scription shown in Fig. 137, using as packing mixture equal parts animal charcoal, wood charcoal and charred leather. The work was run 45 minutes after it became red-hot, then dumped in cold water, and gave excellent results. The links tested showed up well, and the chains gave the best of satisfaction when on the wheels. A different stock was procured, and it was found by experiment that links made from the new stock could be run only 25 minutes after they became red-hot. If run the same length of time as those made of the first stock used, they would break very easily, but when run only 25 minutes gave very good satisfaction.

In many shops it is customary to make snap gauges of machine steel. They are much easier made, the cost of material is less, and, if hardened properly, they will wear well. It is best, in cases of this kind, to use open hearth steel rather than Bessemer, as the latter runs more uneven. The best results will be obtained if we use as packing material granulated leather instead of bone. When packing, mix with an equal amount of granulated charcoal, run five or six hours, if the gauge is ¼ inch thick or more. Run at a very low heat, and dip in the oil bath. It will be found to be very hard, and probably straight. If hardening small pieces, it is advisable to use smaller boxes than when large pieces are being treated, as it takes some time to heat a large box through. Pieces near the walls of the box will become hot quicker than those in the center, and consequently will be hardened deeper.

Many pieces of work are made of tool steel when machine steel would answer the purpose as well, or better, were it not for the coarseness of the grain when

the piece is case hardened. The fine grain may be necessary to resist pressure and wear on some small part of the surface, or possibly it is to be subjected to the action of blows, and the grain being coarse, the surface has no backing and is soon crushed in. The causes of the open grain are: first, that it is the natural condition of the stock; second, the pores are open when heated, and the steel is absorbing carbon. The higher the heat to which the pieces are subjected, the coarser the grain.

It is possible to heat machine steel in such a manner as to produce a fine grain—in fact, as fine as that of the nicest tool steel. While the writer would not be understood as advocating the use of machinery steel in the making of nice tools, as so good an article cannot be produced as if made of tool steel, yet for certain purposes cutting tools are made of a good grade of open hearth steel, case hardened very deep, with fine compact grain, which gives excellent results. This is particularly the case where the cutting part is stubby and strong. Cams made of low grade steel, and hardened by this method, will resist wear as well as though made of tool steel and hardened, and they are not as liable to flake off or break. Punch press dies that are to be used for light work, cutting soft metals where there are no projections, will do very satisfactory work. Gauges, whether they be snap, plug, ring or receiving, are hardened with much less liability of their going out of shape, are easier to make, and will wear as long as though made of tool steel. Then, too, the necessity of allowing them to "age" after hardening, before grinding to size, as is the case when gauges are made of tool steel for accurate work, is done away with.

Many bicycle parts, formerly made of a good grade of tool steel, are now made of machine steel, and the best of results are obtained. Such is not apt to be the case if they are simply case hardened by the ordinary method, as the grain is too coarse to resist the peculiar action of the balls, particularly on the cones and ball seats. Spindles of machines, where there is considerable tendency to wear, also a pounding or twisting motion to resist, where tool steel would be liable to break and ordinary case hardening would yield to such an extent as to make the bearings out of round, can be treated very successfully by this method.

All that is needed is a good hardening furnace, large enough to receive as many boxes as we may need, a plentiful supply of boxes, some granulated raw bone, a good supply of charcoal and a small amount of hydrocarbonated bone, and some charred leather for our nicest work. We should also have a suitable supply of water in a large tank, and a smaller tank arranged so that we can heat it to any desired temperature, and a bath containing raw linseed oil. The work should be packed in the hardening boxes as for ordinary case hardening, run about the same length of time, and left in the oven to cool the same as for annealing.

When cool, the articles may be heated in the open fire, muffle furnace or in the lead crucible, and hardened the same as tool steel; or, if the articles are small, and there are many of them, they can be repacked in the hardening box with charcoal. But do not use any carbonizing substance, as that would have a tendency to open the grain, and the object of the second heat is to close the grain. The lower the hardening heat, the more compact the grain will be, as is

the case with tool steel. This method not only gives a close grain, but a very strong, tough surface, and, the center being soft, the piece is very strong.

