of the cutter teeth in order that the temper colors may be readily discerned.

The writer has had best results by holding the cutter over a fire, or a hot plate, and warming the circumference to a degree that made it impossible to

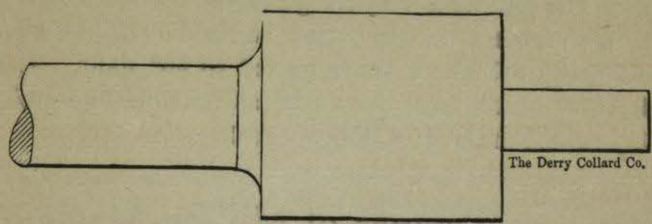


Figure 83. Plug for heating milling cutters.

hold the hand on it, previous to placing the cutter on the plug. It was then placed on the plug and turned constantly until the proper temper colors showed, when it was plunged in oil to prevent its getting too soft.

The object attained in heating the outer surface first, was that the heat given was sufficient to make the steel at this point somewhat pliable; whereas, if the cutter had been placed when cold on the red hot plug, the cutter absorbing the heat would tend to expand the steel toward the outer, rigid surface. If this expansion should prove, as it does many times, to be greater than the steel could stand, cracks would result.

The amount of heat necessary to give a milling machine cutter when drawing temper can not be stated arbitrarily. It is desirable to leave it as hard as possi-

ble, and yet not have it too brittle to stand up when in use; consequently, it should not be heated any hotter than necessary when hardening. It should *not* be plunged in a bath of extremely cold fluid, neither should it be checked in cold water when the temper has been drawn sufficiently.

While it is not considered advisable by many mechanics to make cutters of this description of a *high* carbon steel, the writer's experience has convinced him that better results are obtained by using a high carbon steel extremely *low* in phosphorus, and using *extreme* care in the heating. Then quenching in a bath of warm brine, 80° to 100° Fahr.

For ordinary work, a faint straw color (430°) gives best results, although it may be necessary at times to draw to a full straw color, 460°.

A kettle of oil, heated to the desired temperature, furnishes an ideal method of tempering cutters of this description. This method has been fully described under the proper section on pages 121 and 122, and should be carefully considered in connection with tools of this character

Hardening Shank Mills.

The percentage of carbon necessary to give the best results, depends on the make of steel. For ordinary work, however, a steel having 1¼ per cent. gives good results.

The methods employed in heating and quenching shank mills when hardening, depend in a measure on the form of the mill and the custom in the individual shop. Mills of the form shown in Fig. 84, may be heated to a uniform low red heat for a short distance above the teeth, stopping the heat in the necked portion, marked *a*. In some shops it is the custom to leave the shank quite a little larger than finish size in order that it may be turned to size in the lathe and fitted to

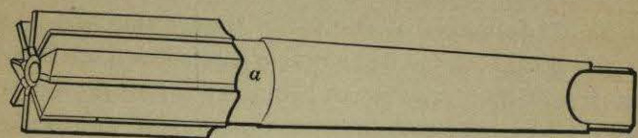


Figure 84. How to harden shank mills

the collet or spindle after hardening. In such cases it is necessary to leave the shank soft its entire length. In other shops it is the custom to turn the shank nearly to size before hardening, leaving on just enough to allow for grinding to a fit and remove any untruth resulting from springing in hardening. If it is necessary to leave the shank soft its entire length, care should be exercised in heating and dipping in the bath that the shank is not hardened in the least. If it is to be ground to a fit, the same care is not necessary, although greater care must be exercised in grinding if the shank is hard for a short distance and the balance is soft; but if careful when taking the finishing cuts on the grinder, no trouble need be experienced. If the cutter is made as represented in Fig. 85, it will be necessary, in order to harden the teeth the entire length in a satisfactory manner, to harden the shank for a short distance.

When hardening a cutter of the description shown

in Fig. 86, having a recess of considerable depth in the end, much better results will be obtained if it is dipped in the bath with the hole uppermost, as shown in Fig. 87—that is, provided it is necessary to harden the walls of the hole. If this were not desirable, then it would be safest to fill the hole with fire-clay, mixed with water, to the consistency of dough, and the cutter dipped as shown on next page. If the hole was not filled and the cutter was dipped in the bath with the hole down, the steam generated would drive the water away from the teeth at end; and furthermore, the steam would very likely cause the thin walls to crack.

