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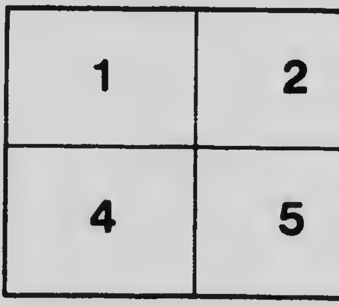

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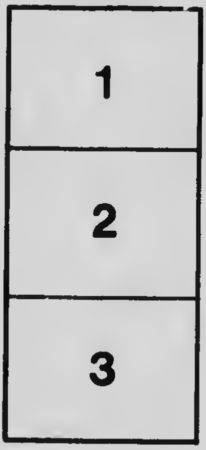

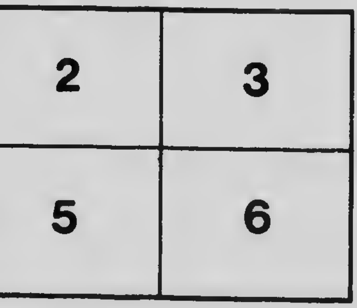

UNIVERSITY OF TORONTO STUDIES

PAPERS FROM THE CHEMICAL LABORATORIES

No. 116: SOME PHENOMENA OBSERVED IN ELECTRIC FURNACE ARCS, BY J. KELLEHER

(Reprinted from the Transactions of the American Electro-Chemical Society, 38th General Meeting)

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A paper presented at the Thirty-eighth General Meeting of the American Electrochemical Society, in Cleveland, September 30, 1920, President Landis in the Chair.

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SOME PHENOMENA OBSERVED IN ELECTRIC FURNACE ARCS.[1]

By J. Kelleher.[2]

As electric furnace loads increase, the regulation or maintenance of these loads at a uniform value becomes of great importance. There are at present many different automatic regulators, each having certain advantages. No matter how well any one of these regulators is adjusted, much is still to be desired. To those who have much to do with furnace regulation it soon becomes evident that the movement of the carbons or electrodes is not the only factor tending to cause variations of load in an arc furnace. It will be observed that in large ferro-alloy furnaces, and especially those furnaces where the charge consists of second-class conductors, the movement of the electrodes has to be considerably slower than in a steel furnace, for example, to prevent hunting.

Another peculiarity is often found in three-phase furnace work: Although the current flowing to the furnace is apparently constant, the regulators often act upon the electrodes, unbalancing the load. The Thury regulator, which moves the electrodes through a small distance at regular intervals of time, has, as the load of the furnace approaches the normal, a peculiar hesitating action; that is the intervals of time between the movements of the electrodes become greater, as if the regulator waited for the furnace to reach the normal load without further assistance. This peculiar action led to the theory of a furnace "time element."

By "time element" is meant that in a certain furnace, if the electrode is moved through unit distance, it will take a certain length of time for the current to become stable. This length of time may vary for different materials, temperatures, etc.

In order to study the time element, a number of experiments were made in the electrochemical laboratories of the University

[1] Manuscript received August 21, 1920.

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of Toronto and the FitzGerald Laboratories, Niagara Falls, N. Y., to ascertain if this time element really existed and, if so, how it was affected by material, temperature, etc.

During the winter of 1919-1920, at the University of Toronto, preliminary experiments were carried out on a Siemens single-electrode furnace employing direct current, the main object of these experiments being to determine the effect of slags of different compositions upon the current variation caused by a given movement of the electrode. The average power used in the furnace was 20 kw., and the electrodes ranged from 2 inches (5.1 cm.) to 4 inches (10 cm.) in diameter, both graphite and carbon

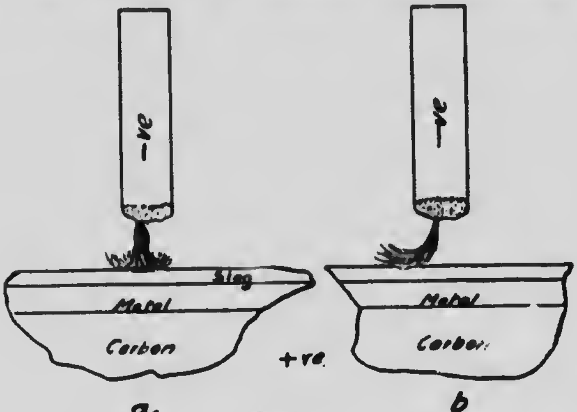

FIG. 1.

being used. Due, however, to the difficulty of maintaining constant potential across the furnace terminals, the results were rather confusing, and perhaps even untrustworthy. It was during these experiments that certain phenomena were observed which appear to be worth recording at this time, although the work planned has not been completed.

A bath of iron-nickel alloy covered by an acid calcium silicate slag was melted in the furnace. To observe the arc under these various conditions the following arrangement was employed: An opening was made in the front wall of the furnace. The opening was then covered by a piece of sheet iron in which a pin-hole had been drilled. The light emerging from the opening was allowed to fall on a ground glass screen, which was moved backward and forward until a clear inverted image of the arc was obtained, thus permitting sketches and even photographs of the arc to be made. A few of the sketches made are shown in diagram form. Fig. 1, *a* and *b*, represents what will be called a normal arc, that is, one where the movable electrode is the negative pole. The flame apparently flowed from the electrode to the slag, depressing the slag and flaring out to all sides, as in the case of diagram *a*, Fig. 1, or to one side in the case of *b*, Fig. 1. An arc length of about 3 inches ((7.6 cm.) could easily be maintained. Under these circumstances the arc was silent.

