

## THE HERING "PINCH EFFECT" FURNACE.

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MR. F. W. HARBORD, VICE-PRESIDENT, *in the Chair.*)

The "pinch phenomenon," was first noticed in connection with electric furnaces by Mr. Carl Hering. It may be defined as a contraction of the cross-section of a liquid conductor through which current is passing, the contraction being due to an electromagnetic force which acts from the circumference to the centre. Under certain circumstances this contraction or pinching may be sufficient to completely rupture the circuit.

Mr. Hering discovered this phenomenon when working on a furnace in which it was a distinct disadvantage to have it. He therefore set to work to find out how it could be made useful, and the result has been the further discovery of a valveless electromagnetic pump. The principal patent claim (there are thirty-four claims) reads as follows:—

"For an electric furnace, a hearth for containing a mass of molten material, columns or channels connecting with said hearth and adapted to be filled with molten material in communication with said molten mass to constitute the furnace resistor, and electrodes in end-on communication with said columns or channels, the square of the current transmitted through said electrodes to the molten material in said columns or channels with relation to the cross-section of said columns or channels being great, whereby said mass of molten material is automatically stirred."

Fig. 1 represents the cross-section of two liquid conductors *AA* surrounded by non-conducting material, *BB*. The current enters and leaves by water-cooled electrodes *CC*, *D* being the transformer. Assuming for the moment that each liquid conductor is made up of a number of elemental conductors, these will be attracted together in accordance with the so-called law that "like currents attract." Circulation of the liquid is therefore set up, as shown by the arrows, by the liquid moving from the circumference to the centre. As one end of the hole is stopped up by the electrode any pressure set up can only be relieved by the liquid moving upwards as a fountain, and that is what actually happens.

It may be interesting to note that when in Sydney the writer saw a metal pipe which had been struck by lightning. The great inward pressure due to the current travelling along the pipe had completely collapsed it. It was not simply flattened, but had crinkled all round.\* Again, it may have only been an accident, but about nine years ago, when making calcium-carbide, the writer noticed that the blocks generally came out of the furnace smaller in section at the middle than at the ends.

\* See *Proc. of Royal Society of New South Wales*, vol. xxxix., p. 131 (1905).

Messrs. Leeds and Northrup make an ammeter for very large currents which works by means of the pinch phenomenon on a column of mercury.\*

The furnace may be a tilting one (as shown in Fig. 2), or there may be a tapping-hole just above the top of the resistor tubes. In any case, the resistor tubes must not be emptied, and sufficient metal must be left in the bottom of the furnace to connect them across.

As Fig. 2 is drawn to scale, it shows very clearly how small the two electrodes are, compared with the bulk of the furnace. It also shows how the electrodes are inclined, this being done in order to squirt the metal

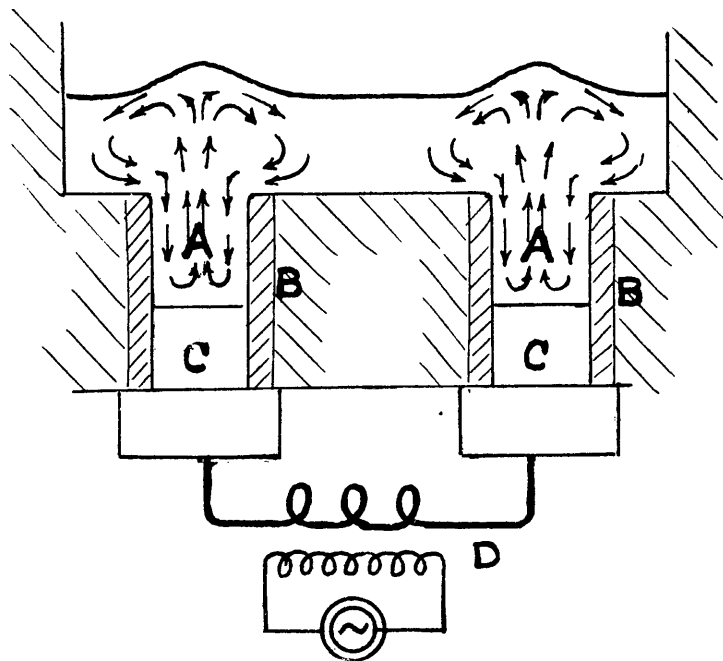


FIG. 1.

against the blanket of slag at an angle, to produce good circulation and to expose a larger surface of metal to the slag action.

