cal 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.

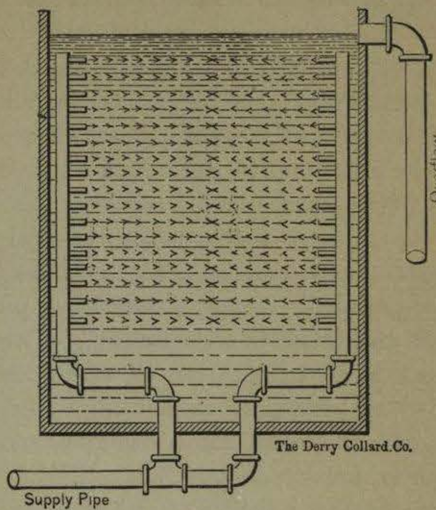


Figure 151. Bath for cooling slender case hardened articles.

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, it is generally safer to state the requirements of the spring to some reliable steel maker, allowing him to furnish the stock best suited for the purpose, than to attempt to specify the exact quality wanted—unless, of course, the operator or manufacturer has, either by experience or by study, acquired the knowledge necessary to qualify him to judge as to the quality needed.

As previously stated, the hotter a piece of steel is heated for hardening the more open the grain becomes; and as hardened steel is strongest when hardened at the refining heat, it is always advisable to heat no hotter than is necessary to accomplish the desired result. But as springs are generally made of a steel lower in carbon than ordinary tool steel, and as low carbon steel requires a higher heat to harden than is the case when tool steel is used, it is necessary to experiment when a new brand of steel is procured, in order to ascertain the proper temperature in order to produce the best results.

When steel is heated to the proper degree, it may be plunged in a bath of oil or tallow and hardened, the character of the bath depending on the size of the piece to be hardened and the nature of the stock used. For ordinary purposes a bath of sperm oil answers nicely. In some cases tallow will be found to answer the purpose better. It is necessary sometimes to add certain ingredients to the bath in order to get the required degree of hardness.

The following is used by a concern when hardening clock springs: To a barrel of oil add 10 quarts of resin and 13 quarts of tallow. If the springs are too hard, more tallow is added. If, however, the fracture indicates granulation of the steel rather than excessive

hardness, a piece of yellow bees'-wax of about twice the size of a man's fist is added to the above.

The following mixture has been used by the writer with success in hardening springs which, on account of the thickness of the stock or a low percentage of carbon, would not harden in sperm oil:

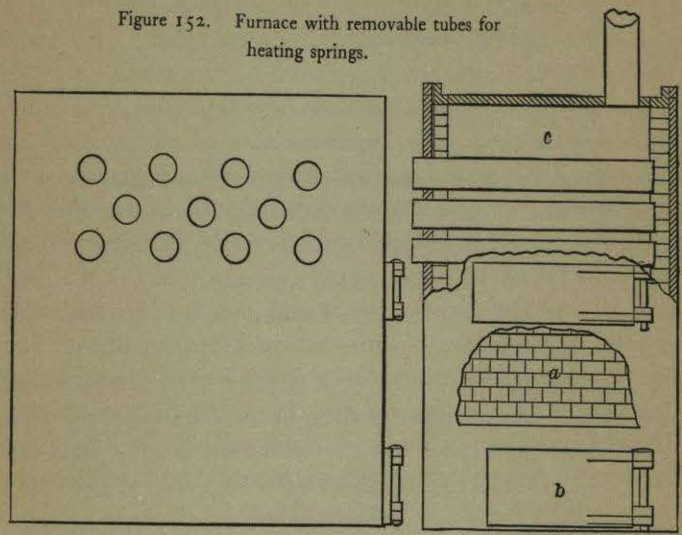
Spermaceti oil	48	parts.
Neat's foot oil	46	"
Rendered beef suet	5	"
Resin	1	"

The proportion of the different ingredients may be changed to meet the requirements of the particular job. Resin is added to the oil to strike the scale. As the scale or oxidized surface of the steel, when subjected to heat, is liable to raise in the form of blisters, and as these are filled with gas, the contents of the bath can not act readily on the steel. A small proportion of spirits of turpentine is sometimes added to the oil for the same purpose, but as it is extremely inflammable, it is somewhat dangerous to use unless great care is observed. The presence of resin in a hardening bath has a tendency to crystallize the steel, and on this account is sometimes objectionable.

