tion of the furnace, the pieces treated fall slightly forward at each revolution, gradually progressing toward the discharge end, where they enter a proper receptacle or bath upon reaching the desired temperature.

In certain classes of work, such as balls, nuts, and uniform shapes, the helical or worm type, as shown in Figs. 92 and 93, is used, but for irregular shapes, where the smooth lining can be used, the cost is less and a greater life is insured. Fig. 93 shows the details of construction

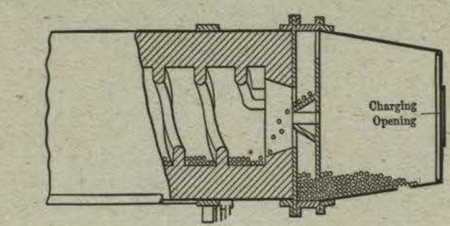


Fig. 92. — Section of same furnace with helical or worm interior.

of a furnace built on the same principle, with the exception that the work is held in a revolving retort, and the heating gases surround this in such a way that they do not come in contact with the work.

Oil or gas fuel may be used and perfectly uniform results obtained, as the work treated is heated gradually with every portion of its surface exposed to the direct action of the hot gases and lining, and both tem-

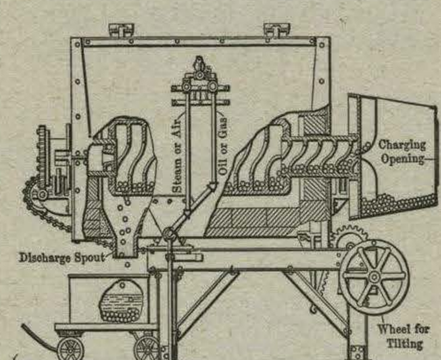


Fig. 93. — Sectional view of furnace with closed retort for work.

perature and time are maintained constant. The furnaces are built to suit a wide range of requirements, and in sizes that will handle up to 2000 pounds of stock per hour. While they were designed principally for hardening steel pieces, they are also useful for annealing non-ferrous metals, such as brass cartridge shells, etc.

Automatic apparatus has also been added to furnaces to carry the

work through quenching and cleansing baths of various kinds. In one case an automatic gas-heating furnace discharges its work into a tank for quenching. The quenching tank contains a conveyer for removing it from the tank into receptacles with which it can be carried away. Two tanks can also be coupled together; into the first one of which the work is dumped from the furnace for quenching. From there it is conveyed to the second tank, in which the work is cleaned, and from there conveyed to pans, trays, or other containers in which it can be easily handled. The work drops from the furnace into the quenching bath in a continuous stream, and from the hopper it is fed through a perforated

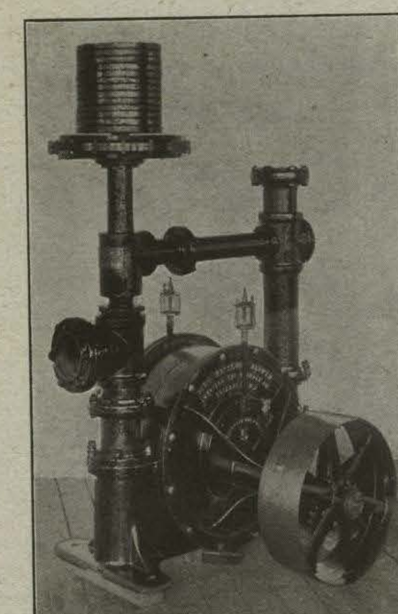


Fig. 94. — Gas booster to supply furnaces.

barrel, that inclines down to the other end of the tank, where it is picked up by the conveyer and discharged from the tank. The perforated barrel revolves slowly to agitate the articles, thus bringing them in contact with the quenching liquid on all sides. The barrel end next to the hopper is movable, so it can be raised or lowered to make the work travel fast or slow. The liquid is admitted to the tank beneath the receiving end of the barrel, and as it becomes heated, by contact with the articles, it rises and is drained off, from the top of the tank, near the discharge end of the barrel. At the lower end of the barrel the pieces are picked up by the lower loops of an endless chain that is formed of buckets open on the inner side. They are elevated by this and dumped into a fixed hopper within the upper loop of the chain, and from there the discharge chute leads them away from the tank. The buckets are perforated so as to strain the liquid from the pieces hardened.

The double tanks may be used to quench work in the one, and then send it through a cleaning compound in the other. For instance, work that is quenched in oil may be sent through a second tank containing some liquid that will cut the oil from the work and leave it clean, or a liquid containing chemicals that act as a rust preventative may be used in the second tank. In fact there are many combinations for the double tank.

The gas pipes from the street or the main in the street are sometimes found to be too small to supply the necessary gas to the furnaces when installing them. In this case a gas booster, similar to that shown in Fig. 94, is used. This sucks the gas from the main faster than it would naturally flow, and delivers it to the furnaces as required.

With gaseous fuels, it is probably as easy to control the temperature of furnaces to within a few degrees of a given point as with any fuel used. The latest invention along this line is the automatic apparatus, for controlling the temperature of gas furnaces. It was put on the market by the American Gas Furnace Company in December, 1909, and controls the temperature to within 5 degrees of a given point. Pyrometers being required to measure these high heats, the pointer on the pyrometer indicator was used as a starting point. The pointer was left free to oscillate back and forth as the temperature rises or falls in the furnace, as anything that would retard the action of this pointer would throw the pyrometer out of true and ruin it for accurate temperature readings. At the same time it was necessary to have power enough to instantaneously open and close the gas and air valves that admit the fuel to the furnace. The mechanism also had to be positive in its action.