*Stirring Action.*—Looking at the top of the charge, its appearance is somewhat similar to rapid boiling of water at two spots where heat is localised, but, of course, there is no noise. Also there are no bubbles unless the charge contains gases or volatile matter.

In some cases the agitation at the top of the metal charge is so great that the surface is inclined at 45 degrees. The suction down into the bottom of the resistance tubes is also considerable, and on one occasion air was drawn in through a leaky tap-hole with a whistling noise.

It should be noted that the heating is entirely effected at the bottom of the charge, and the circulation from there is in a natural direction upwards. Heat is thus transferred to the whole of the charge by a vigorous stirring, and not by mere conduction.

*Electrodes.*—The electrodes are usually made of the same metal that is

\* See *Physical Review*, June, 1907, also *Journal of American Electrochemical Society*, May, 1909.

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being melted. The sections of the electrodes and the current that passes are so proportioned that the ends of the electrodes are raised to a temperature as nearly as possible equal to the temperature of the molten charge.

The problem was to find conditions that give lowest heat losses, and this Mr. Carl Hering has found to be when the section and length of the electrode are such that the current heats the hot end of the electrode exactly to the furnace temperature. An electrode should be a good electrical conductor to reduce the loss of energy due to electrical resistance; on the other hand, good electrical conductors are as a rule also good heat conductors;

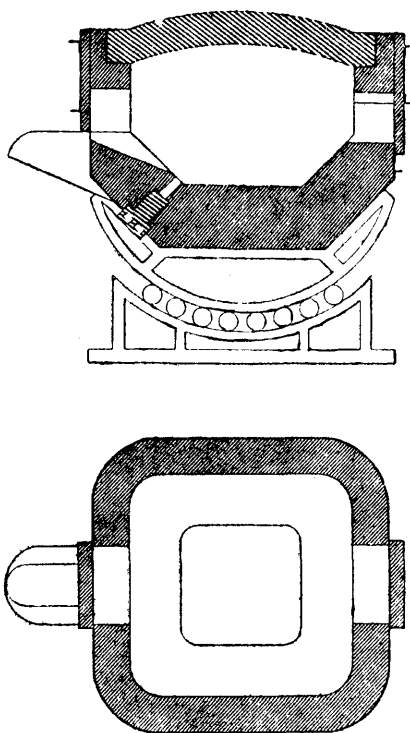


FIG. 2.—Tilting Furnace fitted with two "Pinch Effect" Electrodes.

they thus tend to conduct heat away from the inside of the furnace where the heat is wanted. Increasing the cross-section reduces the former loss but increases the latter, while increasing the length does the reverse. In the Hering furnace no heat is abstracted by the electrodes from the charge in the furnace, the entire loss of heat energy being thus only that portion generated in the electrodes. This is the condition under which the total loss of energy is lowest, for under any other conditions the total combined losses will be greater and the electrodes will either chill the furnace product or develop excessive heat where they pass through the walls.

Of the various materials for electrodes Mr. Hering's experience goes to show that metal electrodes are distinctly cheaper and more economical in energy. Copper is the best and iron nearly as good; gas carbon is the worst, graphite being only slightly better than gas carbon.

The electrodes being small and out of the way do not affect the size and

shape of the furnace, as is the case with other types of furnaces. Waste space in a furnace, and electrodes that are too large, diminish the efficiency very considerably.

*Refractory Lining.*—As the hottest metal flows up the centre of the resistor tube, the lining does not have to withstand the greatest heat. Again, there is very little eroding action due to friction on the wall, because the pinch effect tends to pull the metal away from the lining; indeed, it tends to form a vacuum there. This is just the opposite to some furnaces, where the circulation of the molten metal has given trouble by eroding the lining.

Alundum, which is made by fusing bauxite in the electric furnace, has been used for the lining. Magnesite powder is now employed; it is packed in whilst in plastic condition, and forms an extremely hard and smooth glossy surface after being heated.

*Action of Slag.*—The rapid circulation obtained in the furnace allows chemical changes to take place rapidly, and this means great economy in time. The maximum temperature at any point does not need to be much above the normal. In other furnaces where circulation is sluggish the temperatures in the charge vary a good deal. To allow for effective action of the slag it is important that the hottest metal should impinge directly on it. This is just exactly what takes place in the Hering furnace, for when it leaves the centre of the tube, the heated metal is forced up against the blanket of slag. Reaction with the slag is an essential factor in many processes, especially in steel-making.

