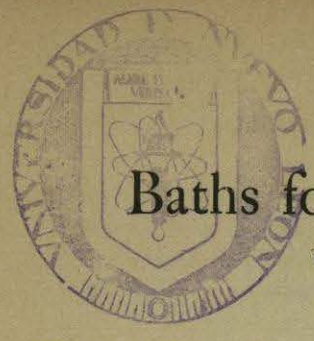

Baths for Hardening.

The Lead Bath.

When comparatively small pieces of work are to be hardened in large quantities, as, for instance, the various small parts of bicycles, sewing machines and guns, red-hot lead furnishes an excellent means of uniformly heating in a very economical manner. It is a speedy, and at the same time a very reliable means to use, as the heat can be maintained so uniformly, it can be applied safely. By using a proper amount of precaution, there is no danger of burning the outside of the article before the center is heated. Large and small parts are heated alike, and quite a number of pieces can be heated at the same time, thus making it a cheap, rapid, yet reliable way of heating. It is necessary to have a uniform heat under and around the crucible that can be maintained for quite a length of time.

A furnace burning illuminating gas as fuel, gives the most satisfactory results, although excellent results may be obtained by the use of a furnace burning gasoline or crude oil. If it is not found possible to obtain any of these, good results can be obtained by the use of one burning charcoal, hard coal, or coke; but in order to obtain uniform results, a great deal of attention must be paid to the fire.

If but a few pieces are to be hardened at a time,

and it is not considered advisable to purchase or make a furnace especially adapted to this kind of work, a crucible may be placed in a fire on an ordinary blacksmith's forge. Build up around it with bricks, placed far enough away from the crucible to have a fire all around it, and fill this space with charcoal. It will be found necessary to raise the crucible occasionally and poke coals under it.

The most satisfactory crucible is one made of graphite, especially for this purpose. A cast iron one is sometimes used, but as a rule is not as satisfactory and is more costly, as it burns out very quickly.

The graphite crucible should be annealed before using, as this toughens it, reduces the liability of cracking and makes it longer lived. In order to anneal the black lead crucible, place it in any oven or furnace where a uniform heat can be obtained, heat it to a red, take it out and place it where it can cool off slowly without any drafts of air striking it.

It is very essential that the proper quality of lead is used. Red-hot steel is very susceptible to the action of certain impurities. Many brands of lead contain sulphur in such quantities that it is very injurious to the steel. Nothing but chemically pure leads should be used. It is the custom in some shops to use lead of any kind, and when unsatisfactory results are obtained, the method, instead of the material, is condemned, because the operator does not understand the cause of the trouble.

If the lead contains sulphur, even in small quantities, it will ruin the steel. The article will have a honeycomb appearance, and portions of the outside stock will be eaten away. When using lead that is

chemically pure, this difficulty will not be encountered.

Many hardeners are averse to the use of the lead bath in hardening on account of the tendency of the lead to stick to the work. To prevent this trouble, different compounds are used.

The writer has had excellent results with a solution of cyanide of potash in water. Dissolve one pound of powdered cyanide and one gallon of boiling water. Let it cool before using. If this should not prove to prevent the lead sticking, put in a larger portion of cyanide. Some use a strong solution of salt and water. Dip the articles in the solution; place them where they can dry, preferably in a hot place where they will dry more rapidly. It is not safe to put them in the lead when damp, as any moisture would cause the lead to fly.

The writer has used the following mixtures with very gratifying results when hardening such work as small milling cutters, taps, reamers, broaches, cherries, rotary files and similar tools having fine teeth likely to hold the lead. This formula is taken from the report of the Chief of Ordinance of the War Department, and is used in the U. S. Government shops when hardening files. The following is a copy of the report: "Before hardening, the files are treated with a mixture of salt and carbonaceous material to protect the teeth from decarbonization and oxidation. The kinds and proportions of the ingredients are exhibited in the following table:

Pulverized charred leather..... 1 lb.
Fine family flour.....1½ lbs.
Fine table salt.....2 lbs.

The charcoal made from the charred leather should

be titurated until fine enough to pass through a No. 45 sieve. The three ingredients are thoroughly mixed and incorporated while in a dry state, and the water is then added slowly to prevent lumps, until the paste formed has the consistency of ordinary varnish. When ready, the paste is applied to the file with a brush, care being taken to have the teeth well filled with the mixture. The surplus paste is then taken off the file by the brush, and the file is placed on end before a slow fire to dry. If dried too quickly the paste will crack or blister. If not dry enough, the remaining moisture will be transformed into steam when dipped into the hot lead bath, and cause an ebullition or sputtering of the lead, throwing out minute globules of the latter, which may endanger the eyes of the operator. The fusing of the paste upon the surface of the file, indicates the proper heat at which the file should be hardened."