In Fig. 95 is shown a muffle gas furnace with the complete automatic temperature controlling apparatus attached thereto; Fig. 96 shows, on a much larger scale, the apparatus connected to the indicator; Figs. 97 and 98 show the operating mechanism of the apparatus connected to the indicator, and Fig. 99 shows the apparatus connected to the furnace. The instrument operates as follows:

In Fig. 95 the thermo-couple or hot end of the pyrometer is inserted into the furnace at *A*, and connected to the indicator at *B*. Underneath *B* is the mechanism shown in Fig. 96, while at *C* is that shown in Fig. 99. At *D*, in Fig. 96, is located a thumb screw that revolves the disk *E* and moves the pointer *F* with its arms, *G*, to the temperature at which it is desired to maintain the furnace. The arms *G*, as well as the rest of the mechanism, are operated by power supplied from a fan located in the case *J*. This is revolved by a current of air that is sent through a ¼-inch pipe, and blows against the blades of the fan.

How the arms *G* operate is best shown by the drawing, Fig. 97, which is a view that looks down on their top. When the temperature rises in the furnace, the indicator pointer *I* travels to the right until it passes under the left-hand arm *G*, which is now stationary, and comes in contact with the right-hand arm *G*, which is constantly oscillating in and out of

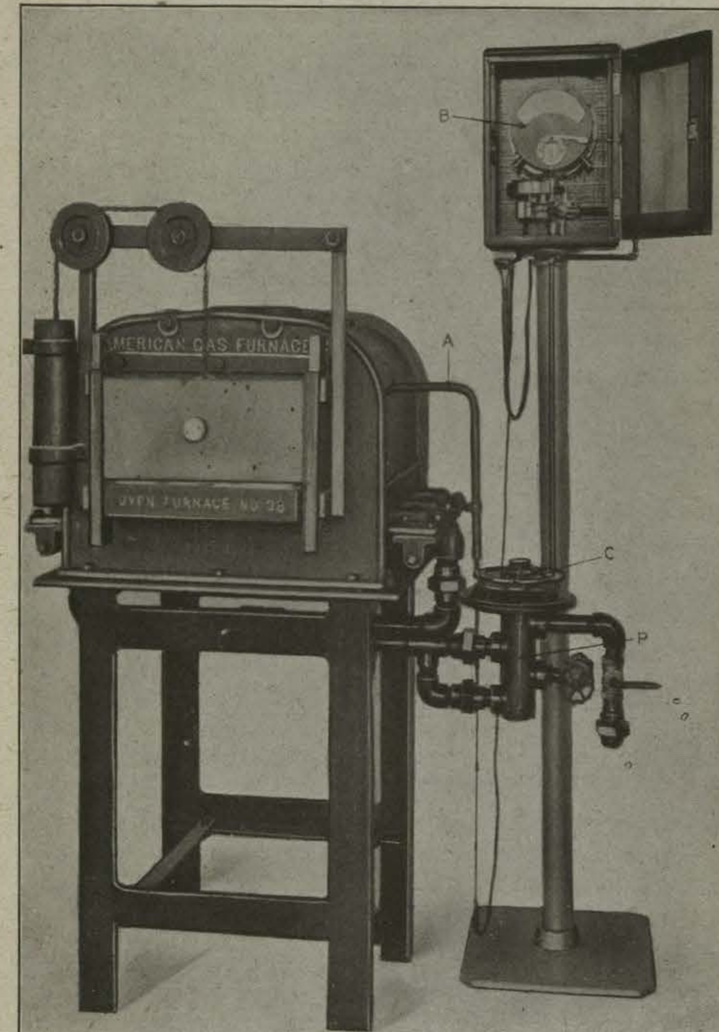


FIG. 95.—Instrument for automatically controlling temperature of furnaces.

slot *H*. When it arrives at the position shown, right-hand arm *G* grips it for an instant, and this trips the arm and throws it back to the position shown by left-hand arm *G*, so that the indicator pointer *I* will pass it and register any rise in temperature which may occur after this, due to the lag. When right-hand arm *G* is thrown back to the stationary position, left-hand arm *G* is started oscillating in and out of slot *H*, by means of a cam. The valves that admit the gas and air into the furnace for fuel are then shut off, thereby stopping the heat. Then as the furnace cools and the indicator pointer *I* travels back to the left to record the lowering temperature, left-hand arm *G* catches it, trips, turns on the gas and air, and the right-hand arm *G* starts operating.