*Current.*—Regarding the amount of current required, it may be mentioned that a furnace having resistor tubes only  $\frac{3}{4}$ -inch diameter and 4 inches deep, with metal about 2 inches deep over the tops of the tubes, took 3,000 amperes at 5 volts. Starting from cold, in a short while the metal was dull red, and when the current reached 5,000 amperes the squirting action was very active.

For such low voltages and large currents the homopolar direct-current dynamo is excellently suited, and as an efficient and mechanical design is now available, there is no reason why this type should not be used.

The pinch effect varies directly as the square of the current and inversely as the section of the conductor, Mr. Carl Hering's formula being as follows:—

$$P = 0.0000002248 \frac{C^2}{S};$$

where—

P = pounds per square inch;

S = square inches;

C = current in amperes.

*Power Factor.*—It should be noted that the furnace will work with either direct or alternating current, because the direction of flow of the liquid in the resistor tube is independent of the direction of the current. The pinch effect is also the same. Three-phase currents can be used, there being then three electrodes instead of two and each resistor one-third shorter for the same current. With alternating current the power factor can be very high indeed, practically unity, and in this respect the Hering furnace is sharply marked out from induction furnaces, which have a low power factor. In the latter the power factor may be 0.7 to 0.8 with 25 cycles, but only by using some extraneous and expensive device, such as an over-excited motor-generator. Again, the frequency can be anything that is used in everyday practice; it need not be specially low. As a consequence standard electrical machinery can be used for the Hering furnace.

*Self-regulation.*—One feature, which may turn out to be a very important one, is that if the electrode is made of the same material as the resistor the furnace tends to be self-regulating as to temperature. Thus, when the temperature increases, the electrodes automatically become longer and the resistor column therefore shorter, whereby less heat will be generated. The reverse also holds good. The place where the electrode ends, and the resistor column begins is that plane across which no heat flows; the heat generated above this point going out to the furnace, and the heat below going to the terminal. The plane will of course move automatically up or down.

The heat may be regulated with great nicety to suit the metallurgical requirements. This is not so in the arc furnace where the temperature is frequently much higher than is necessary when the melting is done in an induction furnace.

*Excessive Pinch Effect.*—One criticism that has been made is that the pinch effect may be too great and the continuity of the liquid conductor be broken. This, however, is only a matter of correct proportioning of the size of the resistor tube and the amount of current. It may be mentioned that Mr. Hering has several times allowed the metal in the resistor tubes to cool and harden overnight, and then found that he could start up next day from the cold state. This showed that the metal had not broken apart in the shrinking.

Some metals pinch off more readily than others. For example, in the induction furnace, aluminium, because it is light, pinches off with a current only a little higher than that required to melt it. But this only means that greater care must be exercised in proportioning the resistors and depth of metal in the Hering surface.

*Large versus Small Furnaces.*—It is interesting to note that some inventions and developments which work well on a small scale, will not do at all on a large scale. On the other hand, other inventions give the best results on a large scale. In this respect the Hering furnace is on the right side, as it promises to give best results for large furnaces, because the resistor tubes can then be shorter and of large diameter. In furnaces where the resistor tubes are of small diameter, a slight increase in current may pinch off the column, but in furnaces with larger columns there is not that risk. Indeed, the pinching pressures may be enormous without danger of discontinuity.

*Melting Non-conductors.*—But it may be asked, how are materials which when melted are non-conductors, to be dealt with? The answer is, by means of a bath of suitable metal kept molten in the bottom of the furnace, e.g., glass, or whatever non-conductor it was required to melt, would be placed over the metal. The non-conductor does not enter the resistance tube.

Zinc and arsenic ores can be tackled in a similar way, and it is worthy of notice that it is not so easy to treat such materials in an arc furnace.

*Smelting Iron Ore.*—In his patent specification Mr. Hering makes the valuable suggestion of a double furnace for making steel direct from the ore. He proposes to dissolve carbon in the iron in one part of the furnace and the oxide in another. The carbon-monoxide gas given off can also be burned to pre-heat the ore, thus making use of the total energy of the carbon.

One feature which above all others will surely appeal to iron- and steel-makers is that the furnaces are very little if any different from those they have been accustomed to. In the past, electric-furnace working has been handicapped to some extent by the unusual, not to say complicated, designs which engineers have hitherto put forward. This objection cannot be brought against the Hering pinch-effect furnace.

So far as heat loss is concerned a section of a sphere gives the smallest

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area from which heat can be radiated. A square-shaped bath is next, and the rectangular shape a bad third. But the worst form of all is the long, winding, narrow channel of the induction furnace. Considered from the economy of heat point of view, nothing could be worse.