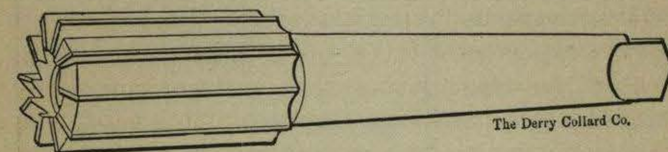


Figure 85

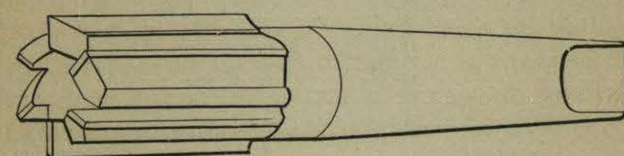


Figure 86. Shank mills.

When hardening cutters of the form shown in Fig. 88, known as T slot cutters, it is necessary to harden the entire length of portion necked below size of shank for several reasons. When the neck portion is slender, this is necessary, in order to strengthen this portion so it will not spring or twist off when the cutter is in operation. If the cutter is of a size that makes the necked portion large and strong enough to resist the cutting strain, it might not appear at first thought necessary to harden this. But as it is generally made but a few thousandths of an inch smaller than the slot it travels in, it will, if left soft, become roughed up by the fine cast iron chips, which are liable to get between the walls of the slot and the stem. Consequently, it will be readily seen that in most cases it is advisable to harden the entire length of the necked portion.

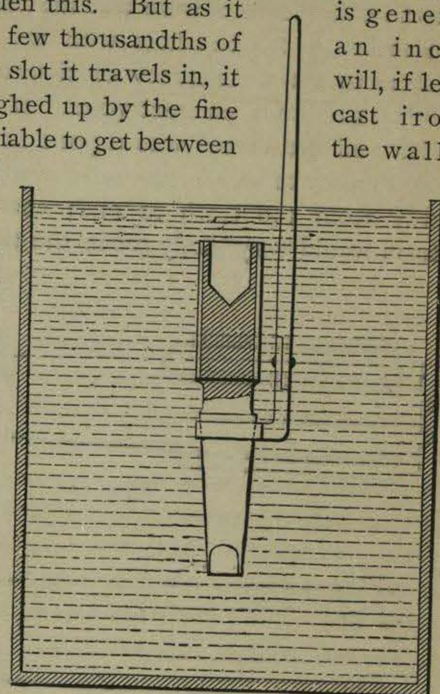


Figure 87. Proper method for treating shank mills.

If there is considerable difference between the size of the cutting portion and the shank of the tool, the cutter should be made, if possible, with a fillet in the corner, as shown at *a*, in sectional view of Fig. 89. If, however, this precaution has not been taken, or it has not been possible to do it, a piece of iron wire may be wound around, as shown at *b*. This wire being red-hot when the cutter is dipped in the bath, has the effect

of keeping the contents of the bath away from the sharp corner until the larger and smaller portions of the mill have become hardened to a degree, thus reducing the liability of cracking at this point. When the cutter has been heated to a low red, it should be plunged into a bath of water or brine from which the chill has been removed; work around well in the bath until it is of the same temperature as the bath, when it may be removed and the temper drawn.

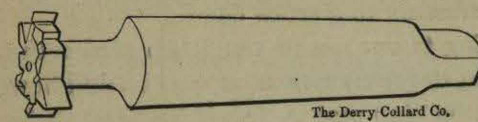


Figure 88. T slot cutter.

If it has not been possible to heat the cutter in a muffle or in a piece of pipe or other receptacle, it will be found an excellent plan to have a strong solution of potash and water, which should be heated quite warm. Before the cutter is heated, it may be plunged into the potash solution. Place it in the fire and heat to the proper hardening temperature and plunge in the hardening bath. The effect of the potash is to cause any thin scale of oxide which may have formed on the surface to drop off the instant the tool touches the bath. If this scale adheres to the piece, it has a tendency to rise in the form of a blister when in contact with a cool liquid, and consequently it keeps the contents of the bath from acting on the steel directly underneath.

