than it would be if it were drawn to the proper temper color and allowed to cool off slowly, or plunged in warm oil or hot water. In the case of large, heavy pieces, or where brittleness would do no particular harm, this precaution need not be observed so closely. But on the other hand, if brittleness did no harm, it would not be necessary to draw the temper, because few tools are ever too hard for the purpose for which they are intended. For, as previously explained, the process of hardening makes them too brittle to stand up well when they are in use, consequently they are tempered to reduce the brittleness to a point where they will stand up. But the process of tempering is also (unfortunately for cutting tools) a process of softening.

It should be the aim of the hardener at all times to harden steel at the lowest heat that will give the desired result, because in this condition the steel is the strongest possible, and consequently will not need the temper drawn as much as though it was given a higher heat and made brittle. Many times the writer has seen hardeners heat a diamond point turning tool to a temperature much hotter than was necessary when hardening, then draw it to a full straw color in order to reduce the brittleness so it would be able to cut and not flake off, or the surface cave in when the tool was cutting.

Now, the tool in this condition could not do anywhere near its maximum work in a given time. Neither would the life of the tool be as long as though it were hardened at the proper heat, and in this case it is doubtful if it would be necessary to draw the temper at all, provided it had not been improperly heated when forging. Many times tools of this description

can have the temper drawn sufficiently by immersing the tool after hardening in a dish of boiling water and leaving there a few minutes.

Examples of Hardening.

When hardening articles made of tool steel, it is necessary to consider, first, the nature of the steel used, the construction of the article, next the shape of the article, and the use to which it is to be put. It is also necessary to take into consideration the means of heating furnished by the shop, and the bath to be used in quenching the article after it is heated.

The operator should adapt himself so far as possible to circumstances as he finds them, although it is not advisable to attempt the impossible, because a failure is generally counted against the man making it, rather than to any lack of apparatus necessary to do a job successfully. By this is meant that it is not policy to attempt to heat a piece of steel for hardening in a fire that cannot be made to heat the piece the entire length under *any* conditions—that is, if it is necessary to harden it the entire length—because such an attempt must end in a manner disastrous to the steel. It is, however, the best plan to attempt to find some means whereby the piece may be heated properly by means of the apparatus at hand.

The writer remembers, when a boy, seeing a tool

maker heating a long taper reamer. The only means of heating furnished by the shop was an ordinary blacksmith's forge. By building a large, high fire he was not able to do a job satisfactory to himself, so he cleaned the fire out of the forge, and then took some fire brick,

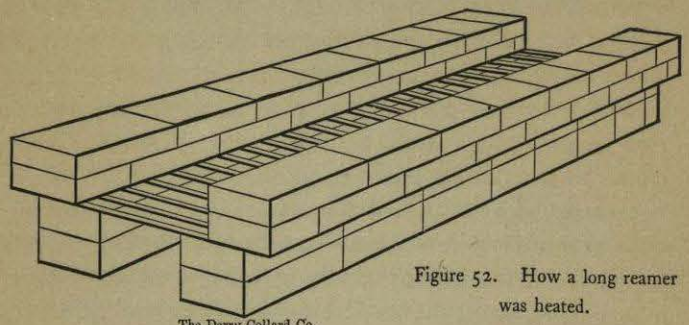


Figure 52. How a long reamer was heated.

The Derry Collard Co.

placing two rows on the forge, as shown in Fig. 52. On these he placed pieces of wire, about one-half inch apart, built two rows of bricks on top as shown, thus forming an oven, and then built a fire of charcoal on the wires between the bricks. By standing bricks up at the openings at the ends, he was enabled to get a very good fire in which he heated the reamer in a very satisfactory manner.

While it would not have been wise to have pursued this method of heating, if there had been many pieces of the kind mentioned to be hardened, yet the fact that this man was able to adapt himself to circumstances and devise a way of doing a seemingly impossible thing, made him a valuable man in the estimation of his employers. It is the man who can do the seem-

ingly impossible things about a shop that is looked upon as the invaluable man, and it generally counts, as would be seen if his pay envelope was examined.

While it is advisable, whenever possible, to study up some way of doing the work, do not attempt the impossible unless some one over you in authority assumes the responsibility. It is better to acknowledge your lack of ability than to spoil a costly piece of work, when it would have been considered advisable by those in authority to have sent the article to some one having the necessary equipment, had their attention been called to the matter.