File makers have methods of hardening files that differ very materially from the above process, but it has proved particularly valuable when applied to the tools mentioned. Small articles, if of an even size or thickness throughout, may be put into the lead when they are cold and left until red-hot, although they should be turned over occasionally. But pieces, such as shank mills and similar articles of irregular contour, having large and small parts in connection with each other, should be heated nearly to a red before putting into the lead, as the sudden expansion of the large thin parts would tear them from the more solid portions that could not heat and expand so quickly.

The purpose of putting such pieces into the lead is for the uniform heat that can be finally obtained on the

unequal sizes and thicknesses, making them much less liable to crack when dipped in the bath. If an irregular shaped piece were plunged suddenly into the red-hot lead, and thereby cracked, it probably would not be noticed until it was hardened, and the natural inference would be that it had cracked in the cooling bath; but a careful examination of the fracture would show the walls to be black, proving it to have been subject to heat after it was cracked. If it were sound until dipped in the bath, the walls would have a brighter appearance, although it might be somewhat stained by the contents of the bath, yet they would not be black.

The following question may suggest itself. If the piece of work is to be partly heated in another fire, why not heat to the hardening heat? The reason for this is, that a much more uniform heat can be obtained in the lead crucible than in an ordinary open fire. When it is necessary to harden a portion of the piece, leaving the balance soft, it need only be dipped in the lead the required distance, moving it up and down to prevent a fire-crack. It is likely to crack at the point where the heat leaves off, just as a piece of red-hot steel will crack if dipped into water in such a way that some of the red is out of the bath and the piece held in that position. It then cracks at the point where the contraction ceases, while in the first case it cracks where the expansion ceases.

If impossible to do the first heating in an open fire, or if it is considered advisable to heat it in red-hot lead altogether, the piece may be immersed in the lead, left there for a moment and withdrawn. It may then be immersed again, leaving a little longer than the first time and withdraw it again, repeating the operation

until the steel is heated to a point where the intense heat will not cause it to crack from the sudden change of temperature.

To prevent dross from forming on the lead, keep the surface covered with broken charcoal. This not only has a tendency to prevent dross forming, but the charcoal, catching fire and burning, keeps the surface

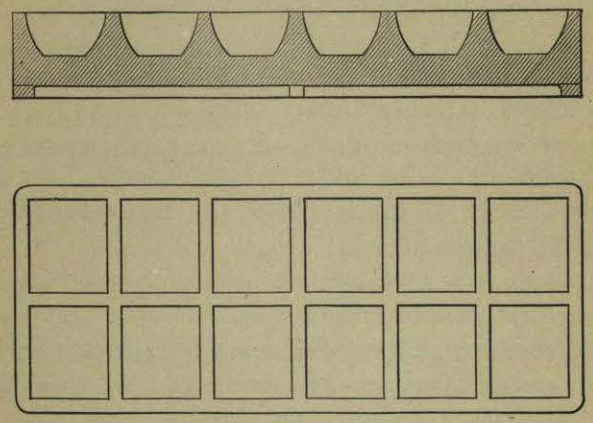

Figure 39. Mould for casting lead.

of the lead at a more uniform heat, than if not used. But despite all these precautions, more or less dross will form in the surface of the lead. This should be skimmed off occasionally, in order that it may not stick to the work.

When no longer using the crucible, the lead should be emptied out, as if left in the crucible until it cools and solidifies, the crucible will probably crack when the lead is heated again. It may be removed by means of a ladle and emptied into small moulds. When the cru-

cible is nearly empty, it may be lifted from the fire and the balance of the lead poured out. As it is necessary to put the lead into the crucible in small pieces, it is best to use a mold of the form shown in Fig. 39, as this makes a very convenient size to put into the crucible again. To get good results when hardening, the lead should be stirred up from the bottom occasionally in order to equalize the heat, as it will be hotter at the bottom than it will be toward the top.

When heating pieces with fine projections or teeth, it is well to use a stiff bristle brush to remove any lead that may stick in the bottom between such projections. This should be done before dipping into the bath, to prevent soft spots. Steel will not harden where lead adheres to it, as the liquid in the bath cannot then come in contact with the steel.