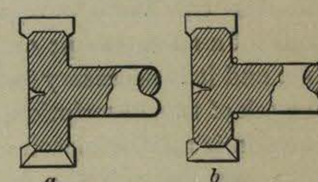


Figure 89. Fillets for T slot cutters.

When drawing the temper of a tool of this description it is necessary, in order that the necked portion be as strong as possible (especially if it is slender), to draw it to a purple or even a blue color, while the cutting teeth need drawing to a straw color.

It is surprising to one not thoroughly posted in the effects of different degrees of heat on steel to find how hard a cutter of this kind may be left if it was properly heated when hardened. This is best seen by comparing with one that was heated a trifle too hot, yet not to a degree that is generally considered harmful to the steel. In the case of the cutter properly heated—that is, to the refining heat—it may be left when tempering at a faint straw color, while if given a trifle more heat, it is necessary to draw it to a full straw, a difference of 30° of heat, and a vast difference in the amount of work it will do between grindings. In order to successfully draw the temper, the necked portion may be placed in the flame of a gas jet, a Bunsen burner, the flame of a spirit lamp; or, if none of these are available, and it is necessary to use a blacksmith's forge for all work of this description, a piece of sheet iron having a hole in it may be placed over the fire. A jet of flame will come through the hole, which may be made to strike the necked portion. In this way the desired temper may be obtained.

Hollow Mills.

When articles having a hole running part way through them, as, for instance, the hollow mill shown in Fig. 90, are to be hardened, it is advisable to dip

them in the bath, with the opening uppermost, as represented in Fig. 91. If the mill were dipped with the opening down, it would be almost impossible to get water to enter the hole for any considerable distance,

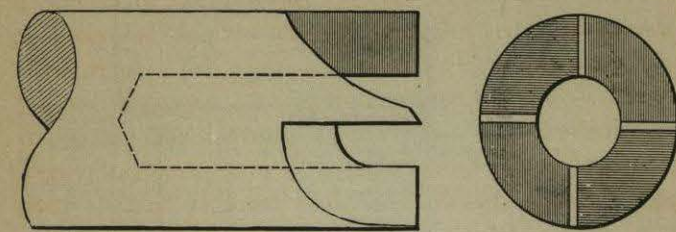


Figure 90. A hollow mill.

as the steam generated would blow the water out. As a consequence, the walls of the hole would not harden, and the steam would in all probability cause the steel to crack.

Then again, best results will follow if the frail end is not chilled until after the heavier, solid portions have contracted somewhat. If the lighter portions are chilled and contracted before the heavier ones, the tendency is for the heavier parts, which are stronger than the lighter, to pull them into conformity with themselves, and as the steel is hard and rigid, it must crack. While this principle is explained elsewhere in this work, it seems wise to show the adaptability of this peculiarity of steel to pieces of this description.

When making articles having holes, as shown, if the piece is to be hardened, the liability of cracking will be lessened if the stock at the end of hole is left, as shown in Fig. 92. If, however, the piece is made with a sharp corner, as shown in Fig. 93, it is advisable to fill in this sharp corner with fire clay, or graphite, in order that there may be no pronounced difference in the contraction of the two portions.

When hardening pieces of this character, it is, generally speaking, good practice to use a bath of tepid water or brine.

When it is considered desirable to harden a piece a certain distance, and no farther, and the facilities for heating do not allow of heating exactly the right distance, it is necessary to dip in the bath with the teeth down. In order to overcome the tendency of the steam to blow the water from the hole, a small vent hole is drilled through the wall of the piece, as shown in Fig. 94. If this hole is large enough to allow the steam to escape, good results will follow if a bath is used having a jet of water coming up from the bottom, as, by this means, water is