Cases like this may often be used to good advantage in pointing out the advisability of securing better facilities for hardening and tempering. As long as it is possible to get along without any equipment but a common blacksmith's fire, it is often very hard to obtain anything better.

Hardening Dies.

If it is necessary to heat a large die in an ordinary blacksmith's forge, it can be done. It is done right along by men who have had years of experience, and very satisfactory results are obtained. The writer knows a man who is considered a very successful hardener. He does very little else but hardening large drop forging dies. He heats them in an open fire and has very good success. He could have, were he to ask for it, the very best equipment that money could buy, but he prefers heating by the method mentioned.

The writer also knows of an old man who lives

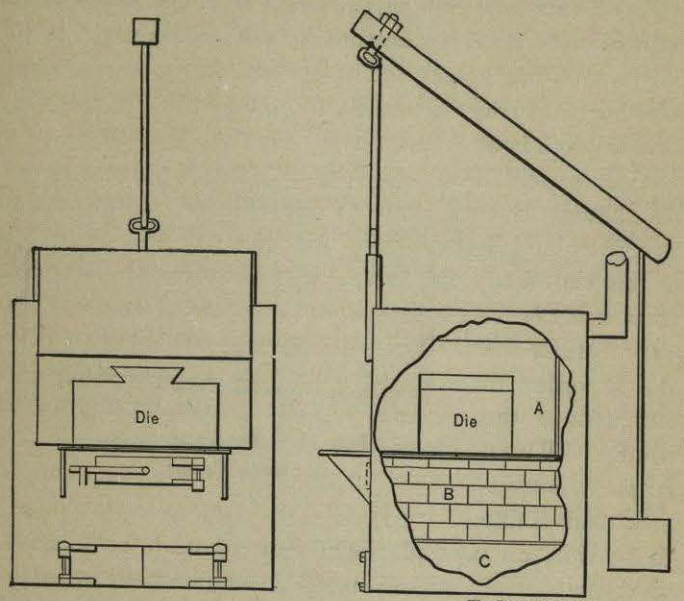
four or five miles from the city. The electric cars run within five hundred feet of his house, but rather than ride on "them air new fangled devil's contraptions," as he calls them, he walks to the city, unless some of his neighbors give him a ride in their carriage. It may not seem to be a parallel case. If it isn't, the odds are in favor of the farmer, as there may be a certain danger in riding in the trolley cars.

Now, it is possible to heat a large piece of steel, such as a drop forging die, in a blacksmith's forge by building a large, high fire of charcoal, placing the die on this, making certain that the face is buried in the live coals to a depth of several inches. It would be necessary to raise the die occasionally and work the coals under it, as it would not do to allow the air from the blast to strike the face. It is very necessary to heat the face uniformly. In order to do this it may be found necessary to move the die, so that some part that is heating slowly may be placed in a position where it will get more heat.

Now, while it is possible to heat work of the description mentioned by the method described, it is not policy to do it, provided any other means is at hand, or can be procured—that is, if there are many pieces to be hardened. If there are but one or two pieces, it is possible by using extreme care to get good results; but if there are many of them it is folly, speaking from a commercial standpoint, to heat by this method.

A furnace which gives very good results may be made, if it is not considered advisable to purchase one especially adapted to this class of work. Fig. 53 represents a muffle furnace burning hard coal as fuel, although charcoal or coke may be burned; but it will

be found easier to maintain a uniform heat by the use of hard coal, and as the products of combustion do not come in contact with the piece being heated, they cannot in any way harm it. A represents the muffle which receives the work. This is located directly over the



The Derry Collard Co.

Figure 53. "Home-made" furnace for die work.

fire box B. The heat and gas from the fire pass up the sides and back of the muffle, thus insuring a very strong heat. The ash box C is provided with a door which has a sliding damper to furnish a draft for the fire. The smoke pipe is connected with the chimney. This is also provided with a damper to use in controlling the fire.

The die may be blocked up from the bottom by

means of several pieces of iron or fire brick to prevent the face coming in direct contact with the floor of the muffle. The door of the muffle should have an opening, which should be covered with a piece of mica in order that the heat may be readily observed without cooling the die.

When many very large, heavy dies are heated it is advisable to have the bottom of the muffle on a level with the floor, sinking the fire box and ash box in the ground. By having the muffle on a level with the floor it is not necessary to raise the die in order to get it into the muffle. When it is not considered advisable to do this, an iron platform may be built on a level with the bottom of the muffle. The heated die may be run out on this and then taken with tongs or grappling hook and carried to the bath.