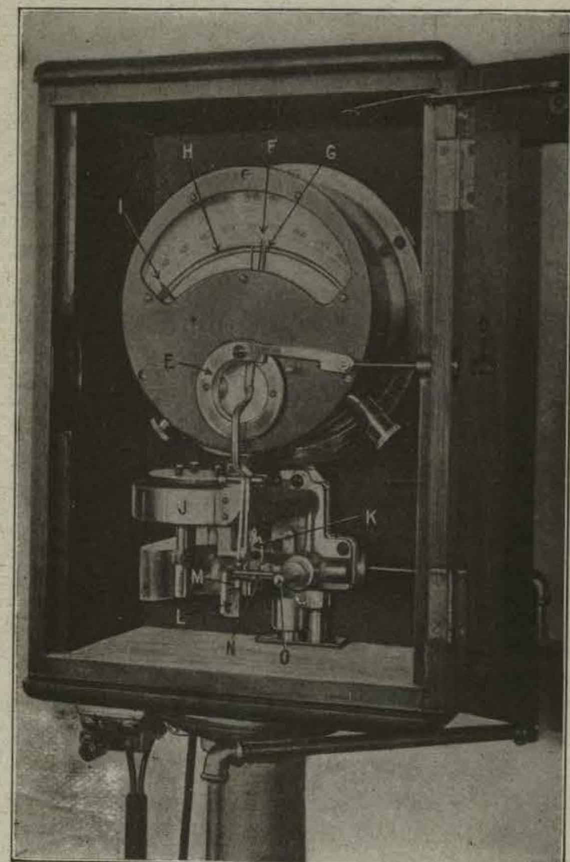
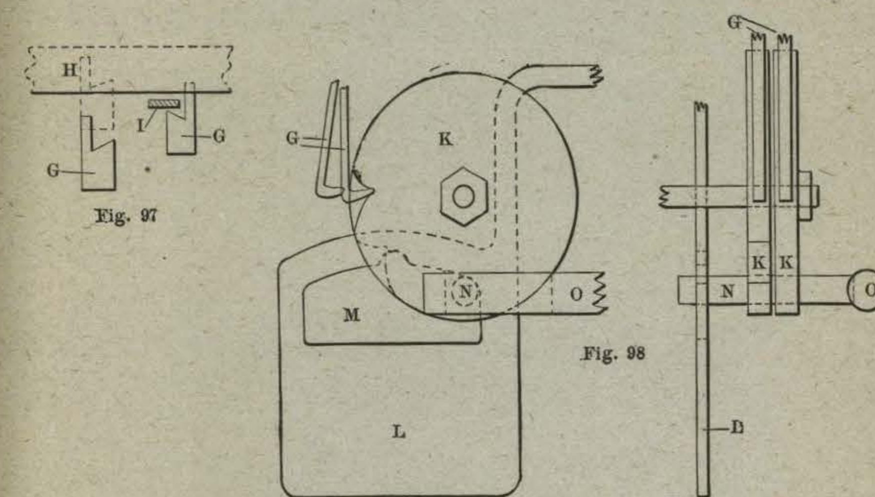


FIG. 96. — Apparatus connected to the indicator.

The arms *G* are given their oscillating motion or held stationary by the lower end riding on two disks *K*, that alternately act as cams and are fastened together, as shown in Figs. 96 and 98. The disks *K* are moved back and forth on their centers by piece *L*, which is moved back and forth the distance of the opening *M*. Piece *L* rides on bar *N* for one-half of this distance, and for the other half, the half round in the top in the opening *M* drops over the bar *N* and moves it back and forth to oscillate the disks *K*. While doing so, the end of bar *N* rides on a flat spot in the valve rod *O*, but when one of the arms *G* is tripped and the other starts oper-

ating, the end of bar *N* pushes in or out the valve end *O*, and opens or closes an air valve that sends a current of air into a diaphragm that is located in the lower part of the apparatus shown in Fig. 99. As will be seen in Fig. 98, one of the *G* arms is riding on the cam of the disk *K* and is therefore in motion, while the other *G* arm is riding on the outer circle and is therefore stationary.

In the lower part of the apparatus two square holes are provided in the cylinder *P*, Fig. 95, to act as openings for the air and gas to pass through, and over these is a plate that raises and lowers to open and close them. The amount that these can be opened and closed is regulated by moving the arms *R* and *S*, in Fig. 99. These move the center rings up or down on the screw, and they can be clamped to it by the set screws back of the



FIGS. 97 and 98. — Operating mechanism connected to indicator.

arms, when the proper amount of motion for the valve slide is decided upon. The pin *T* is connected to the slide and allows it to be moved from the top to the bottom ring by the air that is admitted to or shut off from the diaphragm through the pipe *U*.

One point on the arbitrary scale on the disk *S* means a motion of $\frac{1}{64}$ of an inch for the valve slide, and when the arm *R* is placed at the "open" mark, and the arm *S* at the "shut" mark, the air and gas passages can be opened or closed by the slides traveling their full distance. This is seldom done, however, as the furnace can usually be regulated by turning on or shutting off a part of the heat.

This apparatus promises to fill a long-felt want in furnaces for heat-treating metals, as any one who operates them knows how difficult it is to keep the temperature at a certain given point by hand-operated valves.