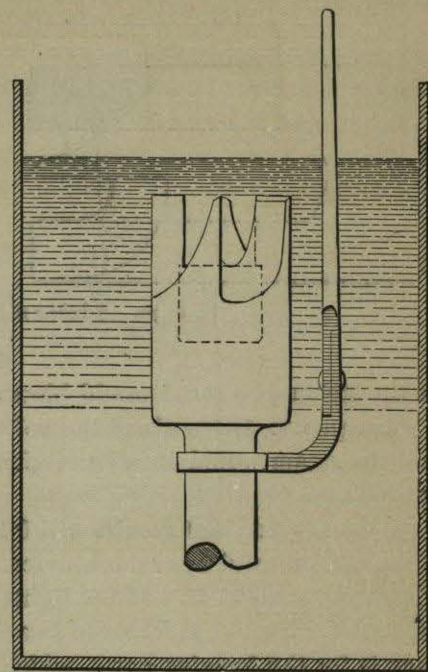


Figure 91. Method for hardening hollow mills

forced into the hole. However, the operator should bear in mind that it is never good practice to have

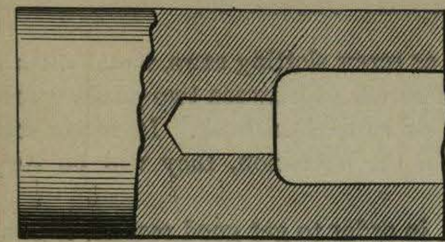


Figure 92. Hollow mill with rounded corners.

the hardening stop at a shoulder, either inside or outside of a piece of steel. Where possible, stop the

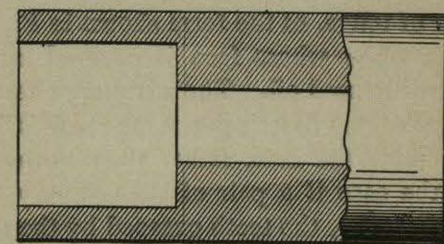


Figure 93. Hollow mill with sharp corners.

hardening somewhat short of the shoulder, but if this does not meet the requirements, harden a trifle

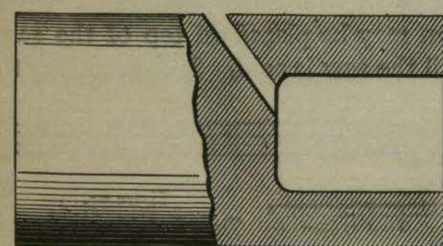


Figure 94. Hollow mill with hole to allow escape of steam.

beyond the shoulder. This may seem like a little thing to bother about, but it generally means the difference between a good job and a poor one, and it's one of the little points that count in making a successful hardener.

Thin Articles.

Thin articles, as screw slotting saws, metal slitting saws, etc., may be hardened between two plates whose faces are covered or rubbed with oil. If reasonable care is exercised in the operation, they will be very straight.

It is essential, in order to get good results, to heat the pieces on a flat plate. They should be heated no hotter than is necessary to accomplish the desired result. When at the proper heat, the saw may be taken by a pair of tongs, of the form shown in Fig. 95, and placed on a plate whose face is covered with lard, sperm or raw linseed oil. The advantage derived from using tongs of this description is, the saw is held by the portion near the hole, rather than by the teeth, as would be the case if a pair of the ordinary style were used. In that case, the teeth grasped by the tongs would not be of the same temperature as the balance of the saw; and, as a consequence, the hardening would not be uniform. Another plate, whose face has been treated in a similar manner, may be placed on top of the saw and held there until the saw is cold. It is necessary to

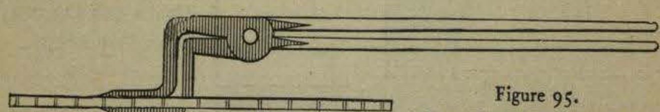


Figure 95.
Tongs for holding flat plates.

place the top plate in position as quickly as possible, after the saw has been placed on the lower plate.

If the saw should become chilled before the upper

plate is placed on it, it will spring somewhat, and the upper plate cannot straighten it. Should it be sprung

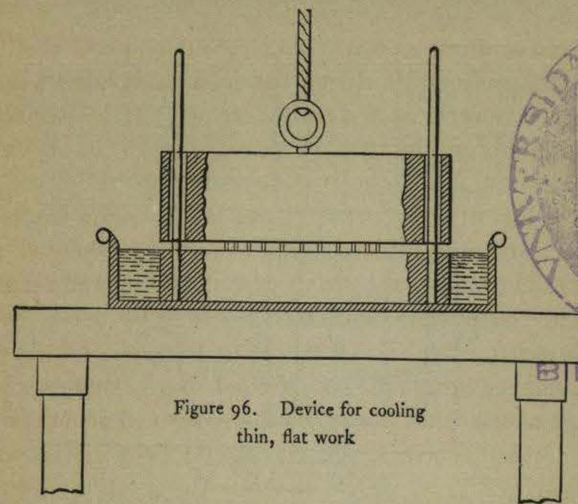


Figure 96. Device for cooling thin, flat work

very much, the pressure applied to the upper plate will, in all probability, break the saw, as it would be hard and unyielding.