There is no one method of heating steel which is so generally used that is a source of more annoyance than the one under consideration, because attention is not paid to a few simple points. But if a chemically pure lead is used in the crucible, the contents of the crucible is stirred occasionally, and as low a heat as possible is maintained, excellent results will follow.

A serious mistake, which is made many times, is to heat the lead too hot, leaving the piece of work in just long enough to bring the surface to the desired heat, then removing and quenching. The objection to this method is, the heat is not uniform throughout the piece, consequently poor results follow. If the article is left in the lead long enough to become uniformly heated throughout, it will become too hot. If the lead becomes too hot, it is best to plunge a large piece of iron or scrap steel into it, allowing it to absorb the

extra heat, thus reducing it to the proper temperature. It is then safe to go ahead with the heating, and not until then. Do not neglect this precaution.

It will readily be seen that the lead should be of about the same temperature as the steel should be heated, and the articles left in it long enough to become uniformly heated throughout.

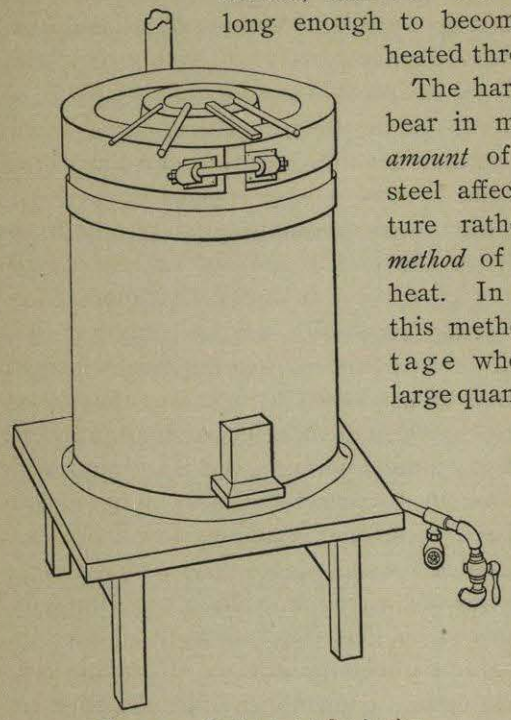

Figure 40. Drying steel before heating.

The hardener should bear in mind that the *amount* of heat given steel affects the structure rather than the *method* of applying the heat. In order to use this method to advantage when hardening large quantities of small articles, quite a number of pieces may be heated at a time in the lead. This may readily be accomplished by dipping a number of pieces in the cyanide solution, laying them on the top of the furnace as shown in Fig. 40. When these are thoroughly dried, place them in the lead, dip another batch in the solution, and lay on the furnace as described. By this time the pieces in the lead will

be hot enough to dip in the bath. As one is taken from the lead, another may be taken from the top of the furnace and put in its place, another should be dipped in the solution and placed on the furnace. In this way a rotation may be kept up, which insures the maximum amount of work in a given time.

Before taking a piece of work from the lead, it should be plunged below the surface and held there long enough to equalize the heat. Articles being heated in lead should be turned over occasionally, in order that they may heat uniformly. If long articles are to be heated by this means, it is necessary to stir the lead from the bottom frequently, or the piece will be the hottest at the end nearest the bottom of the crucible.

When heating certain tools, as long reamers, broaches, etc., it is sometimes advisable to place a piece of cyanide of potassium on the surface of the lead. It will fuse and remain for some time in a body around the steel. The tool may be raised and lowered in the lead through this melted cyanide occasionally, and especially just before quenching in the bath.

If the article is dipped in a bath of water, heated as hot as it is possible to hold the hand in, the teeth will be found very hard and the tendency to spring or crack will be reduced very materially. If it is desirable to have the tool extremely strong, that is, able to stand strains, as would be the case if a broach used for draw-broaching were being hardened, the tool could be heated as described and quenched in a bath of raw linseed oil, or into a bath of sperm oil and tallow, to which is added a small quantity of resin. The amount of resin added should be very small, as it has a ten-

dency to crystallize the steel if too great a proportion is used. Generally speaking, one part resin to 100 parts of oil, or oil and tallow, will be sufficient, and generally it will not be found necessary to use it, if tallow is added to the oil.