When hardening tools whose office it is to cut metals, it is always best to use a packing mixture of equal parts of charred leather and charcoal. The kernels should be fine and of about the same size, if possible, for if the kernels of the leather were large, and those of the charcoal were small, the tendency would be for the finer to sift to the bottom of the box. Leather gives a stronger, tougher effect than bone, it being practically free from phosphorus, while bone contains a large percentage. The presence of phosphorus in steel makes it brittle, especially when combined with carbon. Yet for most purposes where there are no cutting edges bone works very satisfactorily in connection with machinery steel, and is much cheaper than leather. When using either bone or leather, mix with an equal quantity (by measure) of granulated charcoal. Being well mixed, the particles of charcoal keep the kernels of bone or leather from adhering to each other and forming a solid mass when heated. Then again, the charcoal has a tendency to convey the heat through the box much more quickly than would be the case were it not used.

If small pieces are to be hardened that do not need carbonizing more than $\frac{1}{32}$ of an inch deep, it is best to use No. 2 granulated raw bone. If the pieces require a very deep hardened section, it will need a coarser grade, as they must run longer in the fire. When hardening bicycle cones and similar articles, where it is necessary to carbonize quite deeply, it is best to pack with No. 3 bone and charcoal, equal parts, or better yet, with two parts raw bone, two parts charcoal and one part bone black or animal charcoal. Pack in the hardening box, as previously described, run in the furnace 10 hours after the box is heated through, using the test wires to determine the beginning of the heat. After the work is cold, it can be reheated as described and hardened. It is advisable to occasionally break a piece of work and examine the grain, noticing how deep the hardening has penetrated. If not deep enough,

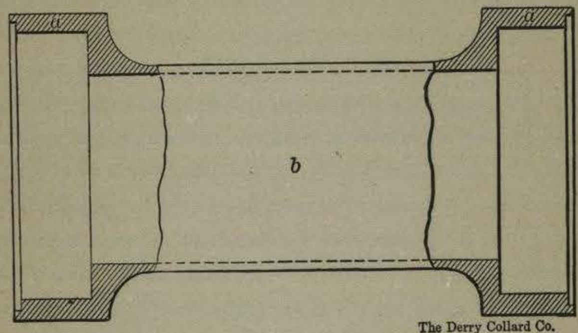


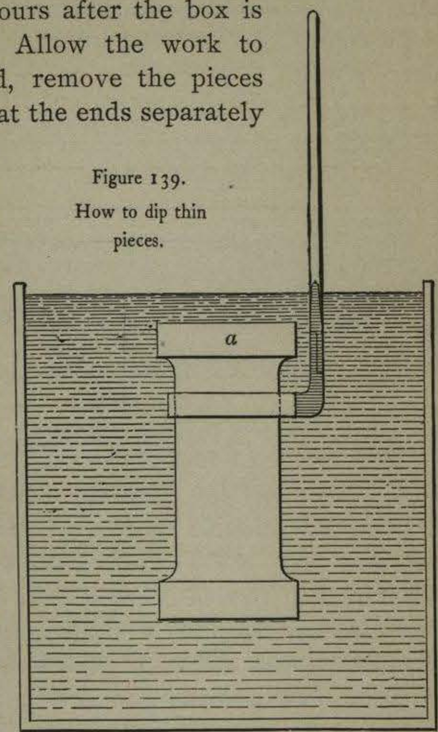
Figure 138. Piece to be hardened, leaving the center soft.

repack in the boxes with fresh material, and run again; but if directions given are followed closely, results will in all probability be found satisfactory. The grain, as far in as the carbon has penetrated, should be as fine as that of hardened tool steel.

In hardening thin pieces, where it is necessary to resist wear or blows, it is advisable to use leather as a packing material, hardening in a bath of raw linseed oil. The pieces will be found extremely tough and hard. It is sometimes desirable to harden the ends of a piece of work, leaving the center soft. Take, for instance, the piece shown in Fig. 138. The surface of the

ends marked *a* needs hardening, while the portions marked *b* should be soft. Pack the ends inside and out with hydrocarbonated bone and charcoal, having previously filled the center with expended bone. Cover the outside of the center with expended bone, run in the oven 7 or 8 hours after the box is heated through. Allow the work to cool as described, remove the pieces from the box, heat the ends separately in the lead crucible, dip in a bath of lukewarm water, dipping with the heated end *a* up, as shown in Fig. 139. Otherwise the steam generated from contact of the hot steel with water would prevent the water from entering the end where it dipped with the heated end down. If the water cannot enter the work and get at the portions necessary to be hard, they certainly will not harden. If the piece is dipped with the heated end as described, the water readily enters. The ends will be found extremely hard, and the grain will be very compact. Not only is this so,

Figure 139. How to dip thin pieces.



but the piece will be much less liable to crack than if the extreme ends were dipped first and hardened, as would be the case with the heated end down.

