Methods of Heating.

The method employed when heating steel for any particular purpose depends on the facilities furnished by the individual shop. As it is not, generally speaking, the office of the hardener to purchase the equipment of the shop; but to use such equipment as may be furnished him, it is necessary that he adapt himself to circumstances as he finds them. The successful man is one who makes the best use possible of the equipment furnished him.

If there are but a few tools to harden, and they are of a character that could be treated in a satisfactory manner in an ordinary blacksmith's forge, it would not be considered advisable to purchase a costly furnace, even though it were known that the work could be done more cheaply per piece, because the limited number of pieces would not warrant the extra outlay of money for equipment.

On the other hand, if work was to be done in large quantities, it would be wise to procure the necessary equipment to do the work in a satisfactory manner at the least cost possible. If the total amount of hardening done in a shop in any one year was 6 or 7 diamond point turning tools and 2 or 3 side tools, it would be folly to invest several hundred dollars in a muffle furnace and an elaborate system of baths. But if the product of the shop was several hundred taps, reamers or

similar tools per day, it would not be considered good business policy to heat them for hardening in an ordinary blacksmith's forge. It would not be possible to do the work as cheaply, neither would it be done in as satisfactory a manner as though apparatus especially adapted to this class of work were used.

But, as previously stated, the hardener should make the best possible use of apparatus furnished him. If obliged to use a blacksmith's forge for heating steel either for forging or hardening, he should see that his fire is clean and that it is high enough above the blast inlet so no jet of air can strike the heated steel.

It is possible to heat comparatively small articles in a satisfactory manner in an ordinary forge by using care in regard to the size and condition of the fire and the location of the piece of work in relation to the blast inlet.

It is always advisable to build a fire large and high enough so that the portion of the piece being heated will be covered to a considerable depth by the coals. Otherwise the action of the oxygen in the air would cause the carbon to be burned out of the surface of the steel, leaving it decarbonized; in this condition it cannot harden.

If the cold air from the blast strikes heated steel, it causes it to crack, particularly if there are teeth or projections, as these are more susceptible to the action of heat and cold than the heavier portions. The steel would expand from the action of the heat, the air striking the projections would cause contraction, and the repeated expansion and contraction would cause the steel to crack.

If large pieces are to be hardened, a large high

fire should be built, as a low fire in a forge having a tuyère—blast inlet—of the ordinary size would not be sufficiently large to heat the piece uniformly. It is always advisable when heating large pieces to use a fire of new coals if charcoal is used as fuel, as coals which have been used for some time are burned to the extent that the fire is dead unless considerable blast is used, in which case the result would be a lot of cracked work.

Charcoal is generally considered the ideal fuel to use when heating tool steel. As it is a form of carbon, it is generally given credit for imparting carbon to the steel heated in it. Now, this is the case, if *low* carbon steels are packed in a tube or box with a good quality of charcoal, away from the action of the fire and air, and run for a considerable length of time. Carbon will then be absorbed by the steel. Before the process of making crucible steel was discovered, iron bars or rods were packed in tubes with charcoal and run for a sufficient length of time to charge the iron with carbon, thus making a union of iron and carbon, or steel, as it is familiarly known. This process is known as "cementation."

It does not seem probable that a piece of tool steel, high in carbon would absorb any extra carbon in the brief time it was exposed to the action of fire, in heating for hardening. On the contrary, if a piece of high carbon steel is heated in this manner, it is apt to lose some of the carbon at the surface. For this reason, a piece of high carbon steel is not so liable to have surface cracks if heated for hardening in a charcoal fire. But from experiments, it can, I think, be truthfully claimed that a piece of 1.5 per cent. carbon steel will

not be as hard on the surface if heated in a charcoal fire, as if heated in a fire burning coke.

But if steel must be heated in a fire, exposed to the action of the burning fuel, it is advisable in most cases to use charcoal, because it does not contain impurities injurious to the steel.

On the other hand, high carbon steel will not be as hard on the surface if heated in a charcoal fire, as if heated in some form of furnace where the article is not exposed to the action of the burning fuel, and as most of the other fuels contain impurities injurious to the steel, it is best to heat in a manner that removes it from the action, not only of the burning fuel, but also from the action of the air. In order to accomplish the desired result, the article may be placed in a tube or iron box, or a muffle furnace may be used.