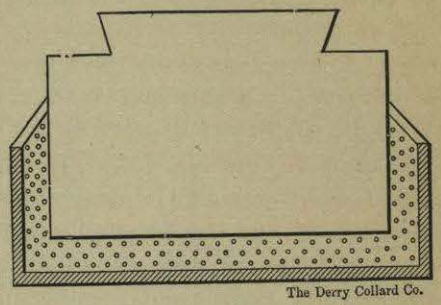


Figure 54. Box for heating dies in charred leather.

Other forms of furnaces which may be used for this purpose are illustrated under the section showing Methods of Heating.

It is customary with some manufacturers who make a great many dies to harden them in the following manner: Take a box 2 or 3 inches longer and wider than the die, and 4 or 5 inches deeper. Put in about 2 inches

of granulated charred leather, place the face of the die on this, as shown in Fig. 54, then fill the box with leather.

Some hardeners use a box large enough to take in the whole die and allow for a cover on top. It is then entirely removed from the action of the fire, even if heated in a furnace where the work is placed directly in the fire. But as it is not possible to get a test wire down through the center of the die, and a wire at the sides of the die would not show the amount of heat the die contained, and as there would be no means of observing the heat, the operator would have no means of knowing whether the die was too hot or not hot enough, or whether it was heating uniformly. And as the decarbonization of the surface of the upper part of the die is of little consequence, the plan suggested by Fig. 54 will be found the most satisfactory, as the heats can be watched and the die moved occasionally in order to equalize the heat, which is apt to be greater in one part of the furnace than in another. The furnace should not be heated much above the temperature desired for the die. It is better to take a longer time in heating than to heat unevenly, thereby setting up strains which are bound to manifest themselves when a piece is hardened, or if they do not at that time they will shortly afterward.

When the proper heat has been obtained, the box may be removed from the furnace and the die taken out and plunged into the bath. The form of bath used for this class of work differs, some hardeners preferring one with a jet of water coming up from the bottom, as shown in Fig. 55. This works very nicely if the impressions are not too deep, in which case the

steam formed has a tendency to rise in the impressions and keeps the water from going to the bottom. When dies of this description are to be hardened, a bath may be constructed with an overhead pipe, as shown in Fig. 56. By this means the die is placed on the rods shown, and when the water is turned on it will go to the bottom of any impression that would be likely to be in any die. This form has the further advantage that a cupful of strong solution of salt and water, potash and water, or cyanide of potash and water may be dashed on the face and into the impression just ahead of the jet of water. This has the effect of starting any scale that may have been formed after the die was exposed to the air.

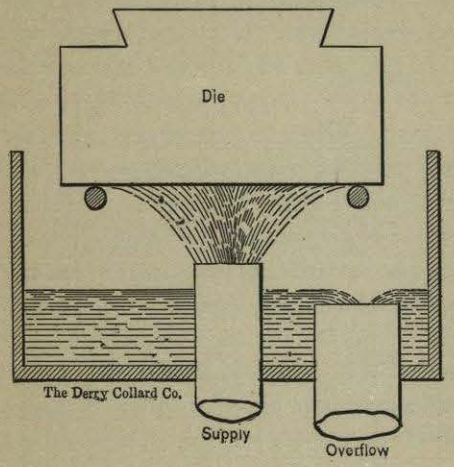


Figure 55. Bath for hardening dies.

Some hardeners have rods in the bath for the face of the die to rest upon, as shown in Fig. 55, then allow the jet to play against the face, while others claim better results if the die is worked up and down somewhat in the bath as described.

It is customary with many manufacturers who

have many dies of this character to harden, to use a bath having an inlet pipe coming up from the bottom, as just shown. When the die is properly heated, it is placed on the rods with the dovetailed tongue down; the stream of water is allowed to play against this side of the die until it is somewhat cooled; this not only prevents this portion springing when the face is hardened, but it allows the heat to run to the face of the die.