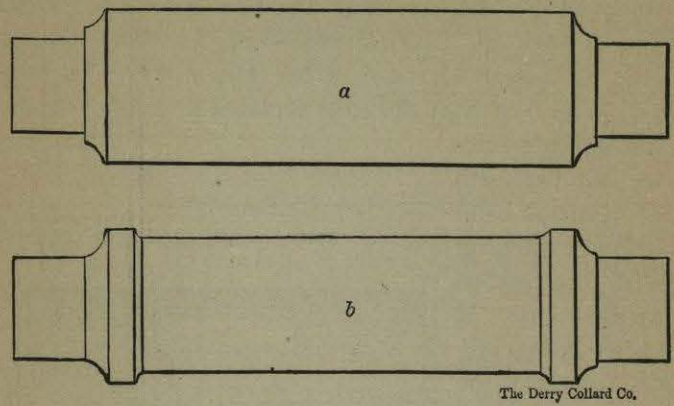


Figure 140. Bicycle axle.

Another method employed when hardening the ends of a piece of work and leaving the center soft, can be illustrated by the bicycle axle shown in Fig. 140. The ends are machined to shape, the center being left large, as represented at *a*. The axle is packed in the hardening box and charged with carbon, as described. The center is then cut below the depth of charging shown at *b*. The piece is ready for hardening. This can be accomplished by heating in an open fire, muffle furnace or lead crucible, and dipping in the bath.

When it is necessary to harden the center of a piece and leave the ends soft, it can easily be accomplished. If the ends are to be smaller than the center,

the pieces may be packed in the hardening box with raw bone and charcoal. Run for a sufficient length of time to carbonize to the desired depth of hardening. Allow the pieces to cool off. When cool, machine the ends, as shown by lower cut in Fig. 141, the upper cut

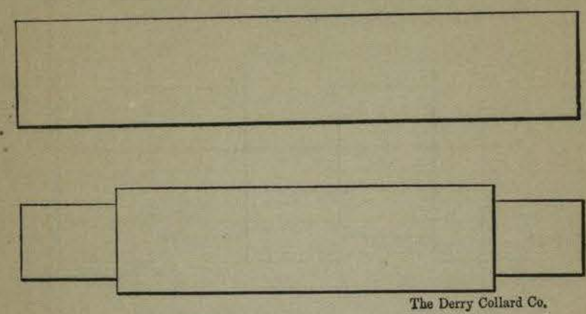


Figure 141. Method of treatment for chain studs.

representing the piece of work before charging with carbon; the lower, after machining the carbonized portions at the ends. It may now be heated red-hot and dipped in the hardening bath in the usual manner. The center will be found hard.

A method employed in making bicycle chain studs that are hard in the center at the point of contact with the block link and soft on the ends, in order that they may be readily riveted in the side links, consists in taking screw wire or special stud wire of the desired size, packing it in long boxes with raw bone and charcoal and running 3 or 4 hours after it is red-hot. Then allow it to cool off. The stock is now placed in the screw machine and cut to shape—that is, the ends are cut down to proper size. The center, being of the proper size, is not machined. The studs may be heated in a tube in any form of fire and dumped in a bath of water or brine. The center will be hard enough to resist wear, while the ends will be soft, the carbonized portion having been removed.

An interesting experiment can be tried, which in itself is of no particular value, except that it acquaints

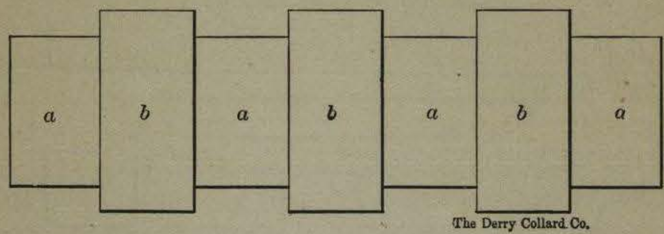


Figure 142. An interesting experiment.

one with the manner in which carbon is absorbed by steel. Take a piece of open hearth machinery steel, turn it in the lathe to the shape shown in Fig. 142, necking in every half inch to the depth of ⅛ inch, leaving the intervening spaces ½ inch long. Pack the piece in the hardening box with raw bone and charcoal. Run five or six hours after the box is heated through. When cold, turn the shoulders marked *b* to the size of *a*, leaving *a* the same size as before charging. Heat to a low red and dip in the bath. The portions marked *a* will be found hard, while the balance of the piece will be soft.