If many pieces are to be hardened, it is advisable to procure a furnace especially adapted to the class of work. The neatest, most easily managed furnace, and the one which gives as good satisfaction as any, is a form made to burn illuminating gas as fuel. These can be procured of almost any size. A very satisfactory style of this type is known as a muffle furnace, from the fact that the piece of steel to be heated is placed in an oven or muffle. The flame circulating around the muffle heats it to any required degree of heat. The steel is heated by radiation, consequently it is not subjected to the injurious effects of the products of combustion; and as the door may be closed, there is little danger of oxidation of the heated surface. If the furnace is not provided with some means whereby the work being heated may be readily observed without removing the door, it is advisable to drill one or two

one-inch holes in the door, covering them with mica. These furnaces are by far the most satisfactory for general use of any form the writer has used. Figs. 4 and 5 represent two styles of these furnaces. If it is not considered advisable to purchase a furnace of this description and one is to be made on the premises, it is possible to make a very satisfactory furnace quite cheaply. If large or long pieces are to be heated and a furnace is to be made of a type where the steel is placed in contact with the fuel, it is advisable to use charcoal, as either coke or coal do not furnish a satisfactory means of heating under the circumstances mentioned. The grate should be made the size of the

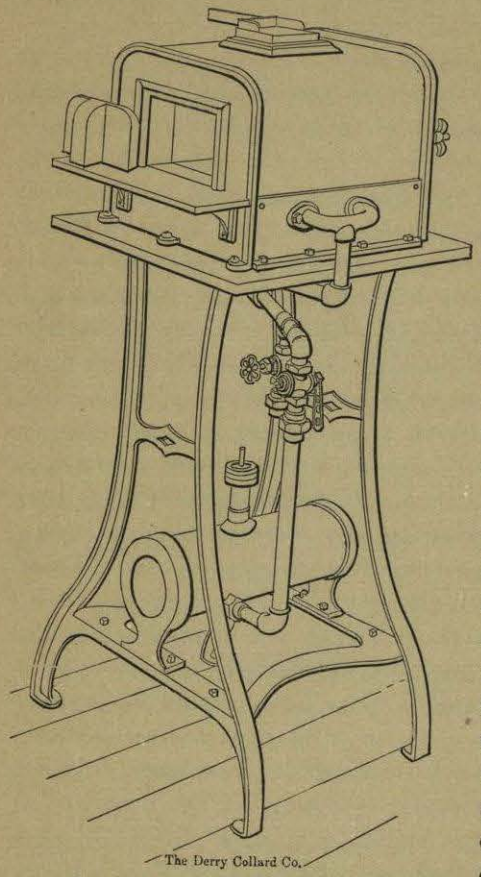

Figure 4. Muffle furnace for hardening.

inside of the furnace, as in this way a uniform heat may be maintained in all parts of the furnace, and it will not be necessary to use a blast. A natural draft will be found sufficient.

Fig. 6 shows a furnace of the type mentioned, the dimensions depending on the size and character of the work to be heated. A damper should be placed in the smoke pipe in order to check the fire if there is danger of its becoming too hot. This damper should not be of the type usually put in the pipe of a coal stove, as these dampers are made with a hole to allow for the escape of gas. It is not desirable to have this hole in the damper, as it is impossible to check the fire on a windy day. The lower door must also be furnished with a damper, in order to furnish draft when desired. It is possible with this furnace to do very excellent work.

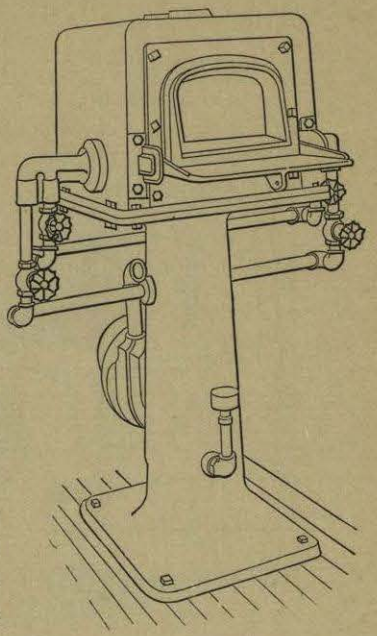

Figure 5. Muffle furnace for hardening.