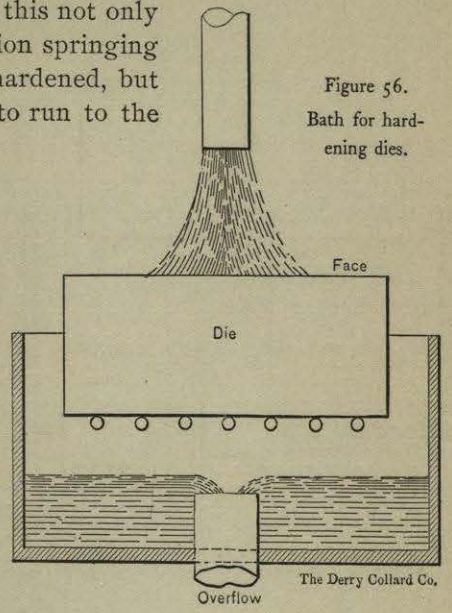


Figure 56. Bath for hardening dies.

After the tongue side is sufficiently cooled, the die is turned over and the stream of water is directed against the face; the overflow is checked sufficiently to allow the water to rise several inches above the face, on the sides of the die; that is, it is immersed several inches in the bath; the depth of immersion depending on the character of the die and the custom in the individual shop.

When dipping large, heavy dies in the bath, it is advisable to hold the die with a pair of grappling hooks, as shown in Fig. 57. These should be attached to a rope or chain and operated by a pulley, in order

that the die may be raised and lowered somewhat in the bath. Then again, it would not be advisable for the workman to dip so large a piece of steel with tongs that necessitated holding his hands and arms over the bath, as the immense volume of steam would be liable to burn him; neither could he properly support the die in the bath.

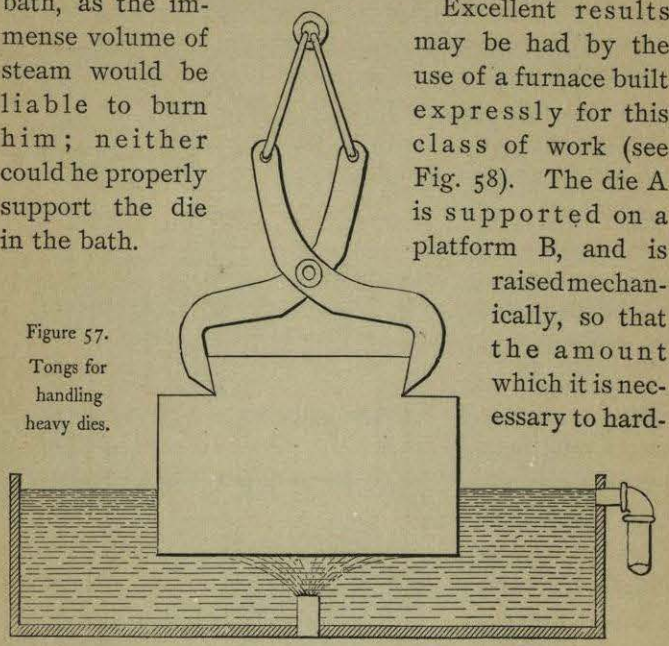


Figure 57. Tongs for handling heavy dies.

Excellent results may be had by the use of a furnace built expressly for this class of work (see Fig. 58). The die A is supported on a platform B, and is raised mechanically, so that the amount which it is necessary to harden is in the furnace, while the rest of the die is below and removed from the action of the heat. The heating chamber is on top, with burners entering opposite sides and projecting the flame against the top lining and distributing it evenly. The die should not be placed on the platform until the furnace is evenly heated, when it may be raised by means of the lever D, until the face enters the furnace the desired amount. The face of the die can be observed through the opening C. When heated to the desired degree, the platform is lowered, the die withdrawn and quenched. The weight of the die is counterbalanced by the weight shown, which can be shifted as occasion requires.

Dies used in making molds for hard rubber and similar work, whose faces are engraved, may be packed as described and represented in Fig. 54, and run until the required heat is attained. After the heat becomesequalized—*i. e.*, the same throughout—the die may be dipped in the bath of brine, using the arrangement shown in Fig. 57. It is necessary to get the die in the bath as soon as possible after removing from the packing material in order to prevent oxidation of the face containing the engraved work.