When pieces are to be case hardened, and it is considered desirable to leave a certain portion soft, it is accomplished many times by making tongs of the proper form to effectually prevent the contents of the hardening bath coming in contact with the portion mentioned Suppose, for example, a piece of the design shown in Fig. 143 is to be case hardened, and it is de-

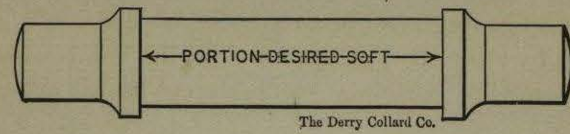


Figure 143. Piece with portion desired soft.

sired to leave the central portion marked soft. Make a pair of tongs to grasp the piece, as shown in Fig. 144. It will be seen that the portion mentioned is effectually protected by the tongs. The piece may be dipped in the bath, and worked around well until the red has disappeared, when it may be dropped to the bottom of the tank and left until cold. When it is desirable to leave a portion of an article

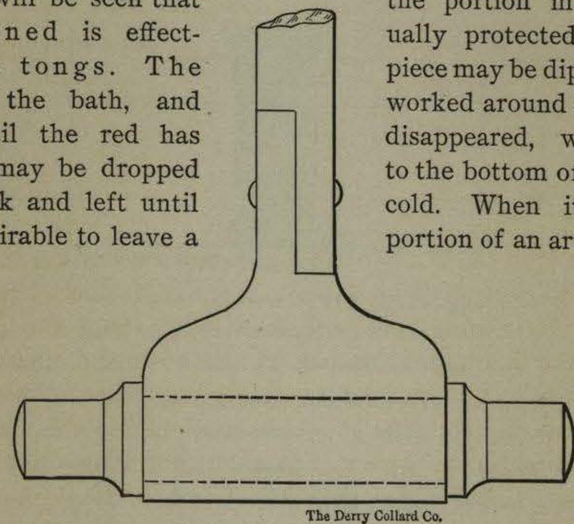


Figure 144. Tongs for handling piece shown above.

soft, as shown in Fig. 145, it is sometimes accomplished by covering the portion to be soft with fire-clay, as shown in lower view. The fire-clay may be held in place by means of iron binding wire; sometimes the fire-clay is held in place by means of plasterers' hair, which is worked into the mass when it is mixed with water. The fire-clay prevents the carbon coming in contact with the stock where it is desired soft.

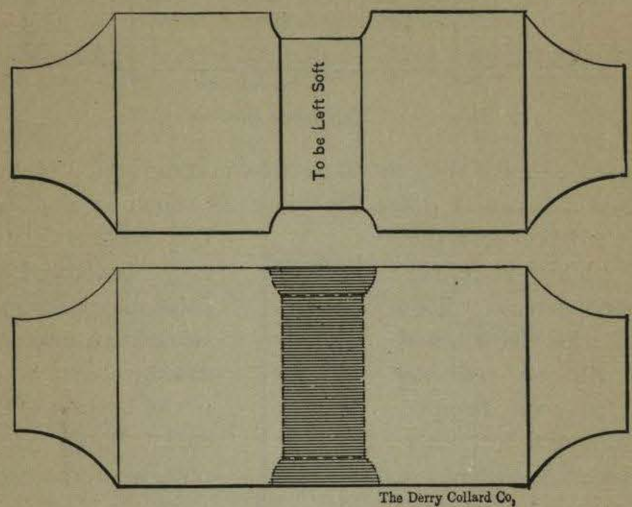


Figure 145. The use of fire-clay for soft spots.

A method employed in some shops consists in wrapping a piece of sheet iron around the article over the portion desired soft, as shown in Fig. 146. The sheet metal is held in place by means of iron binding wire, as shown.

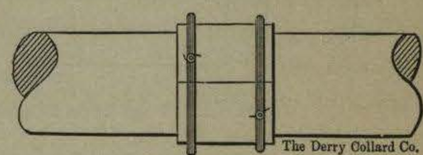


Figure 146. Using sheet iron to prevent hardening.