HEATING IN LIQUIDS

Furnaces using liquid for heating consist of a receptacle to hold the liquid, and a chamber underneath and around its sides that is heated by coal, oil, gas, or electricity; the liquid being kept at the highest tem-

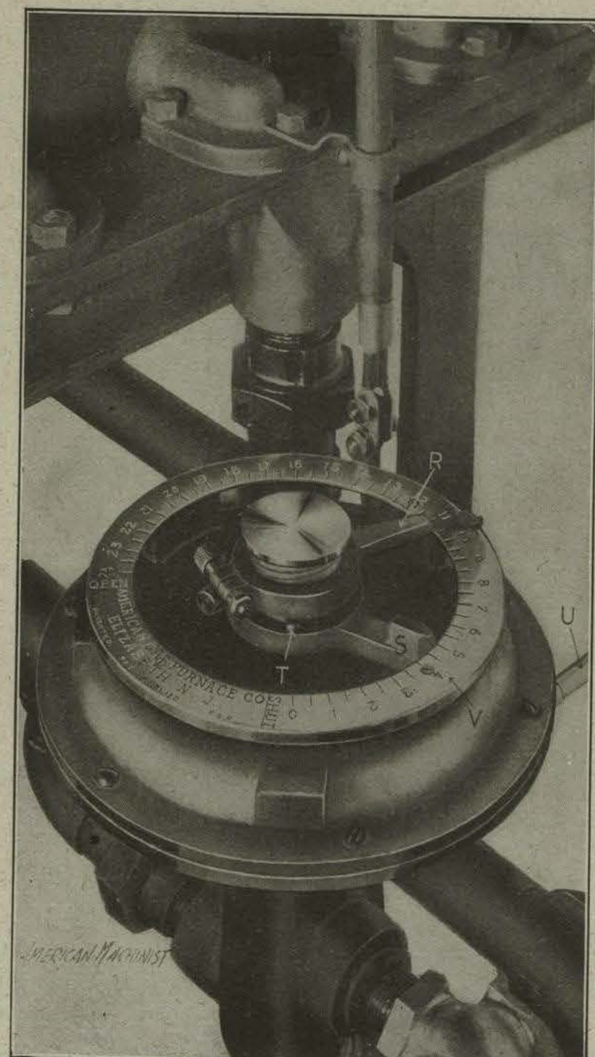


FIG. 99. — Apparatus connected to the furnace.

perature to which the piece should be heated. The piece should be heated slowly in an ordinary furnace to about 800° F., after which it should be immersed in the liquid bath and kept there long enough to attain the temperature of the bath and then removed to be annealed or hardened.

The bath usually consists of lead, although antimony, cyanide of potassium, chloride of barium, a mixture of chloride of barium and chloride of potassium in different proportions, mercury, common salt, and metallic salts have been used successfully.

This method gives good results, as no portion of the piece to be treated can reach a temperature above that of the liquid bath; a pyrometer attachment will indicate exactly when the piece has arrived at that temperature,

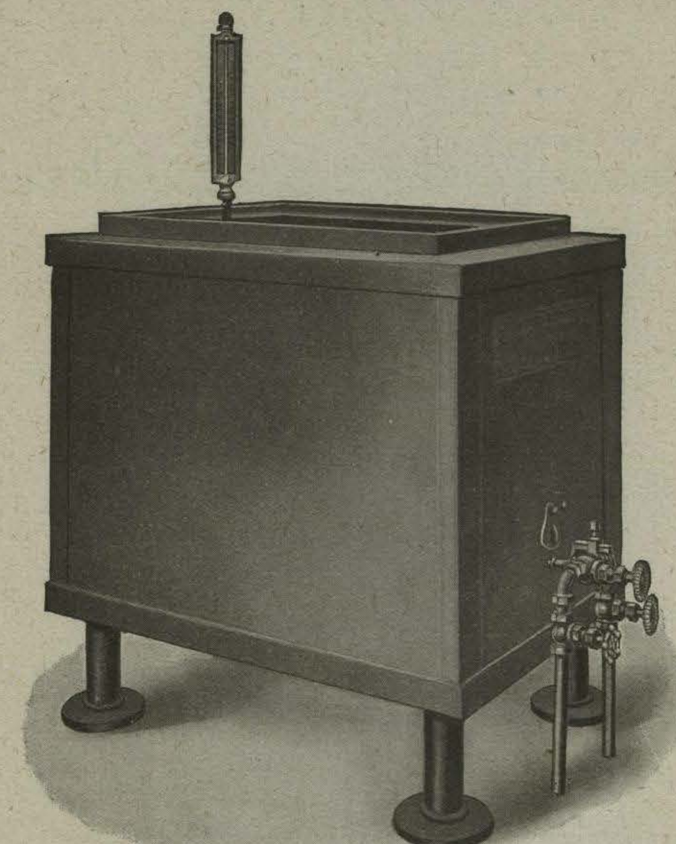


FIG. 100. — Oil or gas lead (or oil) bath furnace.

and its surface cannot be acted upon chemically. The bath can be maintained easily at the proper temperature, and the entire process is under perfect control.

When lead is used it is liable to stick to the steel and retard the cooling of the spots where it adheres. This can be overcome to a large extent by using a wire brush to clean the work with. A better method, however, is to heat the piece to a blue color, which is about 600° F., then dip it quickly in a strong salt water, and then heat it in the lead bath to the hardening temperature. By dipping in and out of the brine quickly the piece is completely coated with salt and this prevents the lead from sticking to the piece when heating it for hardening.