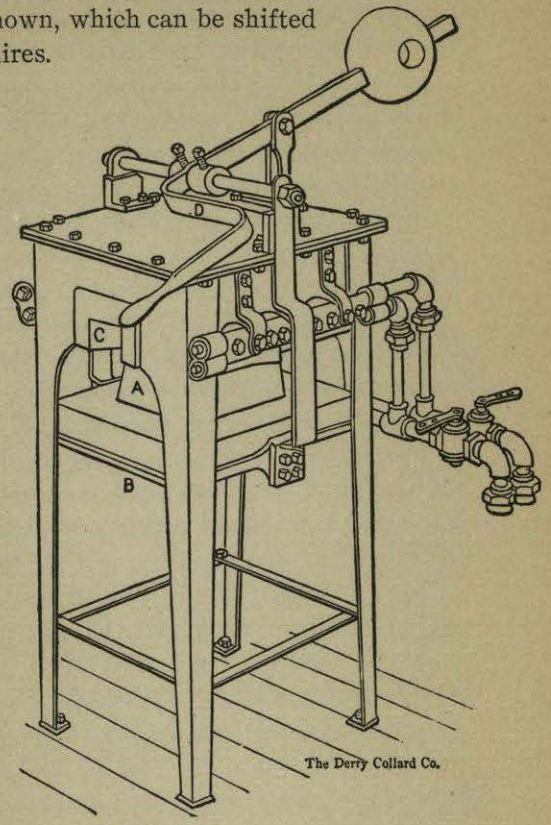


Figure 58. Gas furnace for heating dies.

Punching press dies.

Dies for punch press work, especially those used for blanking—that is, punching blanks from sheet or other stock—occasion a vast amount of trouble in many shops when they are hardened. Observation has led the writer to believe that most of the trouble is caused by *uneven* heats. The corners and edges of the block and the edges surrounding the openings will heat much more rapidly than the balance of the die block unless extreme care is used.

Before putting the die in the fire, all screw and dowel pin holes and holes for guide pins (stops) should be filled with fire-clay, mixed with water to the consistency of dough. This prevents the contents of the bath entering the holes, and reduces the tendency to crack. The die should, if possible, be heated in a muffle furnace, not heating the furnace much, if any, hotter than the desired heat for the die. When it is to the proper heat and uniform throughout, remove from the furnace, catch by one end with a pair of tongs and lower into a bath of brine. Swing slowly back and forth in the bath, in order that the contents of the bath may pass through the openings. This insures the hardening of the walls, as otherwise the steam generated would force the contents of the bath away from the die until it had cooled to a point where it would not harden. When the die ceases to sing, it may be removed and plunged into a tank of oil.

There is not much danger of a die cracking when dipped in a bath, provided it was annealed after the blank had been machined all over and the openings blocked out somewhere near to shape. But it is extremely essential that the utmost care be taken when heating for hardening. Be sure that no part of the die

How to prevent cracking of dies.

block is heated any hotter than it should be. The heat *must* be uniform throughout the piece. If the shape is one that betokens trouble, it is advisable to heat the contents of the bath considerably. Generally speaking, it is not advisable to use an extremely cold bath on this class of work.

The writer prefers using a tank of generous proportions, so the contents would not be materially affected by the heated piece, and heating the liquid to a degree that does away with any tendency to crack the piece. An excellent method to prevent the tendency to crack from internal strains, consists in placing the die, after hardening, in a kettle of boiling water, keeping the die in the water at this temperature for one or more hours, according to the size of the die.

If the temper is to be drawn immediately after the die is taken from the bath, a flat piece of cast iron or scrap steel may be heated while the die is being heated, and quenched. It is customary with some hardeners to heat the piece red-hot. Brighten the face of the die and lay it on the heated iron. The die should be moved around on the heated piece and turned over occasionally to heat both sides alike. When the temper has been drawn the desired amount, the die may be immersed in oil, thus preventing the temper being drawn too much.

While it is the custom of many hardeners to heat the drawing plate red-hot, as explained, before placing the die on it, the writer considers it better practice to heat the plate *somewhat*, leaving it over an open fire. Place the die on the plate and gradually raise the heat. It is rather rough treatment for a piece of unyielding hardened steel to be brought in direct contact with

extreme heat, and is liable to crack the surface of the steel in innumerable places, especially if the operator is not thoroughly experienced in this line of work.

The amount necessary to draw the temper of a blanking die depends on the steel used in its construction, the temperature it was heated to when hardened, and the nature of the work to be performed by it.

Generally speaking, it is advisable to refer the matter of how hard the die or punch should be to some one familiar with the requirements of the work to be done. In *some* cases it is desirable to have the punch the harder of the two, although, generally speaking, the die is left harder than the punch. In some shops, the one that requires the greater expense in making is left the hardest, in order that it may be the least injured in case they strike together when in use. In such cases it is necessary to draw the one that is desired softest considerable lower than the other.