If many pieces of the description mentioned are to be hardened, it is advisable, for the sake of economy, to make a special device for chilling the work, as when two plates are used, it is necessary to have the services of two men, one to handle the saws, and one to work the movable plate. If the number of pieces to be hardened does not warrant an expensive apparatus, two flat plates may be used, drilling two holes in each plate, as shown in Fig. 96. The holes in the lower plate should be a driving size for ½ inch wire, while those in the upper plate should be $\frac{1}{16}$ inch larger than the size of the wires. A cord should be attached to the upper plate, as shown. This cord should pass over a pulley and return to a treadle. The operator,

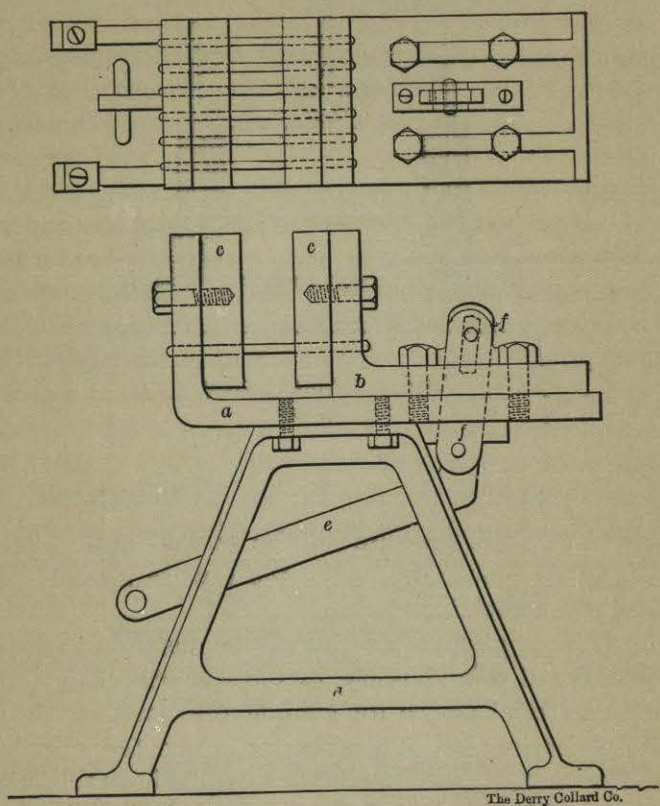


Figure 97. Device for hardening between plates.

by using this device, can handle the saws and operate the plate very nicely.

In Fig. 97 a device is shown for hardening thin pieces between plates, which consists of the base *a*,

and slide *b*, to which are attached jaws *cc*. Through the jaws are several wires for the work to rest on when it is placed between the jaws. The side is operated by the treadle *e*, which is connected to the base and slide by the brackets *ff*. The device is supported by the legs as shown. The advantage derived from using a fixture having the jaws standing in a vertical line, as shown, is, the piece of work is not as liable to chill while closing the jaws, as would be the case were the jaws in a horizontal position.

If the work is hardened in large quantities and the jaws show a tendency to get hot, they may be cast hollow and a water pipe connected with each, providing an outlet on the opposite side. In this way a circulation of water may be kept up through the jaws, thus keeping them cool at all times. In order to insure a

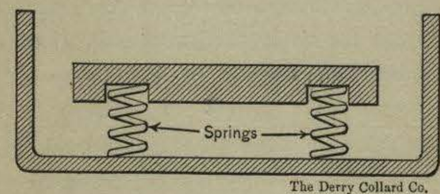


Figure 98. Cooling plate mounted on springs.

uniform circulation of the water, it will be necessary to have the inlet pipe at the lower edge, on one end of the jaw, and the outlet pipe on the upper edge at opposite end. The outlet pipe should be carried far enough to do away with any liability of any of the water getting on the surfaces of the jaws that were to come in contact with the pieces being hardened.