The greatest objection to the lead bath is that impurities such as sulphur, etc., are liable to be absorbed by the steel, and thus alter its chemical composition. This is especially so if the lead bath is used for the hardening heats, as at these high temperatures steel has a great affinity for certain impurities. A notable example of this is its greatly increased attraction for oxygen, which the metal absorbs and retains as oxides

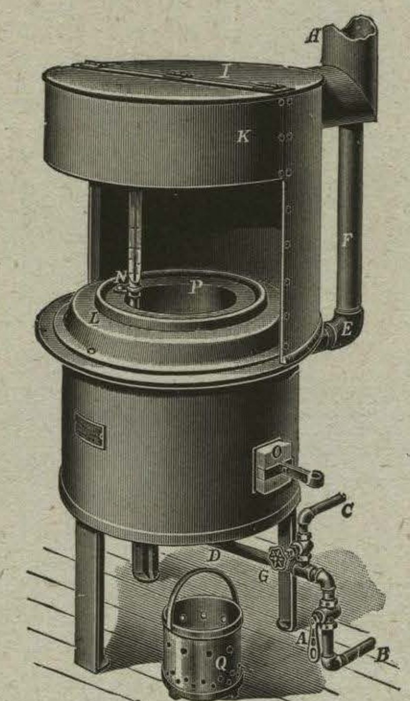


FIG. 101.—Lead bath furnace with hood.

and occluded gases. With high temperatures lead and cyanide of potassium throw off poisonous vapors which make them prohibitive, and even at comparatively low temperatures these vapors are detrimental to the health of the workmen in the hardening room. The metallic salts, however, do not give off these posionous vapors, hence are much better to use for this purpose; but in many cases the fumes are unbearable.

When the lead bath is only used for the lower tempering heats the furnace shown in Fig. 100 is a good design. It can use either gas or oil for fuel, and is supplied with a high-temperature thermometer to measure the heat of the bath. This should never be higher than is desired for

drawing the temper. It is a great improvement, even with this furnace, to place a hood over it that is piped to the outside of the building, and has a good draft, to carry away any fumes that may arise from the bath. This is an absolute necessity, however, when the lead bath is used for the hardening heats, and for that reason a furnace, with its own hood, similar to that shown in Fig. 101, is much better. These of course can be obtained or made with any size or shape of lead pot that is required for the work to be heat-treated.

Cyanide of potassium when applied to steel that has been heated to

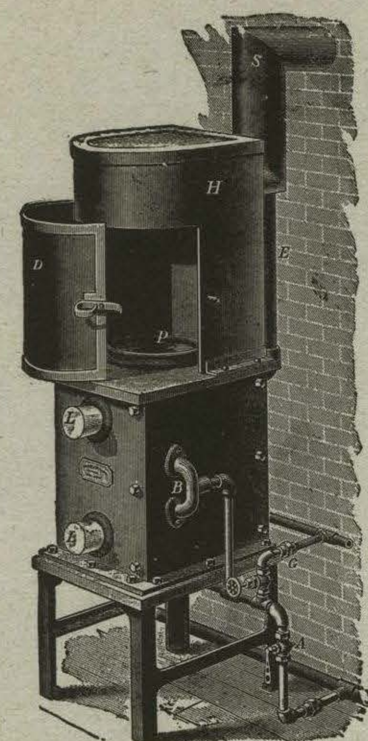


FIG. 102. — Gas furnace for pot of cyanide.

a red heat reduces the oxides and causes any scale that may have formed on the metal to peel off. Thus soft spots that may be caused by scale or blisters when hardening steel can be abolished by dusting cyanide on the piece before quenching it. It, however, has another use in heat-treating steel, as when the metal is heated to a red heat, in a cyanide bath, it is slightly carbonized on the surface and is thus used quite extensively for case-hardening. It should be kept at the boiling point and the metal submerged in it for about 5 minutes and then quenched. This has resulted in the building of a special furnace for heating cyanide, as shown in Fig.

102. Here the cyanide pot P is suspended by its flange over a chamber filled with gas flames, and hood H gathers the flames and carries them out through pipe S.

Molten cyanide sputters and drops fly, like red-hot bullets, and consequently many bad burns are caused by its use. The fumes arising from the pot are also very poisonous, and the cyanide of potassium itself is a rank poison. It is therefore a dangerous product to use. Tools dipped in powdered cyanide and quenched in a bath causes the bath to become very poisonous, and the hand should never be put in the bath to take pieces out, as running sores that are hard to heal may be the result. Cyanide is also injurious to high-carbon or high-speed steels, and as there are many other chemicals coming into use that will do everything that cyanide will do, and some things that it will not do, this material is fast going out of use in heat-treating steel. The metallic salts are taking its place and doing much better work, and they are not poisonous.

A barium-chloride bath offers all the advantages obtained from a lead bath, or cyanide, and to this is added the advantage of the barium chloride forming a coating on the steel while it is being transferred from the heating bath to the quenching bath. This prevents the metal from becoming oxidized, by keeping it from coming in contact with the oxygen in the air. It also volatilizes at a much higher temperature than lead, or any of the other materials, used for heating baths, and therefore is successfully used for the high temperatures that are needed to harden high-speed steeels.

As pieces heated in this bath have the temperature raised evenly, and at the same time, on all sides or exposed parts, it overcomes, to a very great extent, the tendency to warping or distortion which all steels have.

