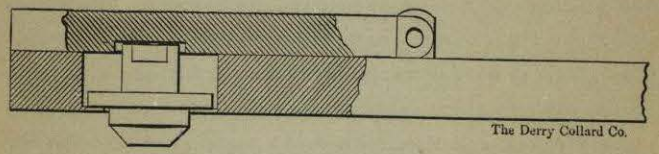

Figure 114. Device for hardening piece shown in Figure 113.

shape shown in Fig. 113. It was necessary to harden the beveled portion extremely hard, in order to resist wear. It was found very difficult to harden this portion without hardening the flange. If this were hardened, it showed a tendency to break when in the wheel, as it was very thin.

In order to harden the bevel and leave the flange

soft, a fixture was made, as shown in Fig. 114. The cone was heated in a crucible of red-hot lead. When it reached the desired temperature, the cover of the fixture was raised and the cone taken from the lead by means of a wire hook made for the purpose. It was placed in the fixture, as shown, the cover lowered, and the fixture immersed in a bath of water, working it around well until the cone was cold, when the fixture was inverted over a tank of boiling water, and the cone dropping into this and remained until a sufficient quantity was in the catch pan, Fig. 45, to warrant emptying it. This tank was found very valuable, as it furnished a means whereby the strains incident to hardening could be removed, and at the same time the temper was drawn sufficiently.

Pack Hardening.

When articles which are *small* or *thin* are heated to a red and plunged in oil, they become hard enough for most purposes, but not as hard as if immersed in water. Articles hardened in oil seldom crack from the effects of cooling, as the heat is not absorbed as quickly as if water were used, neither are they as likely to spring.

The fact that articles quenched in oil showed no tendency to crack, and very little liability to spring, has led the writer to make exhaustive experiments in perfecting a method whereby articles which gave trouble when hardened by ordinary methods might be