But as the circumstances must govern the relative hardness of the two, no hard and fast rule can be given.

It is customary to draw to a temperature varying from that which produces a faint straw color, to a brown with purple spots.

Probably no one class of tools used in machine shop work requires greater care on the part of the hardener than the hardening and tempering of punches and dies; and probably no class of tools involves a wider range of methods of hardening and degrees of hardness essential to produce desired results in the individual shop.

The hardener who is desirous of giving satisfaction will study the conditions in the shop where the tools are to be used. He will also consider the steel

used in the construction of the tools and the nature of the stock to be machined. It will be necessary also to get the experience of men familiar with the work to be done, because a die and punch hardened and tempered in a manner that insured satisfaction in one shop would not meet the requirements in some other shop.

When hardening the punch, use extreme care in heating. If the punch is strong and is to be used for punching comparatively light stock, it is not necessary to harden it the entire length. Take, for instance, the punch shown in Fig. 59, to be used for punching sheet steel $\frac{1}{16}$ inch thick. This will work satisfactorily if hardened to the dotted line shown.

When, however, it is necessary to harden a piercing punch of the design shown in Fig. 60, it will be found necessary to harden the entire length of the end *a*, if the punch is to be used on heavy stock. Should

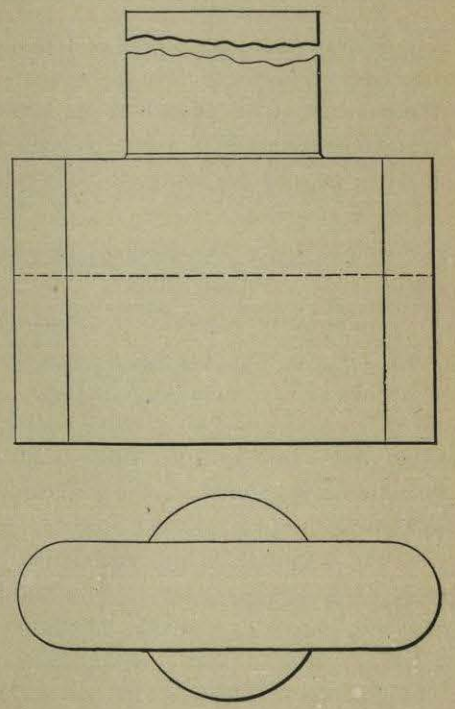


Figure 59. Punch for $\frac{1}{16}$ inch steel plates.

the hardness extend only to the dotted cross line, it would buckle, as shown in Fig. 61, when punching stock as thick as the diameter of the punch.

When making punches that are heavy and strong, and which must retain a good edge, it is advisable to use a steel of comparatively high carbon. But if

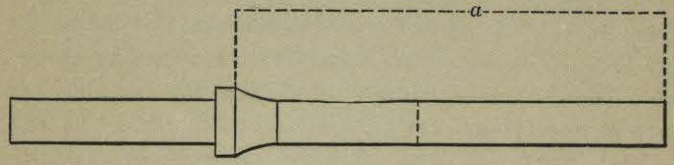


Figure 60. Piercing punch for heavy work.

punches are made of the form shown in Fig. 60, best results will follow if a comparatively *low* carbon steel is used, as it is not as liable to crystallize as if a higher

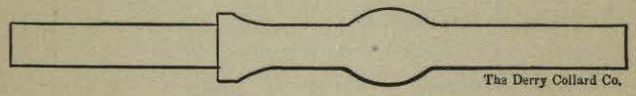


Figure 61. Result of hardening only as far as the dotted line, as shown in Figure. 60.

steel were used. As a rule, drill rod does not give good results when used in making tools of this description.

When punches are sufficiently strong, it is advisable to apply the heat at the shank end when drawing the temper. A block, as shown in Fig. 62, having several holes a trifle larger than the shanks of the punches may be heated red hot and the punches placed in these holes. When the desired temper color is visi-

ble at the cutting end, the punch may be taken from the block and dropped in oil to prevent its becoming too soft. The upper end of punch will, of course, be softer than the cutting end.