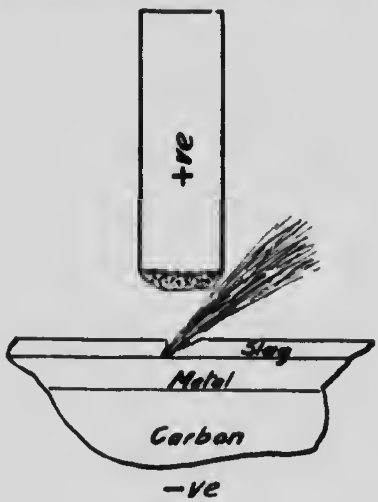

FIG. 2.

Fig. 2 represents what occurs as soon as the polarity of the furnace is changed. A very unstable arc appeared. This arc started below the surface of the slag, the flame moving away from the slag surface and projecting particles of slag into the air with considerable force. The length of this arc could barely be maintained at a greater length than 1 inch (2.54 cm.). The noise of the arc was loud and spluttering.

It had been noticed that if, with a normal arc such as *a* and *b*, Fig. 1, large currents were allowed to flow, the arc became noisy and had a tendency to quench itself, even at comparatively short lengths. What actually happened is seen in Fig. 3. Two distinct arcs were formed, as shown at *c*, Fig. 3. One of these arcs was normal, as shown in Fig. 1; the second arc was formed as in Fig. 2. As long as these arcs remained separate, a good arc length could be maintained. Heavy brown fumes were observed under these conditions.

Should the two arcs come in contact with each other, a very loud noise is at once produced. The arcs often take the form as shown in *d*, Fig. 3, blowing each other out to one side to such a distance that the arc becomes ruptured. At other times they appear like jets of water meeting in midair, splashing and playing out into a fan-shaped mass of flame.

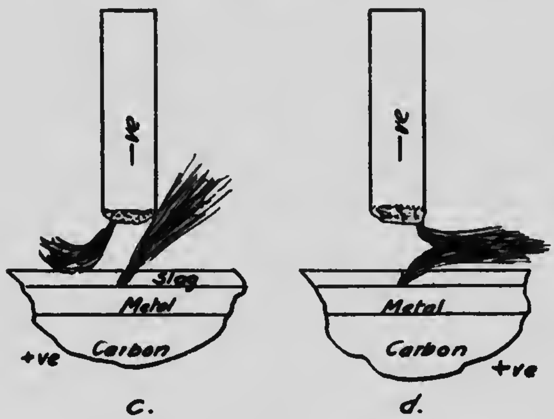

Fig. 3.

The attempts made to obtain photographs of these phenomena were not very successful, due to the rapid movement of the arcs.

During the spring of 1920 a certain amount of work was done at the FitzGerald Laboratories. The main object of these experiments was to study the effect of automatic regulation on the furnace currents.

A single-electrode Siemens type furnace was employed, in which a charge of scrap iron was melted, an acid calcium silicate slag being used. The moving electrode was of graphite, 6 inches (15.2 cm.) in diameter, and the furnace was run at a normal load of 60 kw.

An oscillograph was connected to the bus bars leading to the furnace in such manner as to obtain sufficient potential to operate the vibrator.

Both G. E. and Thury automatic current regulators were employed, and numerous films taken at slow speed when the regulators were operating both to lower and raise the electrodes.

Numerous films were taken to obtain the wave form, and apparently at certain periods of operation a set of distortions covering a certain number of waves occurs at regular intervals of time. Hunting, which has been a great fault of automatic regulation, occurred during several of the runs.

Using the method as described above for projecting the arc on a screen explained hunting in this case to a certain extent. The "arc" normally consisted of a set of small arcs around the periphery of the electrode. These small arcs surrounded a central mass of flame apparently without any special form. The small arcs had the same general shape as a direct current arc between electrode and slag, the movable electrode being the negative pole.

When the electrode was close to the slag a heavy individual arc appeared on the inner edge of the electrode. By inner edge is meant that edge on the inside of the current-conducting loop formed by the bus bars, furnace terminals, electrode, arc and bath.

The results of numerous observations might be summarized as follows: A disturbance takes place in the furnace running on normal load with an arc as already described when the electrode is near the slag surface, tending to increase the current. The regulator immediately starts to raise the electrode. The large arc maintains its original shape until the length becomes so great that it is ruptured. Immediately all the lesser arcs move away to the outer edge of the electrode, leaving about 75 percent of the surface of the electrode end bare. This causes a rapid and large decrease in the current flowing, and the regulator commences to lower the electrode.

These arcs do not spread across the surface of the electrode until the surface of the slag is almost reached. They then suddenly spread over the whole electrode surface, causing a sudden and large increase in current, and the whole cycle of events is repeated.

In a case like this the regulator is hardly to blame for hunting.

Sometimes this hunting lasts for a period of three to five minutes, and ceases as abruptly as it commences.

Provision is being made for conducting further experiments during the coming winter, by means of the arc projections and oscillograms, to obtain a closer and more intimate knowledge of hunting and the general behavior of the arcs in electric furnaces.

The wave form and arc image will be simultaneously projected on the same screen, and "movies" of the two will be taken, so that the arc form will be seen at the same time as the wave when the pictures are projected in the usual manner.