A very common method, which is costly when many pieces are to be treated, consists in forcing a

collar on to the piece over the portion desired soft, as shown in Fig. 147. The collar is removed after the article is hardened.

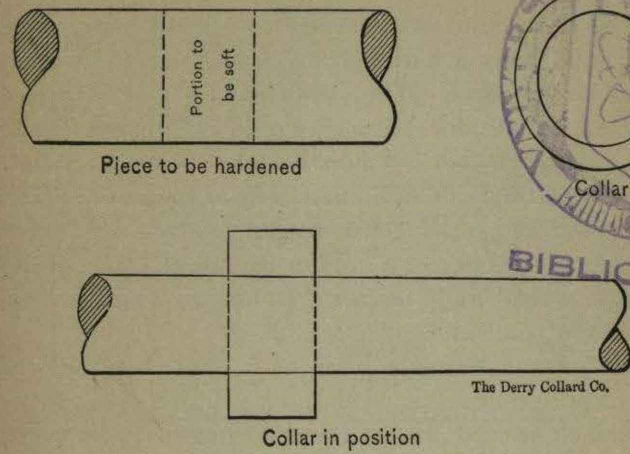


Figure 147. A collar for keeping portions soft.

When machine nuts are to be case hardened, and for any reason it is desirable to have the interior threaded portion soft, it is accomplished by screwing a threaded piece of stock in the hole before the nuts are packed in the hardening box.

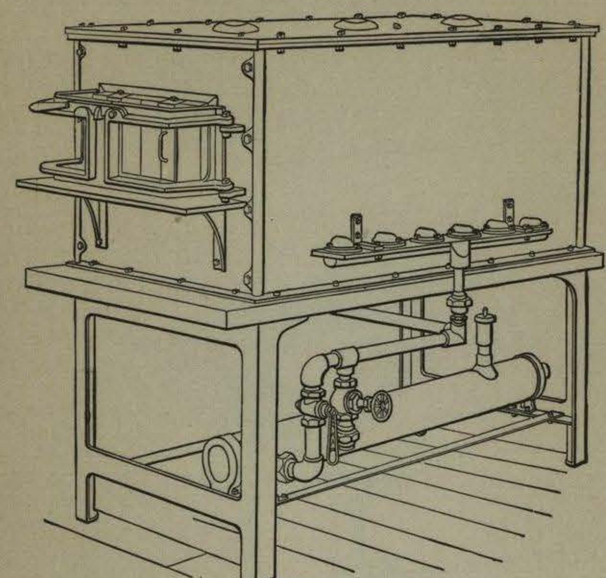
As carbon can not penetrate a nickeled surface, articles are sometimes nickel-plated at portions desired soft; this, however, is, generally speaking, a costly method of accomplishing the desired result.

It is sometimes considered necessary to harden the surfaces of pieces quite hard and leave the balance of the stock stiffer than would be the case where ordinary machinery steel is used. In such cases many times an open hearth steel is selected, which contains sufficient carbon, so that it will become very stiff when quenched in oil. The writer has in mind a gun frame which, on account of the usage to which it was to be put, must have a hard surface, while the frame itself must be very stiff. They were packed in a mixture of charred leather and charcoal, placed in the furnace and run for a period of 1½ hours after they were red-hot. They were then quenched in a bath of sperm oil. The stock used was 30-point carbon open hearth steel. Were the articles heavier or a greater degree of stiffness desirable, a steel could be procured having a greater percentage of carbon.

When toughness or strength is wanted in the case hardened product, a steel having much phosphorus should not be used; in fact, the percentage of phosphorus should be the lowest possible, as steel containing phosphorus, in connection with carbon, is extremely brittle. For this reason, articles which must be extremely tough should not be packed in raw bone, as this contains a very high percentage of phosphorus.

At times a job will be brought around to be case hardened, and one particular part will be wanted quite hard, while the balance of the piece will not require hardening very hard or deep. In such cases, if the portion mentioned be a depression, it may be placed uppermost in the hardening box, and some prussiate of potash or a small amount of cyanide of potash placed at this point, the piece being packed in granulated raw bone or leather, and run in the furnace a short time.

The article may be quenched in the usual manner. The portion where the potash was placed will be extra hard.



The Derry Collard Co.

Figure 148. Gas furnace for case hardening.