When saws or other pieces of considerable thickness are hardened between plates, it is sometimes necessary to provide for a supply of oil around the teeth when the plates are in position. In order to do this, it is necessary to use plates in a horizontal position, as shown in Fig. 98, having the lower plate resting on springs, or other arrangement to keep its upper face above the surface of the oil in the pan, until the work has been placed on it. The pressure applied by the upper plate must submerge them in the oil in pan to a depth that insures the teeth being well covered with oil.

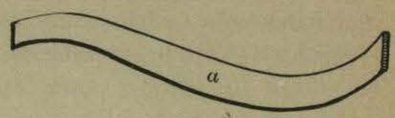


Figure 99. Gun spring.

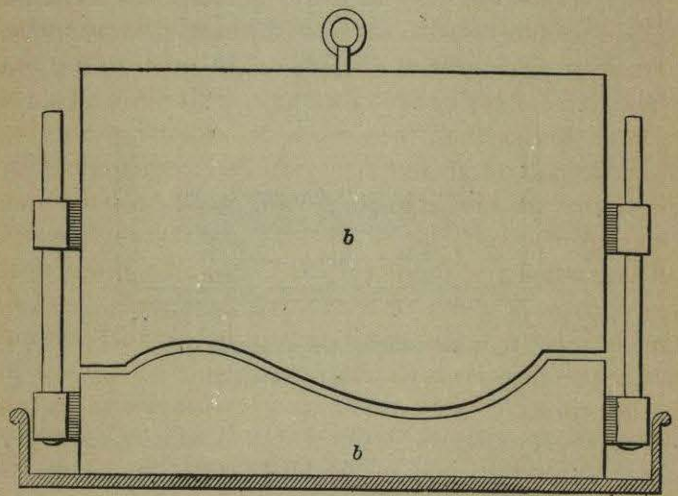


Figure 100. Method for cooling gun spring shown above or other irregular pieces.

When drawing the temper of tools of this description best results can be obtained by putting the pieces in a kettle of oil, gauging the heat by a thermometer. While the degree of heat necessary to produce the desired result can not be given arbitrarily, as very much depends on the steel used, the amount of heat given when hardening, and the use to which it is to be put. But ordinarily, metal slitting saws for general jobbing purposes should be drawn to 460 degrees. Screw slotting saws, $\frac{1}{16}$ inch thick and under, 525 degrees. If thicker, do not draw as low.

The method of hardening between plates may be applied to pieces having other than flat forms. Take, for instance, springs which, in order to maintain a given tension, must be of a certain shape; for example, the main spring of a gun, as represented in Fig. 99. The form of spring is shown at *a*, while *bb* is a pair of plates, having their faces formed to harden the spring and keep it in the proper shape. It is not generally desirable or advisable to use a form when hardening springs of this character, but is sometimes necessary. The method and amount necessary to draw the temper of springs is given under Spring Tempering, and to avoid repetition the reader is referred to that section. It has seemed necessary to repeat some statements in order to show their different applications and to impress them on the mind.

Screw-Drivers.

There is probably no one article so generally used as the screw-driver that gives so much trouble. In the first place, not more than one man in ten understands how to properly make the tool, and then but a small percentage of this one-tenth can harden and temper it properly after it is made.

A screw-driver is better for having been forged to shape, provided it is forged properly; that is, heated properly and hammered in a scientific manner. Unless one understands these operations well enough to do a *good* job, it is advisable to file or machine one from the bar.

A screw-driver should be made with the end that enters the screw slot of an equal thickness throughout, and to nearly fill the slot. At times, this precaution is observed, and the portion immediately adjoining is made much heavier and with square corners, as shown at *a*, Fig. 101. Now, on account of the unequality of size of the adjoining portions, it is a difficult matter to harden and temper it uniformly throughout. Then again, the shape is such that it must break where the heavy and light portions adjoin, on account of the unequal strength of the two portions.