If it is desirable to build a muffle furnace, one may be made to use either charcoal, coke, or hard coal as fuel by taking the one represented in Fig. 7 as a model, and changing the design to meet the require-

ments. The interior of the muffle is represented by A, B is the fire box, C the ash pan. The heat and smoke passing up from the fire box follow the direction of the arrow passing under the muffle and out of the smoke pipe at D. A damper should be placed in the smoke

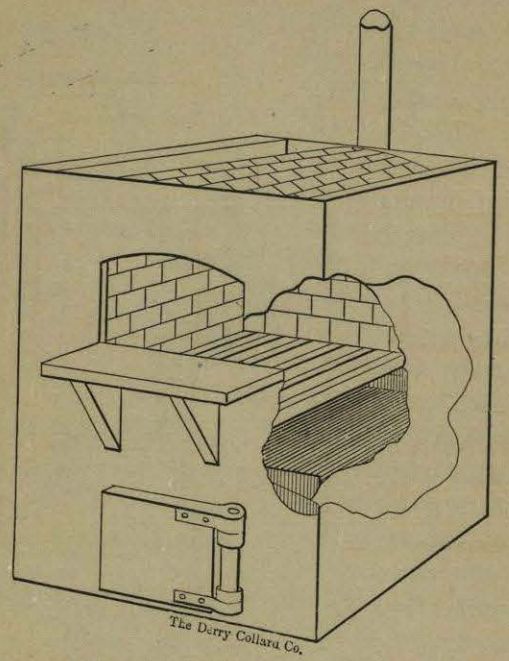

Figure 6. A "home-made" furnace.

pipe and one in the ash chamber door. By means of these dampers the draft can be regulated very nicely. This form of furnace works very nicely in heating dies and similar work.

When small articles are hardened in large quantities a furnace may be made of the design shown in

Fig. 8, where *a* represents the fire box which burns hard coal, charcoal or coke; *b* the ash box; and *c* the chamber for heating the work. The front plate has a number of holes corresponding to the number of tubes it is considered advisable to heat at a time. The tubes are made by taking a gas pipe, plugging one end as

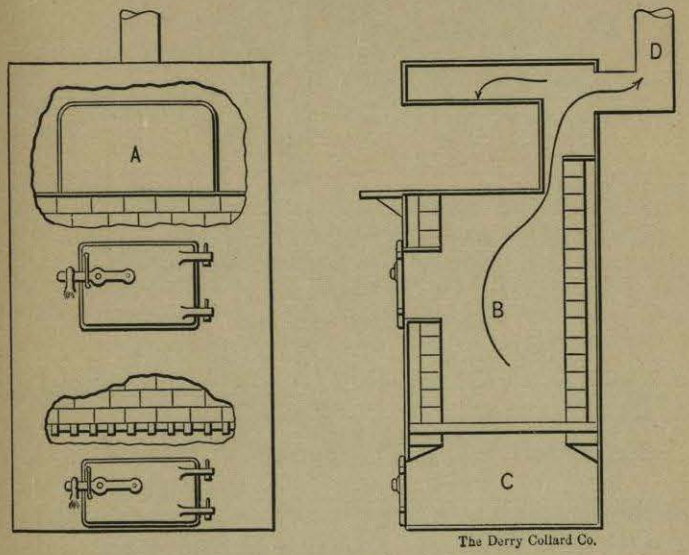

Figure 7. A "home-made" furnace for burning charcoal, coke or hard coal.

shown as Fig. 9, the other end being left open. A number of pieces of work may be placed in each tube and the tubes placed in the openings. The tubes at the bottom will heat more quickly than those at the top, so it is advisable when a tube in the bottom row is taken from the furnace to fill its place with one from one of the top rows. The tubes as they are filled may be placed in the top rows and allowed to heat gradually

and later removed and placed in the lower row. By following this plan it is possible to heat the work

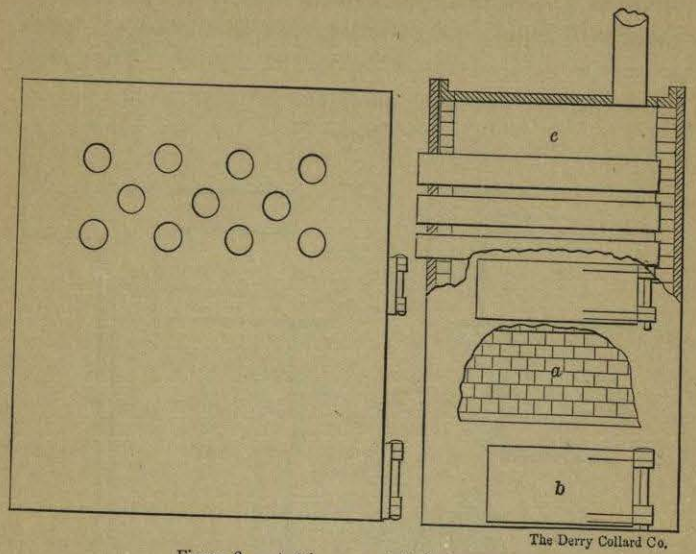

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Figure 8. A "home-made" furnace for heating small pieces.

