temperatures that can be produced in it, so long as the material remains a solid. This is the case in the carborundum and graphite furnaces in which exceedingly high temperatures are generated. This seems to apply also to those resistance furnaces in which the heat is generated in a solid resistor, as for instance in a bed of coke or in blocks of carbon, and is then radiated to the material to be treated. In the latter case, however, the temperature of the furnace products must necessarily be considerably lower or else no heat would reach them, and the speed of heating depends on the rapidity at which the heat can be radiated across the intervening space.

When the material through which the current passes is a liquid in an open channel, there is a very decided limit to the temperature that can be produced, and it is sometimes a seriously low one. This is due to the fact that there is a limit to the current which can be passed through a horizontal open channel containing a liquid, for when the current reaches a certain amount, depending on the cross section and shape of the column and on the specific gravity of the liquid, the column is suddenly contracted by electromagnetic forces until it breaks the circuit; this produces rapid interruptions of the current, which prevent a further increase of current and are fatal to the operation of the furnace. This curious electromagnetic phenomenon was described by the writer some years ago and was named the "pinch phenomenon," by which it is now generally known.

Were it not for this phenomenon, the resistance furnace would approach the ideal in some respects for liquids because the heat is generated in the material itself.

In an endeavor to overcome this serious limit in liquid resistance furnaces imposed by this pinch effect, the writer has derived a form of furnace in which this obstructing force not only cannot sever the conductor, but is even made to produce a very valuable property, namely, rapid circulation of the liquid in the resistor and in the hearth. The principle is shown in Fig. 2.

FIG. 3.

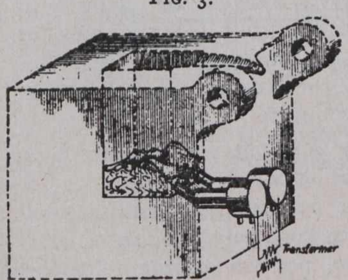
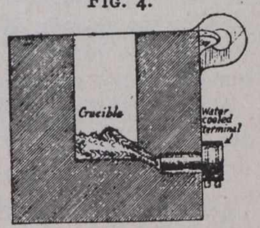


FIG. 4.



If a column of liquid conductor is confined in a vertical cylindrical hole in the bottom of the hearth, opening into the body of the liquid and closed at the bottom by means of the electrode, and if a current be then passed lengthwise through it, the effect of the pinch phenomenon will be to contract this column toward its central axis; the liquid will therefore tend to move radially from the circumference to the center, as shown in the small circle at the top of Fig. 2. These forces in turn, by hydraulic action, then produce an axial force which will force the liquid upward and out of the column, while at the same time the suction will draw in fresh liquid around the circumference, producing a circulation about as shown by the arrows in the lower figure. This peculiar phenomenon acts like a valveless pump, forcing the liquid upward and producing a small fountain.

These liquid columns or resistors, of which there are two, one for each electrode, are so proportioned that the whole heat for the furnace is generated in them, and the diameter and current are so proportioned that the pinching force is sufficient to produce the desired circulation. The freshly heated metal is forced to the top where, in the case of steel refining, it comes into intimate contact with the blanket of slag where the chemical action which constitutes the refining, takes place. The cooler material at the bottom flows into the resistor and is in turn heated and ejected. For three-phase current there are three resistors and electrodes.

Among the advantages claimed are: quick action, which means a large output per day and less standby losses per ton; a very large effective surface of contact with the slag, as this surface is continually being renewed, hence rapid refining action; rapid purification of suspended matter (slag, gases, oxides, etc.), as this is freed as the liquid reaches the top and deposits such matter in the slag; heating from the bottom, which is the more rational method.

Figs. 3 and 4 show it in its outlines only, a small, crude form of crucible tilting furnace of this type. The sketches are self explanatory. It is shown as tilting around the lip, so as to pour directly into moulds. It is started either with a small liquid charge, just enough to connect the ends of the electrodes when tilted; or by melting a small charge in it with an oil flame; or by a casting made to fit the bottom and then melted electrically; a small charge is always left in it and this can readily be melted with the current when it may have become frozen.

Figs. 5 and 6 show how these resistors or squirting tubes and their electrodes may be applied to the usual type of tilting furnace. Fig. 5 is a vertical section through one of the two electrodes and tubes; Fig. 6 shows a top view of a horizontal section at about the level of the doors.

Another form of liquid resistance furnace, which was originally intended to dispense entirely with the electrodes and their troubles, is known as the induction furnace. The

FIG. 5.

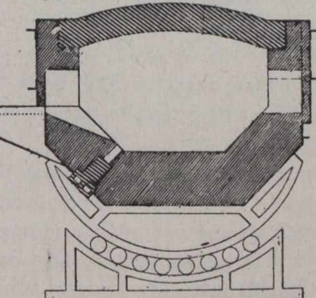
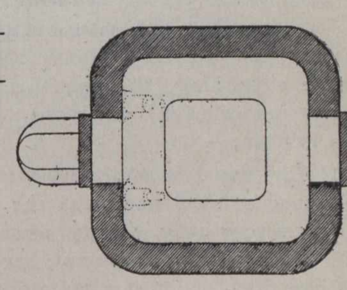


FIG. 6.



liquid is in a narrow circular channel which forms the secondary circuit of a transformer, hence the current is induced in it without the necessity of electrodes. It is so well known, having been invented about twenty-five years ago, that a further description need not be given here. (Numerous forms of it were shown among the lantern slides.) It has come into use in Germany chiefly for steel refining, and its introduction seems to be increasing; it is not yet in use to any extent in this country. It possesses the advantages which liquid resistor furnaces have over arc furnaces, as mentioned above. Its disadvantage, besides its cost, is that the frequency of the alternating current must be quite low or else the power factor becomes very low. This means larger machinery, though not necessarily more power. This disadvantage increases with the size of the furnace.

One of the chief features in the work of the engineer, in the designing of electric furnaces, is the reduction of the losses of heat, that is, the increase of the heat efficiency of