A very good method, when neither resin nor turpentine are used to strike the scale, consists in having a dish of soft soap; or, if that can not be procured, dissolve some potash in water, dipping the steel into this before heating. It has the effect of preventing oxidation of the surfaces, and helps to strike any scale that may have been on the stock previous to hardening.

When small springs are to be hardened, which, on account of their size, cool quickly, they can. if there are many of them, be placed in tubes and heated in a furnace of the description shown in Fig. 152. When the pieces are heated to the proper temperature, a tube is removed and inverted over a bath. The contents should go into the bath in a manner that insures uniform results, that is, the pieces should be scattered in the bath. If the tube was held in the position shown

Figure 152. Furnace with removable tubes for heating springs.



at *a*, in Fig. 153, the pieces would go into the bath in a lump; but if it were held as shown at *b*, the pieces would become scattered, thus insuring good results.

When springs larger than those previously considered are to be hardened, an oven having some means of heating the articles in a manner that keeps them from coming in contact with the products of combustion should be used. Any form of a muffle having

sufficient capacity will do, or the pieces may be placed in a hardening box, having ½ inch powdered charcoal in the bottom, and a cover placed on the box—which need not be sealed. The box may then be placed in a furnace and subjected to heat. The cover may be raised from time to time and the contents of the box noted. This makes an excellent way of heating large coil springs and similar articles.

If the oven is sufficiently large, several boxes may be heated at a time. When a spring shows the proper temperature, which should be uniform throughout, it may be removed, placed on a bent wire and immersed in a bath of sperm oil, having a jet of oil coming up from the bottom, as shown in Fig. 154, A representing the outer tank containing water, B the bath

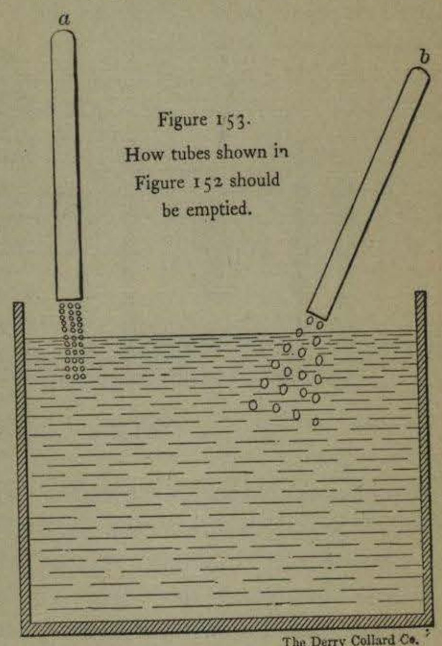


Figure 153. How tubes shown in Figure 152 should be emptied.

of oil, C the pump used in drawing the heated oil from the bath through the pipe D; it is then forced through the coil of pipe in the water and back into the bath through the inlet E. F is the catch pan. The jet of oil is forced toward the top of the tank, as shown at G. The spring should be worked up and down in the bath until all trace of red has disappeared, when it may be lowered to the bottom of the tank and left until the temperature has been reduced to that of the contents of the tank, or until a convenient time comes for their removal.

As previously explained, it is not advisable to remove articles being quenched from the bath until they

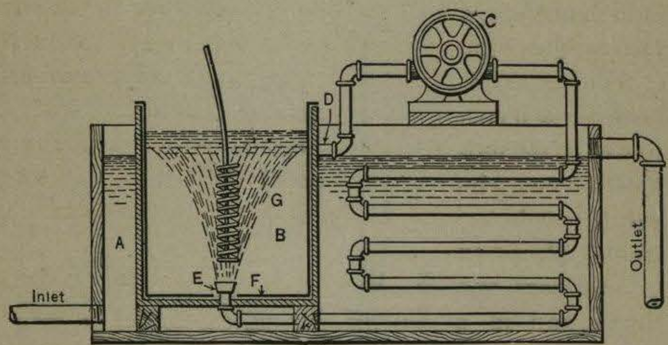


Figure 154. Oil bath for spring tempering.

are of a uniform temperature throughout. While this procedure might not make as much difference with a piece of work hardened in oil as one hardened in water, yet it is not a good plan to remove articles from the bath until they are reduced *throughout* to the temperature of the bath.

In order that the contents of the bath may be kept a uniform temperature, the pump shown in accompanying cut may be connected with the tank, as represented, the oil to be taken from near the top and pumped

through the coils of pipe in the outer tank, which should be supplied with running water.