gradually and yet harden a large amount of work in a given time. The tubes should be turned occasionally in order to insure even heating and satisfactory results.

When but a few small pieces are to be hardened

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Figure 9. Construction of tubes in "home-made" furnace.

a gas blast of the form shown in Fig. 10 answers very nicely. If the pieces are of a size that guarantee their

heating quickly it is safe to hold them in the flame, having a piece of fire brick to reflect the heat. By this means the heat is utilized to much better advantage than if nothing were placed back of the work. It

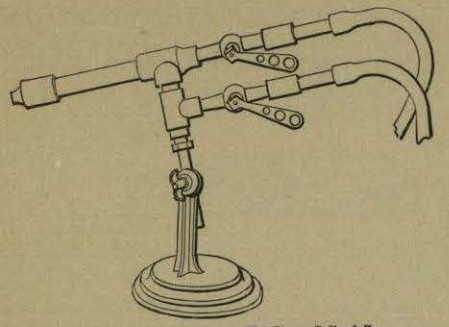

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Figure 10. Gas blast for heating a few pieces.

is possible by forming a cavity in the brick or making a small oven as shown in Fig. 11 to heat a much larger piece of work in an ordinary blow pipe than would otherwise be the case.

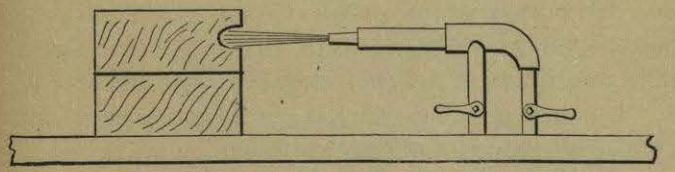


Figure 11. Another form of gas blast for heating

A crude but satisfactory method of economically heating small pieces is furnished by the idea presented in Fig. 12, in which case a small oven is built of fire brick, or a casting of the desired shape may be

obtained. In either case a flame from gas blast should enter at one or both sides through holes provided.

Small articles may be heated by using a Bunsen

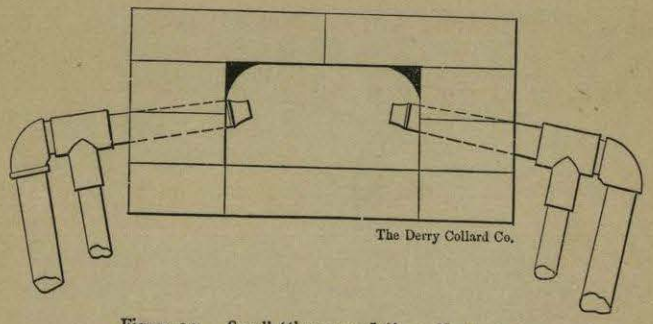


Figure 12. Small "home-made" gas blast oven.

burner, as shown in Fig. 13, which can be applied to a gas pipe in place of the ordinary burner, or may be connected by means of a piece of rubber tube. When using a burner of this description the work can be heated more readily if a piece of sheet iron is placed over the burner at the proper height, the article to be heated being placed beneath this, the sheet metal reflecting the heat and thus increasing its utility.

It is also possible by means of a blow pipe to heat very small articles sufficiently for hardening by means of an ordinary gas jet or the flame of a spirit lamp, as shown in Fig. 14. This is an expensive method when work is heated in quantities, but answers very nicely for one or two pieces.