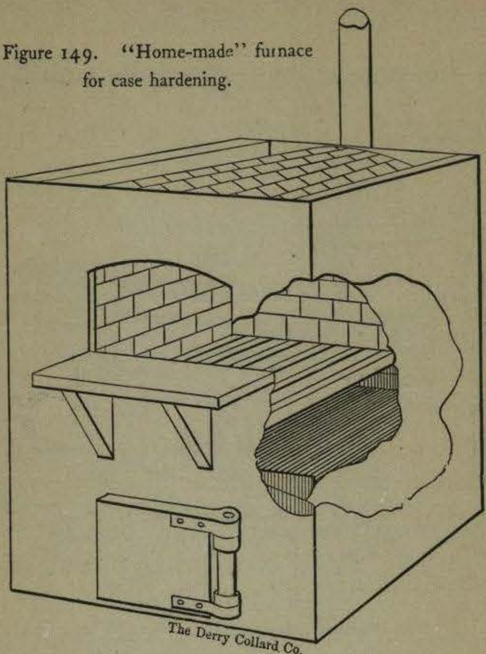
The furnace used in case hardening should receive more consideration than is many times the case; an even heat that can be maintained for a considerable length of time is essential if *best* results are desired.

A very satisfactory form of furnace is represented in Fig. 148; it burns illuminating gas as fuel.

When it is considered desirable to use hard coal as fuel, the furnace made by the Brown & Sharpe Co., of Providence, R. I., gives excellent results.

When it is considered advisable to construct on the

Figure 149. "Home-made" furnace for case hardening.



premises a furnace burning charcoal or coke, the form shown in Fig. 149 will be found very satisfactory.

However, the form and size of furnace depend in a great measure on the character and amount of work to be hardened.

Baths for Case Hardening.

The bath that is to be used for cooling work being case hardened must be suitable to the work being

hardened. Where work is case hardened in large quantities, it is customary in most shops to harden in iron boxes. When the work is in the proper condition, the box is inverted over a tank of water or some fluid, and the contents dumped into the bath. If the pieces of work are large or bulky, and the tank is shallow, they reach the bottom while red-hot, and, as a consequence, the side of the piece that lays on the bottom will be soft. In order to overcome this trouble, the tank must be made deep enough so that the pieces will be sufficiently chilled before reaching the bottom. If it is not considered advisable to have an extremely deep tank and the pieces are large, various ways are taken to insure their hardening.

One method which the writer has used with excellent results is to have a series of rows of wire rods reaching across the tank, no two consecutive rows being in the same vertical plane, as mentioned in the previous section. The work as it descends into the bath strikes these wires, which turns them over and over, bringing all portions in contact with the contents of the bath. These wires also separate the pieces from each other and from any packing material which may have a tendency to stick to them. The wires also retard the progress of the articles, giving them more time to cool before reaching the bottom of the bath.

In order to insure good results, it is necessary to have a jet of water coming up from the bottom of the tank. An outlet is provided near the top for an overflow. The overflow pipe, of course, should be larger than the inlet pipe, and should be located far enough below the top edge of the tank, so that the contents will not overflow when a box of work is dumped into it.

In order to get the hardened pieces out of the bath easily, it is necessary to provide a catch pan, as shown in Fig. 150. The bottom of this pan should be made of strong wire netting or a piece of perforated sheet metal, preferably the former. The holes in the pan allow the packing material to fall through to the bottom of the tank, and also allow the water from the supply pipe to circulate freely around the work and to the top of the bath. This catch pan should be provided with strong wire handles, as shown, in order that it may be readily raised.

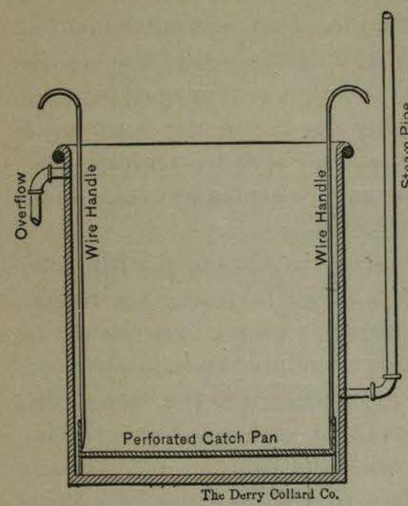


Figure 150. Case hardening bath with catch pan and steam pipe.