Although red-hot lead furnishes an excellent means of heating small articles, and a very satisfactory method of heating certain kinds of tools, yet for most *cutting tools*, the writer has found cyanide of potassium, melted and heated red-hot in a crucible, or a mixture of salt and cyanide of potassium, to give more satisfactory results.

Cyanide of Potassium Bath.

Cyanide of potassium, if placed in a cast iron crucible and heated red-hot, furnishes a method of heating steel that gives very excellent results in many shops.

This method is employed very extensively in heating articles whose shape betokens soft spots when hardened by the ordinary methods. It is also used in hardening dies for transferring impressions onto plates used in printing bank notes and similar work.

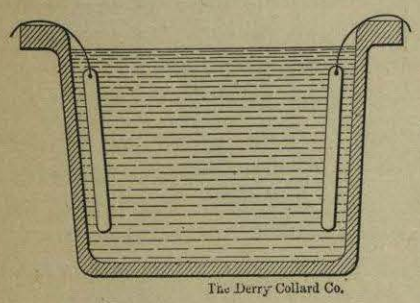

Figure 41. Method of suspending work in cyanide of potassium.

The articles heated by this method are not subject to oxidation from the action of the air on the surface. The cyanide does not have a tendency to stick to the work, and the action

of the cyanide tends to increase the surface hardness, thereby making the tools more durable than when hardened by ordinary methods.

Many dies with finely engraved working surfaces are heated by this method and the best of results obtained. In order to get satisfactory results, it is necessary to use *chemically* pure cyanide of potassium.

It is different from red-hot lead in that iron will not float on its surface, but sinks to the bottom, consequently it is necessary to suspend the pieces being heated with wires which pass over the edge of the crucible in the form of a hook, as shown in Fig. 41.

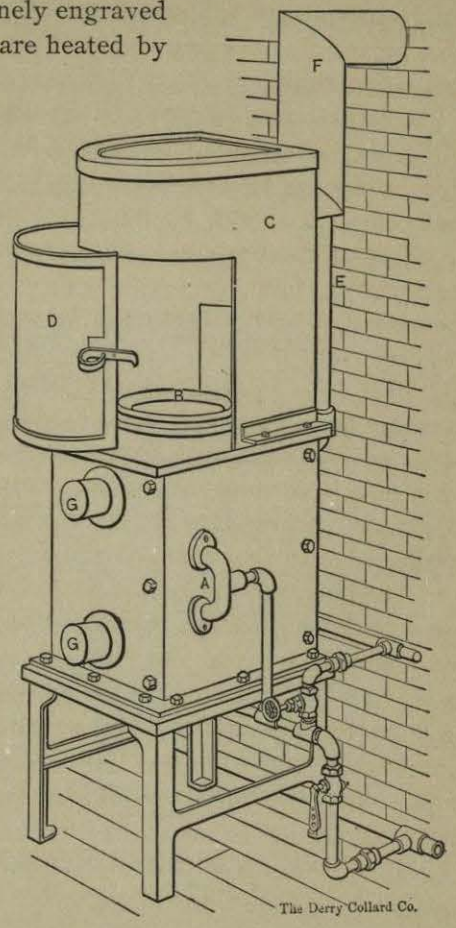

Figure 42. Cyanide hardening furnace, also shown in Figure 18.

As cyanide of potassium is a violent poison, the greatest care should be exercised when using it. The fumes of this chemical are very injurious to the workman, consequently a furnace should be used having some means of conveying the fumes into a chimney or ventilating shaft.

A furnace may be procured of the pattern shown in Fig. 42, using illuminating gas as fuel. A is the pipe furnishing fuel to the burners, B the crucible, C the hood, D the door, E the pipe which conducts the products of combustion to the pipe F, the pipe which conveys the fumes and products of combustion into the chimney. The lighting holes are stopped by the fire clay plugs G G.

If it is considered advisable to make a furnace burning hard coal or coke, the same design may be used as illustrated in Fig. 19. For a lead hardening furnace, a hood must be added to prevent the poisonous vapors getting into the room. This hood must be connected with the chimney.

The operator must bear in mind that in order to get satisfactory results, attention must be paid to the amount of heat given the piece of steel, as previously explained. The strength of the hardened piece depends in a greater measure than mechanics generally realize, on the amount of heat given when hardening. In order to get the best results possible, it is necessary to have the steel at the refining heat.