When a long, slender punch, of the design shown in Fig. 60, is to be tempered, and the punch is to be

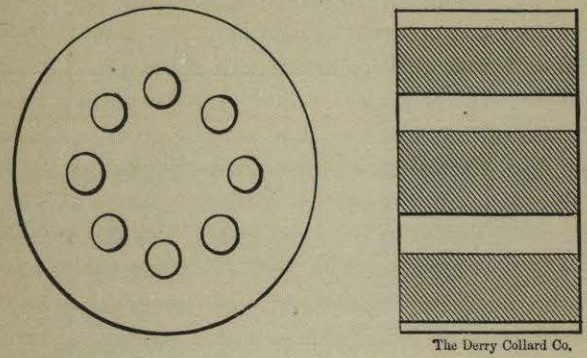


Figure 62. Heating block for tempering long, slender punches.

subjected to great pressure, it must be hardened the entire length, and the temper drawn equally the whole length. This can be accomplished by heating in a heating machine of the design shown in Fig. 48, or the punches may be placed in a pan containing sand and drawn over a fire. Or they may be placed in a kettle of hot oil, gauging the heat by means of a thermometer.

If intended for piercing a heavy, tough stock, they will be found to work very satisfactorily if drawn to a full straw color, 460°.

Many hardeners and others look askance at thermometers and always associate them with theory rather than practice, with the laboratory rather than

the workshop. In reality they are just as practical a tool as a steel scale or a micrometer, and, like them, enable us to measure rather than to guess.

Forming Dies.

When hardening forming dies or dies for compression work, if a great amount of pressure is to be exerted in order to perform the necessary work, the dies will not stand up as well if hardened at a low heat as though heated somewhat hotter. The outside surface will be hard, but under pressure this surface will be forced or crushed in, the interior not being hard enough to resist the pressure on the outer surface. It is, as stated, sometimes necessary in such cases, to heat the block somewhat hotter than if it were a cutting tool, yet care must be exercised that the piece be not overheated. But while it may be advisable to heat somewhat hotter than is the case with most tools, the heat *must be uniform throughout* the die.

It is not, generally speaking, advisable to draw the temper very much on tools of this description, but it is necessary to remove the tendency to crack from internal strains. This is done by heating the die over a fire until it is at a temperature that makes it impossible to hold the hand on it, yet not hot enough to perceptibly start the temper, or it may be boiled in a kettle of water for several hours.

Ring Dies.

When hardening large ring dies or pieces of a circular shape, whose size and weight make it impracti-

cable to harden by ordinary methods, it is a good plan to heat in a furnace made especially for this class of work. Such a furnace is seen in Fig. 63, which shows a circular block A in position for heating. It is resting on strips of iron C supported by pieces of fire-clay B. The circular piece being heated should be in the center of the furnace—*i. e.*, evenly distant from the inner walls. The cover D is attached to the mechanism for raising the cover, and held by the chains EE. It is possible, by using proper care, to heat work very uniformly in a furnace of this description.

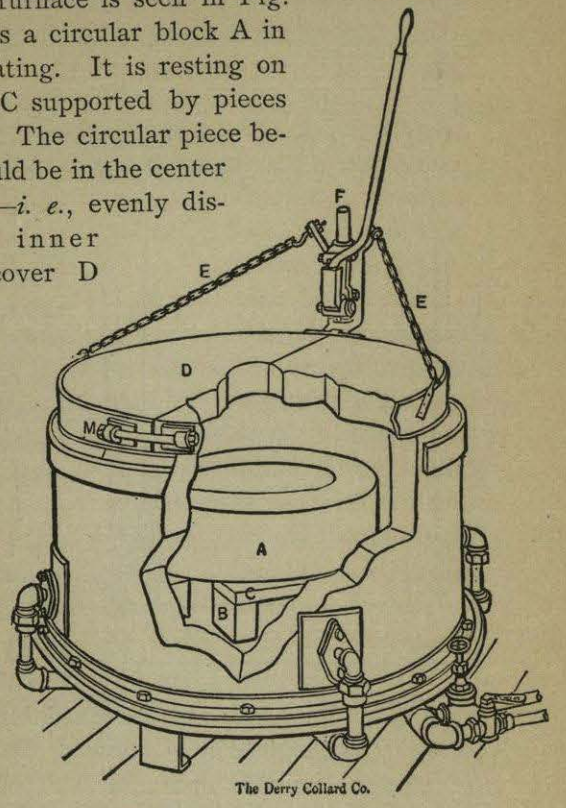


Figure 63. Gas furnace for ring dies and similar work.

A method the writer has used with excellent results when hardening work of this character, consists in placing the ring or circular die in an iron box two or three inches larger each way inside than the circular piece. A circular box gives better results than a square one, as