When steel contains carbon of too low a percentage to harden properly in oil or any of the mixtures mentioned, the writer has used a bath of water at, or nearly at, the boiling point (212°) with very gratifying results. It may be found necessary with certain steels to reduce the temperature of the water somewhat.

Various methods are employed when drawing the temper. The one more commonly used than any other is to heat the spring until the oil adhering to the surface catches fire and continues to burn, when the piece is removed from the fire, burning until all the oil has been consumed. If this method is used, it will be found necessary to provide some means whereby a uniform heat may be obtained, or one part of the spring will be found to be too soft by the time the balance is rightly tempered.

If the spring is of heavy stock, it is necessary to burn the oil off three and sometimes more times, in order to bring it to the proper degree of elasticity. The process of drawing the temper by heating the spring until the oil catches fire from the heat contained in the steel is familiarly known as "flashing." Hardeners say that it is necessary to flash oil off this spring three times, or it is necessary to flash tallow off this spring twice, some using the oil the piece was quenched in, while others prefer some other kind of oil or tallow.

Springs hardened in boiling water may be coated with oil or tallow and the temper drawn as described, if it be found necessary. It is not policy to use a fire having a forced draft or blast when drawing articles to a spring temper. An open fire burning wood or charcoal gives excellent results. A gas flame having no air blast also works very satisfactorily.

Springs of unequal sizes on the various portions require a very skillful operator, in order to get uniform results, if the above method is used. The thinner portions, heating faster than the heavier parts, become too soft before the other parts are soft enough. Consequently, it is advisable to temper these by a different method. The spring may be placed in a perforated pail, which in turn is set into a kettle of oil or tallow. This kettle is placed where a sufficient amount of heat may be obtained to draw the temper to the proper degree.

The amount of heat given is gauged by a thermometer, and varies according to the nature of the steel and the character of the spring. It ranges from 560° to 630°. The exact amount of heat necessary must be ascertained by experiment. This method furnishes a very reliable way of tempering all kinds of springs. The kettle should be so arranged that a cover may easily be placed on it in case the oil catches fire, as otherwise the operator, or the building, might be burned, or the work in the oil spoiled, or the thermometer cracked. The cover should be made high enough to take in the thermometer.

The cover should be provided with a long handle, in order that the operator may not be burned when putting it on the kettle. If it is not considered necessary to provide the cover mentioned, a piece of heavy sacking should be kept conveniently near for use. If this is placed over the top of the kettle, it will generally extinguish the flames.

The thermometer should not be taken from the hot

oil and placed where any current of air can strike it, or the glass will crack. It is advisable to leave it in the oil, letting it cool down with it. If the furnace where the oil is being heated is located where any current of air will strike the thermometer, it must be protected in some manner, or it will crack.

If it is considered advisable to remove the pail of work from the oil before the pieces are cool, it may be done, and the pieces dumped into a wooden box, covering the opening, so that the air will not strike the pieces. The pail may now be filled with fresh pieces requiring tempering. The pail of work should be placed in the kettle of oil. The kettle should not be placed in the fire again until the pieces of work have absorbed considerable of the heat that was in the oil, when the kettle may be placed in the fire and the operation repeated.

When work is hardened in large quantities, it is generally considered advisable to devise methods that allow of handling the work cheaply, at the same time keeping the quality up to the standard. Watch springs are sometimes heated in a crucible containing melted cyanide of potassium or salt and cyanide of potassium heated to the proper degree. The springs are immersed in the mixture until uniformly heated, then quenched. It is stated, however, that this mixture will not do when heating the hair springs, as it causes the nature of the steel to change slightly. These springs are heated for hardening in a crucible of melted glass.

When a make of steel is found that gives satisfactory results when made into springs and tempered, it is folly to exchange it for another make, unless convinced that the other is better. A saving of a few cents, or even dollars, on an order of steel is quite often very costly economy, as many times springs do not give out until in actual use, and in that case they are oftentimes many miles from the factory where they were made.

When large numbers of springs that must receive severe usage are made, it is advisable to give them a test—at least, test an occasional spring. Give them a test somewhat more severe than they will be liable to get in actual use. By so doing it is possible to detect an improper method of hardening or tempering before the whole batch is done.

"Second Blue."

When all springs were made of tool steel and hardened, and the temper drawn one at a time, it was customary with some hardeners to draw the temper to what is known as the "second blue." After hardening, the springs were polished, then placed in a pan of sand and held over the fire until the temper colors commenced to show, the pan in the meantime being shaken to keep the sand and springs in motion and insure uniform heating. The tempers will show in order as set forth in the color table given under Drawing the Temper. After the colors had all appeared, the surface of the steel assumes a grayish appearance. When heated a trifle above this, it assumes a blue color again, which is known as the "second blue." When this color appears, the spring should be dropped in a tank of *hot* oil, leaving it to cool off with the oil.