When heating for forging or any work where the outside of the steel is afterwards to be removed it is

advisable to use a form of furnace where the direct heat of the fire comes in contact with the steel, as it is much more economical and is, generally speaking, a quicker method than heating in a muffle furnace. It is advisable many times when heating large pieces of steel for hardening, to use a furnace, as described, on account of economy. In case

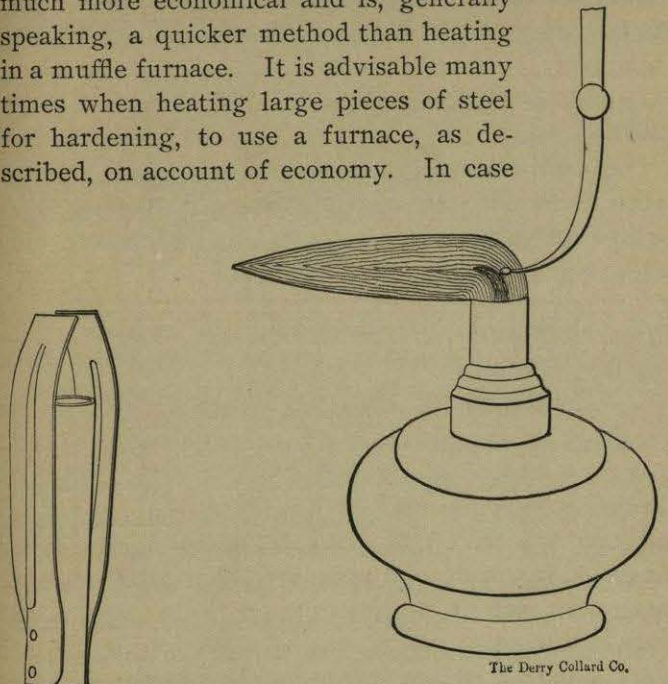


Figure 14. The blow pipe way of heating.

Figure 13. Bunsen burner, for heating small articles.

the outer decarbonized surface is to be ground away, the results will be satisfactory; but if the outer surface must be hard, then it is necessary to protect the surface from the action of the products of combustion. This may be accomplished by several different methods.

Covering paste, and how to make it.

One method is to place the portion of the piece, which must not be decarbonized, in a box with carbonaceous materials—as charcoal or charred leather—and subject to heat until the piece has reached the desired uniform temperature, being careful that the part which is exposed to the direct heat of the fire does not get over-heated.

Another method which is used when an article must be hard on all its surfaces is to cover the piece with a carbonaceous paste, consisting of the following ingredients:

Pulverized charred leather.....2 parts.
Fine family flour.....2 "
Fine table salt.....1 part.

Mix thoroughly while in a dry state. Water is then added slowly to prevent lumps; enough water may be added to make it of the desired consistency, which depends on the nature of the work and the length of time it must be exposed to the action of the fire. If the articles are small and will heat to the proper temperature for hardening in a few minutes, it should be of the consistency of varnish. If, however, the pieces are large and require considerable time for heating, it must be made thicker.

Various substances are heated red hot in crucibles or iron dishes, and pieces to be hardened are heated in them. These exclude the air and so prevent oxidation and decarbonization of the surface of the steel. Among the substances used are lead, tin, glass, cyanide of potassium, a mixture of salt and cyanide of potassium.

Lead is heated in a crucible in a furnace of the forms shown in Figs. 15, 16. It furnishes a very excel-

Heating in molten lead.

lent means of heating work which is hardened in large quantities. When making furnaces to heat lead red hot for use in hardening steel, some means should be provided for carrying off the fumes of the lead, as they are very injurious to the workman. They are especially hard to dispose of, as they are heavier than the atmospheric air; consequently cannot be disposed of as readily by means of a ventilating shaft as other fumes. It is necessary to furnish a pipe connected with an exhaust fan. This pipe may be at the back of the furnace instead of over it, as is generally the case when gases or smoke are to be carried off. It should not be arranged in a manner that will cause the surface of the lead to become cooled by a current of air passing over it.

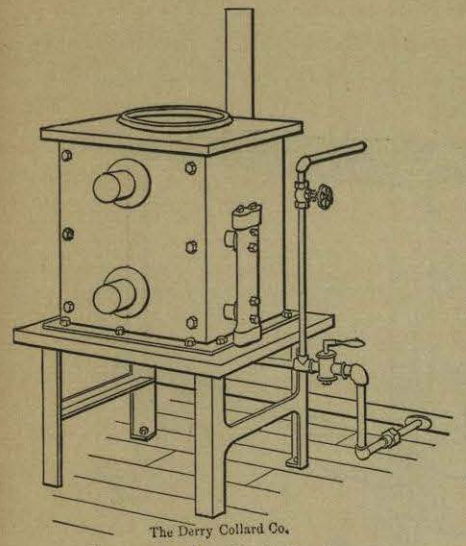


Figure 15. Lead hardening furnace.