While barium chloride forms a coating on the steel heated in it, this coating usually peels off when suddenly cooled in the quenching bath, and any which might cling to the metal is easily brushed off, or it can be jarred off by hitting the tool a sharp rap. This is also considerable of an advantage over the lead, used for heating steel, as frequently spots of lead adhere to the steel and are difficult to remove.

In Fig. 103 is shown a gas or oil burning furnace that was designed especially for barium chloride. It is composed of a sheet-metal shell that is lined with a special fire-brick to withstand the high temperatures that are required. A graphite crucible is used to hold the chloride. After the crucible is set in the furnace, the top, which fits close to the crucible, is placed on. This top is made of the same special fire-brick that forms the lining of the furnace, and it is held toegther by a sheet-metal band with two lugs and a clamping nut. This band is provided with two handles to make it easily movable when the crucible burns out

and it is necessary to take this out and insert a new one. The opening between the furnace top and the crucible should be sealed with fire-clay to prevent the gas flames from attacking the barium chloride in the crucible, as this causes unnecessary fumes, that are almost unbearable, to come from the bath. Two per cent. of soda ash (carbonate of soda) is sometimes added to prevent these fumes.

The gas is sent into the furnace at an angle, as this gives the flame a rotary motion that will create an even heat on all sides of the crucible.

Fig. 103. — Gas or oil heated barium chloride furnace.

The exhaust opening is placed at the side of the gas inlet, and as close to it as possible, so the gas will make the complete circuit of the furnace chamber.

In Fig. 104 is shown a line drawing of the same furnace, supplied with an enclosed hood permanently fitted to it; entrance being obtained by means of a large door. Through this hood the fumes of the chloride are carried away and the burned gases are taken from the furnace through a pipe up into the top of the hood and thence out the chimney.

In heating steels for hardening that do not require a temperature of over 1650° F., a mixture of chloride of barium and chloride of potassium, in equal parts, gives the best results. As the required temperature increases the chloride of potassium should be reduced, until when 2000° F. is reached it should be left out altogether and only the pure chloride of barium used. In all cases the steel should be heated slowly to from 600° to 800° F. before it is immersed in the chloride bath, and if slowly heated to a higher temperature it will do no harm.

With the furnaces shown above, steel cannot be heated to over 2100° F. without its becoming pitted, and with many high-speed steels it is desirous to heat them to nearly 2500°. This is doubtless due to the

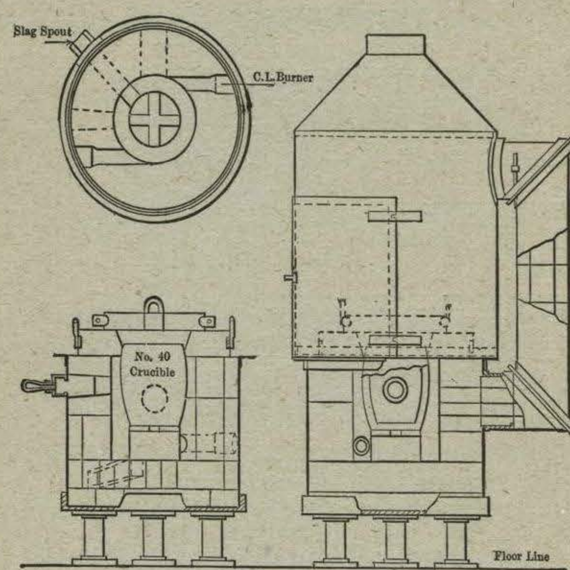


FIG. 104. — Barium chloride furnace with hood.

fact that a graphite crucible is used and particles of it separate from the crucible and float in the chloride bath until the metal is inserted, when they attack it and cause pits to form. With an electric furnace, such as is shown in Fig. 108, this is entirely overcome, as the chloride holder can be made of fire-brick and electrodes inserted in the bath. Owing to the heat being generated inside of the bath, instead of surrounding the pot, a thin-walled crucible is not required, hence the chloride pot can be built up of fire-brick of any thickness that will give it the needed strength.

In starting up for the first time the crucible should be filled with the barium-chloride that can be bought in 1000-pound casks, at about 3 cents

per pound, and this heated slowly until it melts down. After this more mixture should be added until the crucible is nearly full. After the bath is melted, tests should be made with a pyrometer until it is found hot enough for hardening. When through for the day the bath should be allowed to cool with the furnace, and when started again it should be heated up slowly.

After the bath is thoroughly liquid, take a piece of steel with a ground or machined surface, heat it to the temperature of the barium chloride and dip it in the cooling bath, then brush it off, and if there are no "bubbles"