Another method sometimes used when drawing the temper of heavy springs made from high carbon steel consists in heating the article until sawdust dropped on it catches fire, or a fine shaving left from a hardwood stick, such as a hammer handle, being drawn across a corner of it, catches fire at the proper tempering heat.

Mechanics are sometimes surprised when they observe a spring in some conspicuous place which is drawn to a straw color, a brown or a light blue. It does not seem possible to them that a spring drawn to the temper represented by the color visible should be able to stand up to the work. The temper color shown is simply for appearance. The articles are first hardened and tempered to give them the necessary elasticity. This is ordinarily done by heating in a kettle of oil, gauging the heat with a thermometer. After heating to the proper temperature and cooling, they are polished. Any desired color can be given by placing the articles in a pan of sand and shaking over a fire until the desired color shows, when they may be dumped in warm oil to prevent running. This second operation does not affect the hardness or elasticity, provided they were not heated as hot as when the temper was drawn.

Many times it is impossible to harden and temper a spring in a manner that gives satisfactory results, because the spring was bent to shape when cold. Now, it is possible to bend most steel somewhat when cold, and yet have it take a good spring temper; but it is impossible to bend it beyond a certain amount, which varies with the steel.

The writer has seen large safety valve coil springs rendered unfit for use by coiling when cold. If a piece of the same steel was heated red-hot and coiled, excellent results were obtained.

Many times it is necessary to anneal steel one or more times between operations in order to obtain good results. It was found necessary to anneal the spring shown in Fig. 155 after punching the blank and before bending at all. The first operation of bending brought the spring nearly to shape; it was then annealed, and the finishing operation taken. If it was bent to shape without annealing the second time, it would break in the corners when in use, if not in the operations of bending.

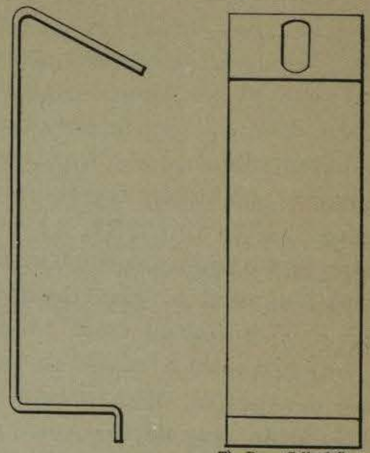


Figure 155. A peculiar case.

When annealing *sheet steel*, whether it be for springs or cutting tools, the utmost caution should be exercised. If the steel is allowed to stay in a red-hot condition for too great a length of time, the stock is rendered unfit for hardening. If heated red-hot and laid aside to cool *slowly*, much better results will follow than if it were packed in an annealing box with charcoal and kept red-hot for a considerable length of time. These long heats apparently have the effect of throwing the carbon out of its proper combination with the iron. It will harden, but can never be made elastic or strong.

Making Tools of Machine Steel.

While it is considered advisable in most shops to make articles whose bearing surfaces must be hard, in order to resist frictional wear, of some form of machine steel, and give the surfaces sufficient hardness by case hardening, it is generally considered necessary to make cutting, forming and similar tools of tool steel.

It is practical, however, to make cutting tools for certain classes of work of machine steel, and harden the cutting edges sufficiently to produce very satisfactory results.

Steel is, as previously explained, a combination of iron and carbon. The grade of iron used in making tool steel is, however, vastly superior and much more expensive than that used in the manufacture of the ordinary machine steel. Being much purer, it is much stronger when carbonized and hardened, and consequently can do many times the amount of work of tools made of the lower grades of steel, even when these are charged with the *same* percentage of carbon. It is also less liable to crack when hardened, as the impurities contained in the lower grades make it, when combined with carbon, very brittle when hardened.

But notwithstanding the facts just presented, it is possible to make tools for cutting paper, wood, lead, brass and soft steel of a low grade of steel, and harden it by a process that gives results much more satisfactory than would be thought possible by one who had never tried it. This method recommends itself on account of the comparatively low cost of the steel, and it can be worked to shape more cheaply than if tool steel were used. But it is usual, when the experiment is tried, to use any piece of low grade steel laying around the shop that will machine to shape in a satisfactory manner, not realizing that it is necessary, in order to get satisfactory results, to use steel adapted to the purpose. As phosphorus, when present in steel, and especially when in combination with carbon, causes it to be extremely brittle when hardened, a grade should be selected that has the least possible percentage of this harmful impurity.