If illuminating gas can be procured at a reasonable rate, it furnishes an ideal method of heating a crucible of lead. Furnaces burning illuminating gas can be procured of a size and shape adapted to the work to be done. If, however, it is considered advisable to make a furnace for this purpose, one may be made which

will give good satisfaction. It can be made to burn oil, coal, charcoal or coke. If oil is the fuel to be used, it is advisable to install a system especially for this method, and as circulars and full explanations can be

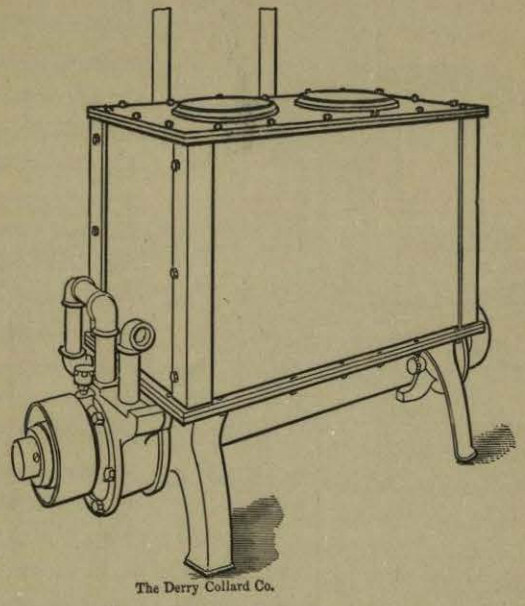
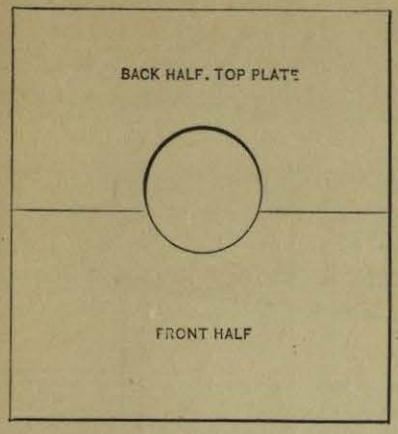


Figure 16. Lead furnace for hardening.

procured from manufacturers who make these outfits, it would not be wise to go into their details here.

If it is considered advisable to make a furnace burning charcoal, hard coal or coke, the design shown in Fig. 17 may be used or changed to adapt it to these fuels. The outer shell may be made of cast iron, although it may be possible to procure an old



boiler, which can usually be bought very cheaply. A piece the desired length may be cut from this, that answers the purpose very nicely. A round grate and the necessary frame to support it may be procured from a stove dealer. The form of grate

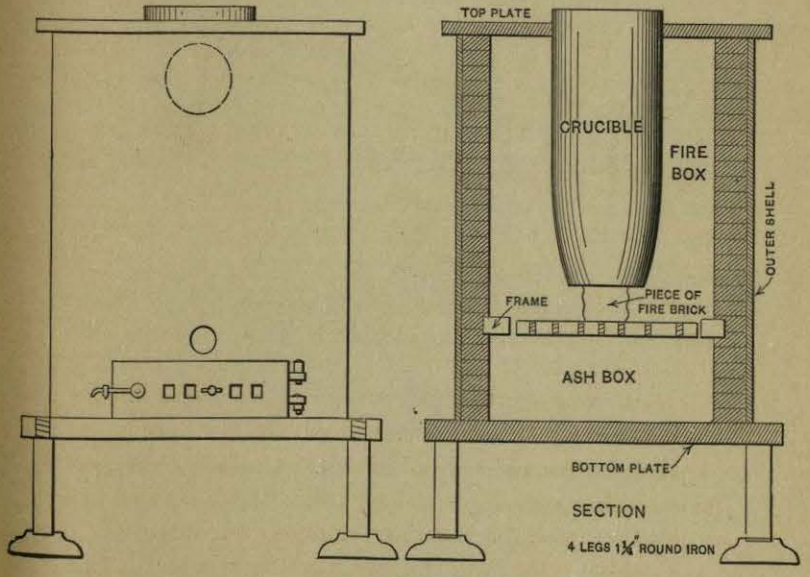


Figure 17. Coal, coke or charcoal furnace for lead heating.

used in the ordinary cylinder parlor stove will answer every purpose. The frame should be attached to the shell or blocked up from the bottom of the ash box, to allow the grate to be turned in dumping the contents of the furnace. The interior of the furnace may be made of circular fire brick, which may be supported by the slab which forms the base or bottom of the ash box and designated as the bottom plate. In case fire brick are used, the grate frame may be built into the brick work as shown. If, however, a stove lining of the desired size can be procured, the bricks need extend only up to the frame, the lining extending from the frame to the top of the shell. It is necessary to cut an opening in the ash box in the front of the shell. This should be covered with a swinging door, containing a sliding damper. This door is necessary in order to remove the ashes.