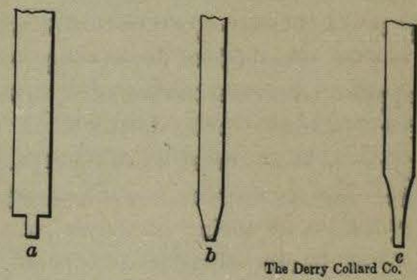


Figure 101. Styles of screw-driver points.

Now, a screw-driver, or any tool which must resist a bending or twisting strain, must be made in such a manner that the tension will be taken up for a considerable portion of the length of the article, thus doing away with a tendency to break at any one point. In Fig. 101, *b* represents a screw driver made in a man-

ner that apparently, according to some mechanics' minds, will just fill the bill. It is symmetrical, that is, there are no breaking points; but look at the end that enters the screw slot—it looks more like a chisel than a screw-driver. Now, when pressure is applied to this form, it, on account of the inclined sides, slips out of the slot. It will not hold, so a stick or piece of iron is placed on top of it in the form of a lever, and one or two men hold down on the end of this, as shown in Fig. 102, and the fellow doing the job gets a wrench on, and yanks. Now, the screw-driver is subjected to two strains instead of one. It tries to get out of the slot, and cannot, on account of the power applied above. It is also subjected to torsional strain from the direct pull of the wrench, and it breaks. Now, if it is made of the form represented at *c*, Fig. 101, and hardened and tempered *properly*, there will be very little danger of it breaking from any ordinary usage.

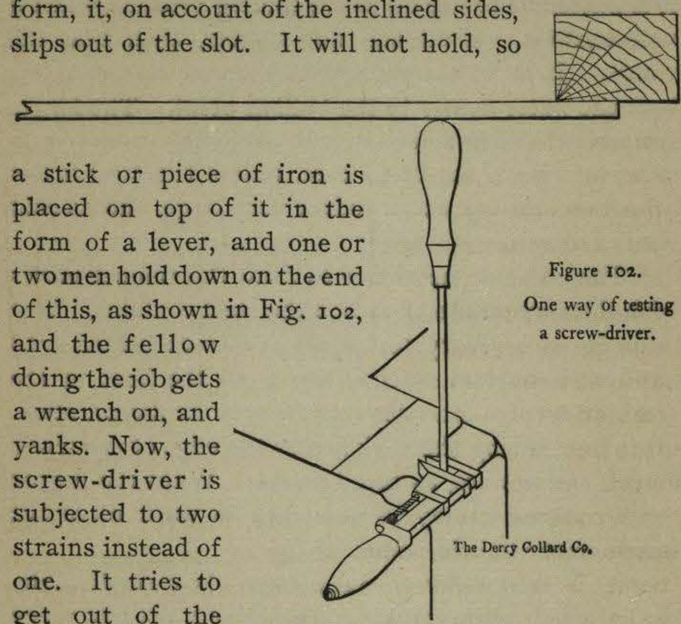


Figure 102. One way of testing a screw-driver.

When heating for hardening, give it the lowest heat that will produce the desired result. Remember, hardness is not the desired quality; it will not be called on to cut metals, it must simply resist strain or pressure, consequently toughness is the quality to be sought. Articles hardened in cold water do not show this quality to such a degree as those quenched in oil, so it is advisable to use oil as the cooling medium when it will answer. If oil will not answer, then heat the water. If it is a comparatively small screw-driver, heat the water nearly to the boiling point. The larger the article, the less heat it will be found necessary to give the water; but in no case, unless the steel is low in carbon and the screw-driver very large, should cold water be used.

The amount necessary to draw the temper varies with the percentage of carbon the steel contains. If it is made of ordinary tool steel, it may be heated until hardwood sawdust catches fire from the heat in the steel, or until a fine shaving from a hardwood stick, made by drawing the stick across the edge of the screw driver, catches fire, as noted before. When the proper temper shows, it may be quenched in warm oil or hot water, never in cold water.

While screw-drivers may seem like a small affair, hardly worth while thinking much about, the frequency with which they are used and the time lost in regrinding after breakage, make them quite an important tool in any shop. Then, too, the damaged screw heads must be counted against them.