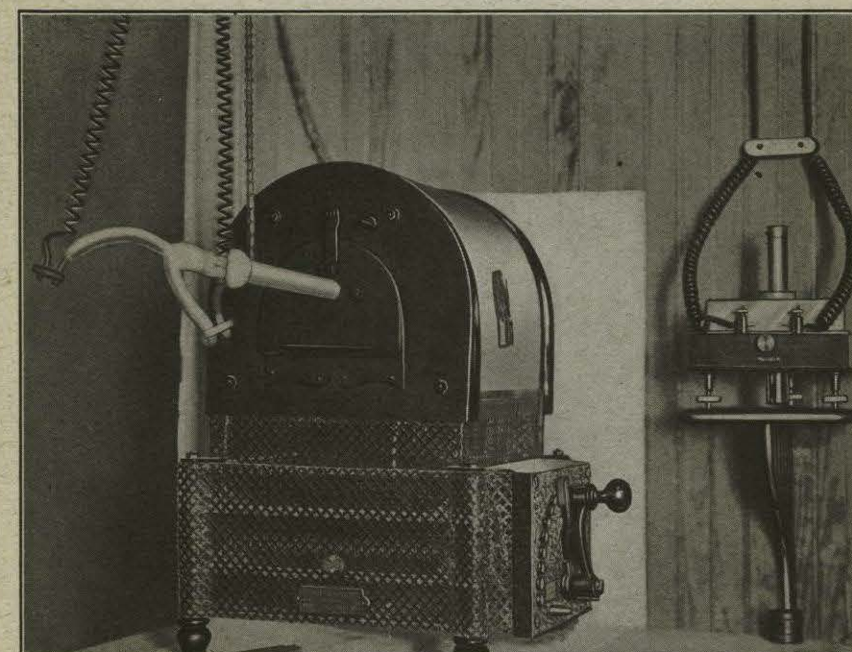


FIG. 105. — Experimental electric furnace for heat-treating steel.

or "blisters" on the piece, heat the bath to a higher temperature and repeat the operation until they do appear, and then note the temperature shown by the pyrometer. For regular use a temperature about 50° below the point at which bubbles appear is the best; the test being made with a new clean bath. These bubbles are the indication of the pitting that occurs at temperatures of 2100° F. or over when the gas or oil furnace is used for heating the barium chloride. As the bath becomes old or dirty, and sluggish from steel scale, etc., bubbles will sometimes appear at a lower temperature than they should, in which case the remedy is a fresh bath in the crucible.

ELECTRIC FURNACES

While the cost of electricity for heating furnaces is probably greater than any of the fuels, the results obtained by its use in heat-treating steel are better than by any other method.

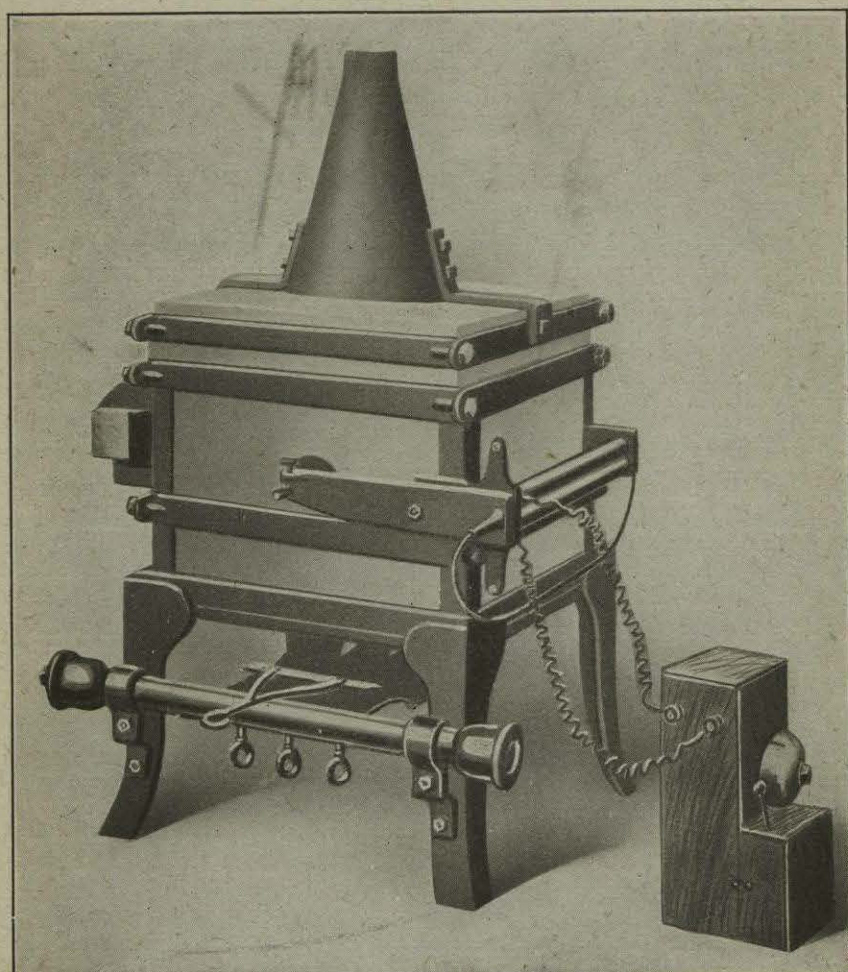


FIG. 106. — Magnetic furnace for hardening steel.

Electric furnaces may be placed in two classes; namely, those which use electrodes and those which have the heating chamber wound with platinum, nickel, or ferro-nickel wire, this being covered with some product, such as calcium aluminate, to protect it from the action of the silicates of the lining. Both of these furnaces are lined with some refractory material, but the latter is not practical for large furnaces, and is

used only for very small work or for experimental purposes. This style of furnace is shown in Fig. 105.