A smoke pipe must be provided to carry off the smoke and gas from the fire. This should be connected with the shell at the top on the back side of the furnace. Over the top of the furnace must be placed a plate, having a hole in the center about one half inch larger than the size of the crucible to be used. This plate should be cast in two pieces, having more than one-half of the hole in the part that goes at the back. The smaller or front half may be moved forward, thus affording an opening to feed the coal to the fire. The object in having more than one-half the opening in the back part of the cover is to prevent the crucible from tipping over when the front plate is removed, when there is not sufficient coal in the furnace to support it. It is necessary to place a piece of fire brick in the center of the grate for the crucible to rest on in order

that the fire may be beneath it. The smoke pipe should be provided with a damper, to enable the operator to properly control the fire. This form of furnace gives best satisfaction when hard coal is used as fuel.

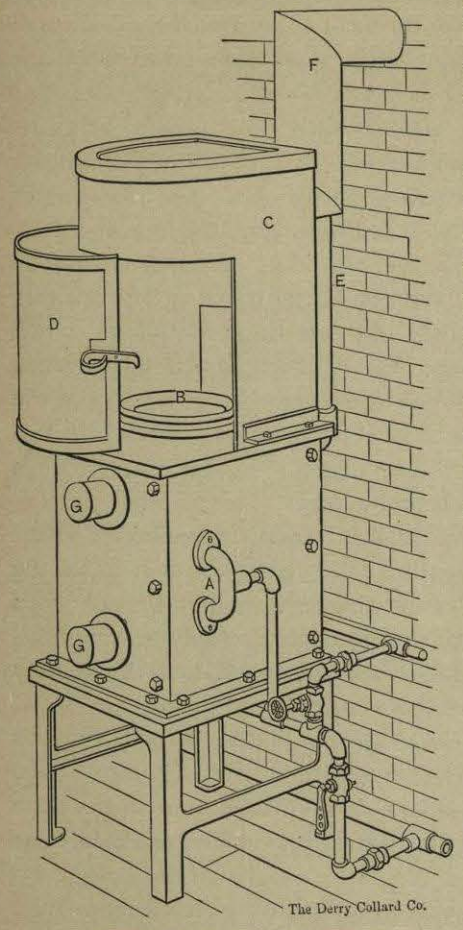


Figure 18. Furnace for heating in cyanide of potassium.

Red-hot cyanide of potassium is used with excellent results in heating tools for hardening. It not only heats the steel uniformly, but, being lighter than steel, the latter sinks in the fluid, thus effectually excluding the air from the surface of the steel. It also has the effect of making the surface somewhat harder than it otherwise would be, without making the steel more brittle.

It should be borne in mind that cyanide of

potassium is a violent poison, and great care should be exercised in its use. Not only is it poisonous when taken into the stomach, but the fumes are highly injurious to the workman if inhaled. However, if furnaces are properly designed and set up, the fumes may be disposed of in a manner that does away with this trouble.

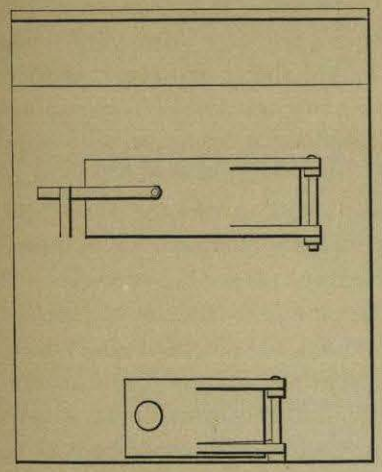
In Fig. 18 is shown a form of furnace made especially for use in heating in cyanide of potassium. The fuel used is illuminating gas, the products of combustion passing up the pipe E to the main pipe F which also conveys the fumes of the melted cyanide into the chimney or ventilating shaft. The burners enter the furnace at A and heat the crucible B, which contains the cyanide. A hood C, which is provided with a door D, keeps the fumes from entering the room as they are conveyed into the pipe F. The lighting holes G G are closed by the plugs shown when the fire is well under way.