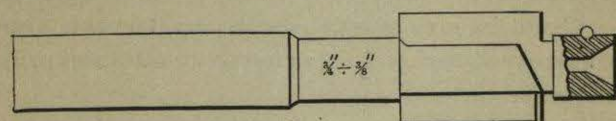
Taper Mandrels.

When it is necessary to harden taper mandrels made of *tool steel*, it is necessary to provide some means of uniformly heating the article. One end, being of a

greater diameter than the other, has a tendency to heat slower. Owing to this fact, it will be necessary to heat slowly. When it has reached the desired heat, which should be uniform throughout, grasp by the small end with a pair of tongs and immerse in a bath of water or brine, which has a jet coming up from the bottom. When it ceases singing, remove and plunge in a tank of oil, allowing it to remain until it is cooled to the temperature of the bath. It should then be reheated to remove the tendency to crack from internal strains.

Counterbores.

The toolmaker or designer should, when designing tools that are to be hardened, avoid, as far as possible, sharp corners between portions of different sizes. If a counterbore is made as shown in Fig. 103, the presence



The Derry Collard Co.

Figure 103. Counterbore with square corners.

of sharp corners is an invitation for the steel to crack from unequal contraction at these points. If the corners are rounded (filleted), as shown in Fig. 104, the tendency to crack is almost entirely eliminated.

Many times serious trouble arises from countersinking center holes too deeply in articles that are to be hardened. Fig. 104 represents a sectional view of countersinking in pilot, which is deep enough for all practical purposes, while in Fig. 103, the countersinking is so deep that there would be a great tendency to crack when hardening. When articles of this description are countersunk too deeply, it is advisable to fill the hole with fire-clay before placing it in the fire. This plan, of course, would not work satisfactorily in the case of mandrels, arbors, and similar tools, whose centers must be hard in order to resist wear.

Heat to the lowest uniform red that will cause the

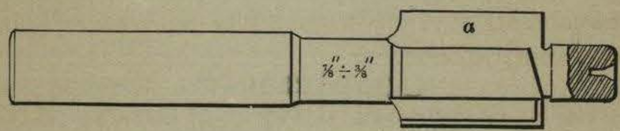


Figure 104. Counterbore with filleted corners.

article to harden, dip in a bath of lukewarm brine, hardening part way up the portion necked below size of shank.

When drawing the temper of counterbores, apply the heat at shank end, allowing it to run toward the cutting end of teeth.

The proper amount to draw the temper depends on the character of the work to be done, the design of the counterbore, etc. It was formerly the custom to draw the temper to a degree that made it possible to sharpen the cutting edges by filing with a sharp, smooth-cut file. If the counterbore is made of the design shown in Fig. 104, it may be sharpened by grinding on the face (a) of cutting tooth with an emery wheel, thus making it practical to leave the tool much harder than would otherwise be the case.

A very common mistake when making tools of this

description is to stamp any distinguishing marks on the tool when finished, thereby springing it; and unless this fact is noticed, the hardener will be blamed for it. *All stamping should be done before the important portions are to size.*

When hardening counterbores having inserted pilots, it is advisable to fill the pilot hole with fire-clay, in order to prevent the water entering. If the design is such that the tool is liable to crack when quenched, it should be dipped in the bath with the teeth uppermost. The contents of the bath should be warmed to reduce the liability of cracking.

Hardening Mandrels, Arbors, Etc.

Mandrels, arbors, and similar articles, which are to be hardened, are generally made of any piece of tool steel which comes handy. Now, it is a fact that tools of this description give a great deal of trouble when hardened, unless the operator is quite skillful. As the only reason for hardening a mandrel is to give it a hard surface and make it as stiff as possible, the desired result may be obtained by using a steel that is not high in carbon. Take, for instance, a steel containing $\frac{7}{8}$ per cent. or one per cent. carbon. As good results can be obtained as if a steel containing $1\frac{1}{2}$ per cent. carbon were used, while the article would not be as liable to crack or spring as if a high carbon were used.

When making articles of this description, steel somewhat larger than finish size should be selected. The outside should be turned off and the piece annealed. After annealing, it may be machined to grinding size and then hardened.

When hardening, a fire large enough to heat the