In Figs. 106 and 107 is shown an electric furnace in which a magnet is used to hold the work until it reaches the point of recalescence, where it becomes non-magnetic. The magnetic attraction is then broken and the work can drop into a bath for quenching. This will give it the greatest hardness it is possible to give the steel, and at the same time make the grain as fine and the molecules as cohesive as they can be made by heat treatment.

Electric furnaces similar to that shown in Fig. 108 are used to heat the liquid baths described above. In this furnace the metallic salt baths

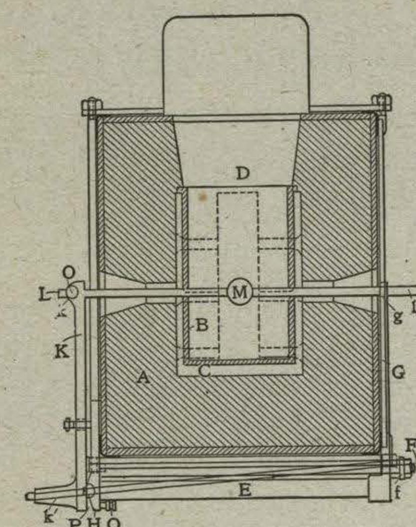


FIG. 107. — Section through muffle of magnetic furnace.

seem to be the most appropriate. These salts completely prevent contact between the white hot steel and the air during the heating, as well as during the passage to the quenching bath; the steel being uniformly covered with a protective coat of the salts during the passage of the steel from the furnace to the quenching bath. On immersion in the cooling liquid this coating immediately leaves it and the surface of the steel always appears smooth. The formation of scale is entirely prevented even after tempering.

The source of heat being inside the bath in this furnace the heat is evenly distributed and the temperature of the bath is uniform throughout every part of it. High temperatures are as readily obtained, and with as little watchfulness, as relatively low ones, which makes it easy to determine the temperatures desired in heat-treating the steel.

The pyrometer can be used successfully in measuring the temperature of the bath. The temperature of the bath is proportional to the current, and one careful determination with the pyrometer is enough to afterward judge the temperature of the bath entirely by the current.

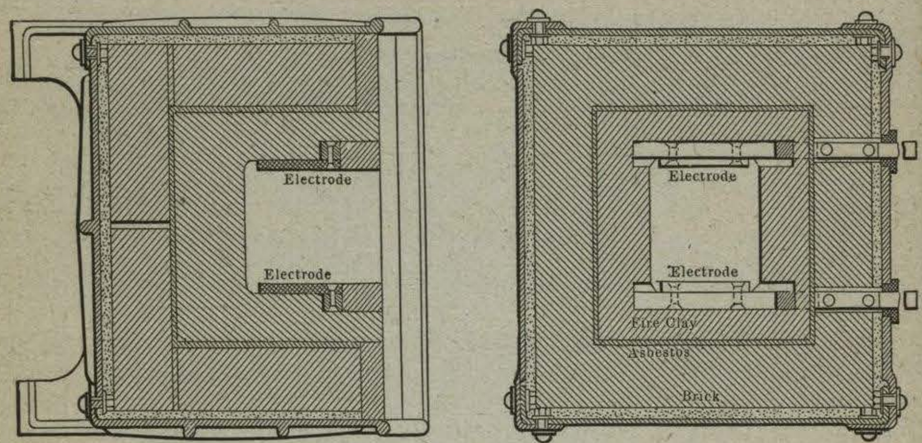


FIG. 108. — Sectional views of electrode furnace.

This style of furnace requires from 15 to 40 minutes to start, according to the size. The cold furnace can be started by passing the current through a piece of carbon until this becomes white hot and melts the surrounding salt, which then becomes conductive and in turn melts the whole mass. When finished using the current is shut off and the salt bath can be kept molten for a long time by putting a cover over it.

CHAPTER IX

ANNEALING STEEL

THEORY, METHODS, MATERIALS USED AND APPLICATION

IF the best results are desired from steel, after it has been rolled, forged, pressed, cast, or put into workable shapes in any other way, it should be annealed before any other work is done upon it. This removes the internal strains that are set up in the metal, when working it into the desired shape for future operation, and also softens the steel. It can then be more economically machined with any kind of cutting tools, can be heat-treated in various ways without the danger of cracks forming, and will have greater strength and endurance when put to its intended use.

The annealing of steel consists in carrying it above the temperature at which its highest point of transformation occurs, and then allowing it to cool gradually. This point of transformation is that at which the steel becomes non-magnetic and its physical structure changes. If a pyrometer is used to indicate the temperature of the steel in heating or cooling, it will show a point at which the rapid change in temperature ceases for a time, and the recording chart will show a line nearly at right angles to that of the rise or fall curve. At this point all the molecules have become non-magnetic and a new crystal-size of grain is born. This refines any large or coarse crystals that may have been produced in the steel by former methods of heating or working. This change in structure releases any strains which may have been set up in the metal, and allows them to readjust themselves so that they are equalized throughout all parts of the piece.

This temperature of the point of transformation varies considerably in different steels. This is partly shown by Fig. 109, which was plotted from two recording pyrometer charts. Steels vary more widely than this, however, in their highest recalescent point; it being affected by the various ingredients that are alloyed with the metal.

Another operation, sometimes called annealing, is that of partially