If it is not necessary to have the hardened surface very deep, a steel having a low percentage of carbon may be used. If, however, the tool is to be subjected to great strains, it is advisable to use a steel containing sufficient carbon to cause the tool to harden enough to furnish the necessary stiffness or internal hardness. The extra amount of hardness necessary to insure the cutting portions standing up when in use, must be furnished by the process of hardening.

The writer has seen reamers, counterbores, punch press blanking, forming and drawing dies, and many other forms of tools made of low grade steel, which, the parties using them claimed, gave the best of results.

As before stated, when making tools which are not to be subjected to a very great amount of strain, or which will not be called upon to resist a great amount

of pressure, a steel low in carbon may be used. Any desired amount of surface hardness may be given the piece. If, however, the tool will be subjected to torsional strain, as in the case of a long, slender reamer, or if it may have to resist a crushing strain, as in the case of a punch press forming die, it is necessary to use stock containing sufficient carbon to furnish the desired result when hardened. If the tool is not to be subjected to very great strain, almost any low grade stock that is practically free from impurities will do.

If a long, slender reamer, or similar tool, is to be made, excellent results are claimed by using a low grade steel of 40-point (.40%) carbon. In the case of a forming die, or similar tool, use a steel of 60 to 80-point carbon. If, however, it was to be subjected to great pressure or very severe usage, the writer's experience leads him to advocate the use of tool steel specially adapted to this class of work.

As it is necessary, in order to get satisfactory results, to have the percentage of impurities as low as can be obtained, in order to have the hardened steel as strong as possible, do not allow it to come in contact with *any form of bone* when heating. The articles should be packed in a hardening box with a mixture of equal quantities (volume) of charred leather and granulated charcoal in the same manner as described under Pack Hardening. It will be necessary to subject the articles to heat for a longer period of time than if hardening tool steel. The length of time the articles are subjected to the action of the carbonizing element depends on how deep it is necessary to have the hardened portion. The test wires previously mentioned should be used to determine when the contents of the box are heated.

If you are reasonably sure the steel used was practically free from injurious impurities and is low in carbon, it may be dipped in a bath of water or brine. Should there be any doubt as to this, dip in raw linseed oil.

If the article being hardened is a cutting tool, or something requiring a fine, compact grain, better results will follow if it is left in the box after being subjected to the action of carbon, the box removed from the fire, and the whole allowed to cool. When cold, the article may be reheated to a low red, and hardened.

While the writer has used a low grade steel in making various forms of tools, and had excellent results when they were put to the use for which they were intended, he cannot recommend its use, unless the parties doing the work select stock suited to the purpose and exercise due care when hardening.

While this subject might properly be classed under the heading of Case Hardening, it has not seemed wise to the writer to do so, because case hardening, according to the interpretation usually given it by mechanics, is simply a process of transforming the surface of the article into a condition that allows it to become hard if plunged red-hot into water. Hardness is apparently the only object sought, but such is not the case when the subject is considered in its proper light.

When applying this principle to tools, it is necessary to consider the requirements of the tools. Knowing this, it is necessary to proceed in a manner that will give the desired results.

If it is considered advisable to make certain tools of a low grade steel, treating it as described, it is necessary to select steel adapted to the tool to be made.

It is never advisable to use Bessemer steel bought in the open market, because it does not run uniform. Always use open hearth steel, procuring it, if possible, of a quality that will give satisfactory results. Steel, with a very small percentage of phosphorus and other impurities, may be obtained from any reliable maker, if the purpose for which it is to be used is stated when ordering.

Special Steels.

To one interested in working steel, the history of the development of this industry furnishes a remarkably interesting study.

Steel may be grouped under four general heads, the name given each class being selected on account of the method pursued in its manufacture.

Probably the oldest of all known steels is the cemented or converted steel. This steel is made by taking iron in the form of wrought iron bars, packing them in a fire-brick receptacle, surrounding each bar with charcoal. This is hermetically sealed, and heat is then applied until the whole is brought to a degree of heat that insures the penetration of a sufficient quantity of carbon. Experience proves that carbon will penetrate iron at about the rate of one-eighth of an inch in twenty-four hours; and as bars of about three-quarter inch thickness are generally used, it requires three days for the carbon to penetrate to the