It is easy to be deceived when heating by the method under consideration, as the effect of the cyanide is to cause the surface of steel to harden at a temperature lower than the refining heat. Consequently the portion beneath the surface may not be hardened at all

when the surface shows hard, if tested with a file. It matters not by what method steel is heated for hardening, there is a temperature at which it should be quenched. If not heated to that temperature, it is not as hard as it should be to accomplish the maximum amount of work possible. If heated to a higher temperature, the pores are opened, the steel made brittle and it is unfitted to do the amount of work it should.

Not only is this method valuable because it furnishes a means of heating steel uniformly without danger of its surface becoming oxidized, but if certain points are observed, the most beautiful colors imaginable may be obtained. It is necessary, in order to procure nice colors on the hardened product, that it be nicely polished, and free from dirt and grease. While grease will burn when subjected to a red heat, yet it leaves a stain on the work.

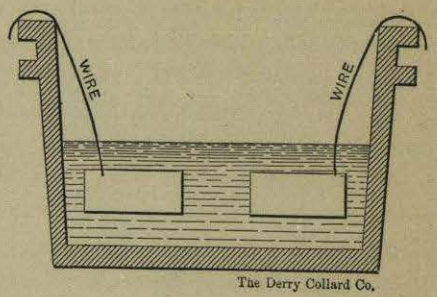

Figure 43. Heating in cyanide for colors.

When colors are wanted, articles made of tool steel may be suspended in the molten cyanide by means of wire hooks, which pass over the edge of crucible, as shown in Fig. 43. When the article becomes heated to a uniform heat, it may be removed and plunged in a tank of water, working it around well until cold, when it may be removed and dried. If it is desirable to draw

the temper and yet retain the colors, it may be done by heating in a kettle of oil, guaging the heat by a thermometer. The work must be left in the oil, away from the action of the air, until it is cooled below the point where temper colors are visible.

This method of hardening is used very extensively in gun shops to harden gun frames, and at the same time procure the beautiful colors often seen on them. It works equally well on machinery steel or malleable iron. It is accomplished by attaching a piece of wire bent in the shape of a hook to the frame, the other end of the hook hangs over the upper edge of the crucible. It is necessary to have the article entirely under the surface of the cyanide. When it is heated for a sufficient length of time, which must be determined by experiment, it may be removed and plunged in a tank of water. In order to produce the

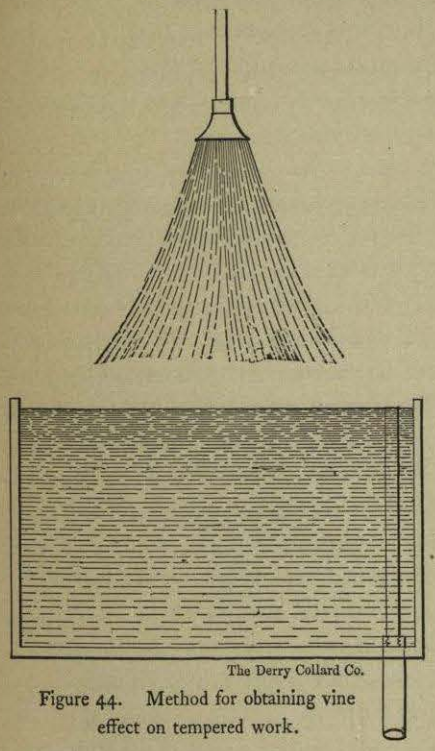

Figure 44. Method for obtaining vine effect on tempered work.

beautiful vine-like effect often noticed, the inlet pipe may be situated about two feet above the tank, as shown in Fig. 44. The end of the pipe may be made to spray the water. The articles when taken from the cyanide crucible should be passed through the spray into the bath. Wherever the fine spray strikes, it produces the vine-like effect mentioned. The colors may be guaged by the heat given the contents of the crucible, also by the temperature of the bath.

After using, a hook must be thoroughly dried before putting in the molten cyanide, as the presence of moisture, even in the most minute quantities, will cause the cyanide to fly. If it strikes the flesh, it produces a burn, which, on account of the poisonous nature of the chemical, is liable to be very sore, but by avoiding the presence of any form of moisture, this need not occur.

Articles made of malleable iron, as cutters for paper, and wood, may be hardened by heating in this manner. If only a few pieces are to be hardened, the cyanide may be heated in an iron dish of suitable size, the articles suspended in the dish until heated sufficiently, when they may be quenched in a bath of cold water, or warm water, according to the nature of the work to be done. Should this prove to make them too hard, a bath of tallow or oil may be used.