When a comparatively small number of small pieces are to be hardened, it is possible to heat the necessary amount of cyanide in a small iron dish in an ordinary forge. The pieces may be held in this until the desired effect has been accomplished, when they may be quenched.

As the work heated in this manner is usually hung from the edge of the crucible by means of wire hooks, it is generally considered advisable to use a square crucible rather than a round one when work is done in large quantities.

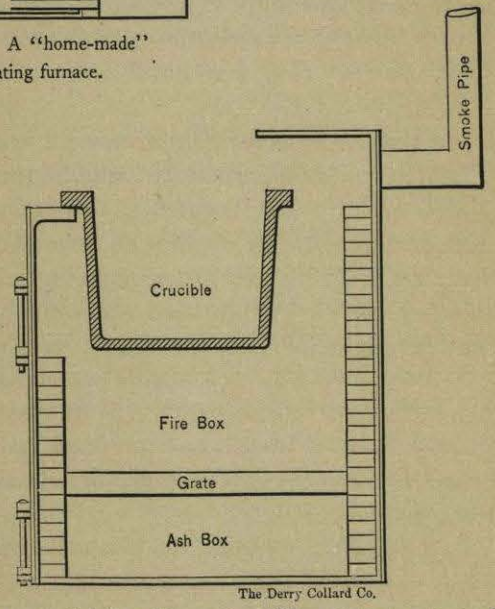
When a furnace is to be made for this purpose, the form represented in Figs. 19-20 will be found to give good results. This furnace burns hard coal. The cruci-

ble which is made of cast iron is square in shape and hangs from the flange, which is cast around the upper edge. The top of the crucible is below the top of the back of the furnace. An opening into this allows the fumes to escape into the chimney.



Figures 19-20. A "home-made" cyanide heating furnace.

A quantity of salt is placed in a crucible and heated red hot. To this is added cyanide of potassium until the steel heated in it shows the proper amount of hardness. This method is used by manufacturers of taps and similar tools, who claim excellent results by its use. The same general



remarks apply to this method as to heating in cyanide of potassium.

Glass heated in a crucible until it is red-hot is the means used by some watch makers to heat the hair springs of the watches. It is claimed that the nature of steel heated in this manner will not change in the least.

Very little attention is paid in most shops to the location of the forge or furnace used in heating steel; generally any out-of-the-way place is selected. If there is any portion of the shop that cannot be utilized for anything else, it is given up to this purpose.

The fire for heating steel should receive more consideration, so far as location is concerned, than almost any other part of the equipment. It should never be located where the direct rays of the sun or any strong light can shine in it, or in the operator's eyes, for uneven results will surely follow. It should never be located in or near a window, neither should the roof be constructed with skylights which allow any of the sun's rays or any strong light to enter the portion of the room where the furnace is located.

An ideal place for the location of a furnace used in heating steel for hardening, is in a room so constructed that no rays of sunshine or direct light can enter it.

It is extremely important that due consideration is given the subject of ventilation. Some means should be provided whereby pure air can be freely supplied without creating drafts, which would cause the operator, who is perspiring freely, to take cold. The room should be so located that it will not be damp, or the health of the workman would be hazarded.

Too often in the past the precautions noted have

received very little consideration, because those in charge did not realize the importance of a properly equipped or located room in which to do this class of work.

Heating Tool Steel.

Tool steel is very sensitive to the action of heat. A slight difference in temperature after a piece has reached the proper hardening heat will be noticeable in the grain of the steel. When heating for hardening, the lowest possible heat that will give the desired result should be used. The amount of heat necessary to produce this result depends on the make of the steel, the percentage of carbon it contains, the percentage of other hardening elements that may be in the steel, the size of the piece, and the use to which it is to be put when hardened—all these must be taken into consideration. A steel low in carbon requires a higher heat than a piece of high carbon steel in order that it may be as hard. A small tool does not require as much heat as a larger one of the same general outline. A tool with teeth or other projections will harden at a lower heat than a solid piece of the same size made from the same bar of steel. There is a proper heat at which a piece of steel *should* be hardened in order to produce the best results, but *this heat varies*, as previously explained.

If two milling machine cutters were made from