I was at one time requested to call at a shop where they were having very unsatisfactory results with their case hardening. An examination showed they were dumping their product into a barrel of water to harden. The box containing the work was inverted over this barrel, and the work and packing material went into the water in a lump. Some of the pieces that happened to get out of this mess were cooled sufficiently to harden somewhat, but the majority of the pieces were soft, or else they were hard on one side and soft on the

other. An examination of the bottom of the barrel showed it to be considerably charred. In places the outline of the pieces was plainly visible. These pieces had reached the bottom red-hot, and had burned their way into the wood. It is needless to say that the side of the piece of work which was down did not harden.

As those in charge of the work did not think it advisable, considering the limited amount which they had to case harden, to get a tank of the description shown in Fig. 150, we made a catch pan as described, blocked it up about 6 inches from the bottom of the barrel by means of bricks. We then bored a hole into the bottom of the barrel, screwed in a piece of pipe, and by this means were able to connect an ordinary garden hose, so as to get a jet of water coming up from the bottom. As the barrel was out of doors, we simply bored a two-inch hole about two inches from the top of the barrel for an overflow, and let the water run on the ground. When the work was ready to dump, we sifted it out of the box into the water gradually, rather than to dump it in a body. As soon as the box was emptied, we grasped the wire connected with the catch pan, and raised and lowered the pan in a violent manner, in order to separate any pieces that might have lodged together. The result was very satisfactory, and I think they are still using that barrel.

Baths are made, when large quantities of work are hardened, with some means of keeping the work in motion after it reaches the bottom of the bath. This is sometimes done by mechanically raising and lowering the catch pan, and at the same time turning it around. Then again, it is done by means of several sweeps, which are attached to the lower end of a vertical shaft, the shaft resting in a bearing in the center of the catch pan. These sweeps, or arms, revolving, keep the pieces in motion, turning them constantly, but unless arranged properly, they have a tendency to gather the work in batches, thereby acting exactly opposite from what they are intended to do. Then again, they have a tendency to scratch the surface of the work, which is a serious objection, if color work is wanted. When it is desirable to get nice colors on case hardened work, an air pump may be connected with the bath, as shown in Fig. 134, the water and air entering the bath together. While it is not advisable to let air come in contact with the pieces to be hardened for colors while passing from the box to the water, yet the presence of air in the water would have the effect of coloring the work nicely.

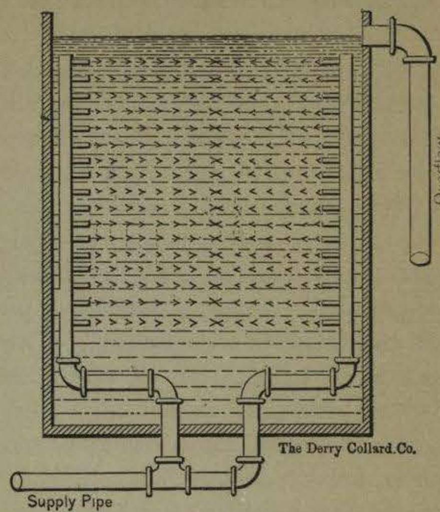


Figure 151. Bath for cooling slender case hardened articles.

When hardening long slender articles or those liable to give trouble if a bath of the ordinary description is used, excellent results may be obtained by the use of a bath with perforated pipes extending up the sides of the tank, as shown in Fig. 151.

Spring Tempering.

When it is necessary to give articles made of steel a sufficient degree of toughness, in order that when bent they will return to their original shape, it is accomplished by a method known as spring tempering.

The piece is first hardened, then the brittleness is reduced by tempering until the article, when sprung, will return to its original shape.

Generally speaking, it is not advisable to quench pieces that are to be spring tempered in cold water, as it would not be possible to reduce the brittleness sufficiently to allow the piece to spring the desired amount without drawing the temper so much that the piece would set. Steel heated red-hot and plunged in oil is much tougher than if plunged in water; and as toughness is the desired quality in springs, it is advisable to harden in oil whenever this will give the required result.

For many purposes a grade of steel made especially for springs gives better results than tool steel; for instance, bicycle cranks made of a 40-point carbon open hearth steel will temper in a manner that allows them to stand more strain than if made of the finest tool steel, and the stock does not cost more than one-quarter the price of tool steel.

When springs are to be made for a certain purpose,