Articles made of machinery steel may be heated in the cyanide crucible for hardening, the amount of hardness and depth which it penetrates depending on the amount of heat given and the length of time the article is left in the cyanide.

If the articles are of a size that warrants it, they may be suspended in the cyanide by means of wires, as previously explained. If they are small and there

are many of them, they may be placed in baskets made of wire cloth and suspended in the molten mass. These baskets should not, however, be made of galvanized wire, or have any solder used in their construction, or the articles will be coated with lead. Care must be exercised when placing the articles in the basket, not to put in too many, especially if the basket is to be dipped into the hardening bath, as the pieces would touch each other when in the water; consequently they would not be hard at these points.

When it is desired to make articles other than cutting tools, and harden them throughout, it may be done by procuring a low grade steel, sufficiently high in carbon to produce the desired result. The steel may be either Bessemer or open hearth. If hearth steel, the temper must be suited to the particular purpose it is to be used for. When the article is ready for hardening, it may be suspended in the molten cyanide; when it has heated for a sufficient length of time, it is removed and plunged in the bath. If hardness is the only quality desired, use a bath of water. If a hard surface is desired, and a very tough, strong interior, use a bath of oil and tallow.

Malleable iron may be hardened by heating in cyanide of potassium, as is the case with machinery steel, the depth of hardening depending on the length of time it was left in the cyanide. If colors are desired, the surfaces must be polished, and a bath of clean water used. If a strong, tough effect is desired, quench in oil.

It is sometimes desirable to color a piece of work in imitation of case hardening, yet leaving the article soft. If the piece is made of machinery steel of low

carbon, or of malleable iron, this is accomplished by using a cyanide made especially for the purpose. This is known as "50 per cent. fused cyanide of potassium."

Hardening Steel.

Having considered the nature of steel, methods of heating for different purposes, and the means of cooling by the various baths, we will proceed to the consideration of hardening articles of various types. As it would be impossible to consider all the articles that require hardening in the various shops throughout the country, such examples have been selected as are representative of the articles that are commonly hardened.

Uniform heats are the secret of success when hardening steel. A greater part of the trouble experienced by men not skillful in this branch of the business arises from this fact not being observed. The writer cannot resist the desire to caution the reader against trouble arising from this cause, and hopes he will be pardoned if he apparently repeats this warning oftener than may seem necessary.

When hardening steel, avoid too rapid cooling of the surface, as it is then rigid and inflexible, while the inside of the piece is still undergoing the change in structure incident to hardening. As a consequence, if the outer surface is hard and inflexible, and the internal portion is undergoing changes in size and structure, the outer surface will crack from the enormous strain brought to bear on it. It is advisable when hardening

small articles to heat the contents of the bath somewhat, to avoid the sudden cooling mentioned.

As stated, when the surface becomes hard before the center has ceased changing its size and structure, there is a tendency to crack the surface from the internal strains.

To overcome this tendency, the piece should be heated to a degree that allows the surface to yield somewhat and conform to the strains in the piece. The amount of heat necessary to produce this result has been ascertained to be at the temperature of boiling water (212 degrees). An experienced hardener can determine the necessary amount of heat very nicely by the sense of feeling, heat the steel until, when touched with the moistened finger, the peculiar snapping sound is heard. This is the same as the housewife tells when her irons have reached the proper temperature for ironing linen.

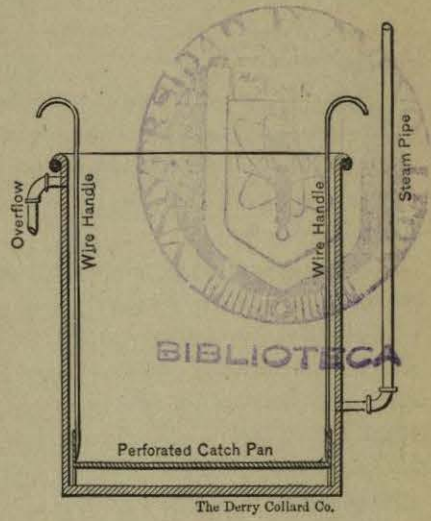

Figure 45. Bath for hardening in hot water.

When pieces are hardened in large quantities, it becomes very costly practice reheating each piece over the fire, guaging the heat by the sense of feeling. A