Continuous Temperature Measurement of Molten Steel

A PROGRESS REPORT ON A CURRENT DEVELOPMENT

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Following the development of rapid methods of steel analysis the need for greater control of bath temperature has become important, particularly in melting shops using oxygen lancing techniques. In arc furnaces there is also the opportunity of using the temperature to control the power input during refining. This article describes the development of a water-cooled thermocouple probe for continuous immersion.

One of the most important variables that the steel melter has to control is temperature. For the best quality and yield of a particular steel there is an optimum tapping temperature, but to arrive at the correct temperature at the same time as the tapping analysis is achieved requires more control than can be given by using a standard immersion thermocouple from time to time throughout the cast. Either many immersions must be made or a holder must be designed to maintain the couple in the bath for prolonged periods (1).

In addition, with the arc furnace it is possible to channel information on metal temperature to a power input control device and thus make considerable savings in power and time as has been shown by the use of Automatic Power Input Control (A.P.I.C.) (2). At present A.P.I.C. is used to control the melting down period of arc furnaces, but the possibility of a continuous metal temperature gives the opportunity of using this technique throughout refining. A scheme is under discussion at Steel Peech and Tozer to use the metal temperature on each furnace as one of the variables in a scheme for maximum power demand control using a computer. This scheme would cover the whole of the new SPEAR melting shop.

The Couple

In the original work in a 120-ton open hearth furnace a normal platinum: 13 per cent rhodium-platinum couple was used. It was soon found, however, that after a prolonged immersion—say thirty minutes—the couple was drifting off calibration. Check dips were made in the furnace as close to the test probe as possible but considerable temperature differences were detected. It was assumed that a great deal of this was due to rhodium migration. To overcome this difficulty, a 5 per cent rhodium-platinum: 20 per cent rhodium-platinum couple was used with much greater success. Variations of only 2 to 3°C are now recorded at 1700°C after 20 minutes immersion. This instrument immediately showed how important it is to rabble the bath well before taking a dip, and how often it is necessary to check the calibration of the recorder. For experimental purposes, and especially to measure temperature while oxygen lancing is in progress, a probe has been made up, mounting a standard thermocouple and an iridium: 40 per cent iridium-rhodium couple side by side in the protective covering. Success with this couple has previously been reported in an expendable cartridge for rapid immersion at 1960°C (3). These high temperature cartridges are now being made by the Amalgams Company of Sheffield, and if continuous temperature records can be made at this temperature, they will be of great value.

The Sheath

The couple is protected by a cermet sheath of molybdenum and alumina. This has high thermal conductivity and may be plunged directly into the steel. This sheath has excellent resistance to thermal shock, but is slowly attacked by slags high in iron oxide. The sheath analysis has been modified, but is about 50 per cent alumina, 50 per cent molybdenum, with a pure alumina lining. The lining is a protection to the thermocouple from contamination that would otherwise be important owing to the long periods at high temperature. For protection from oxidation by the iron oxide in the steel various coatings have been tried on the sheath, the general principle being that a thick layer is not needed but only sufficient to stop the molybdenum from oxidising. The material must also not react with alumina or molybdenum, as the working temperature at which they are in contact can be 1700°C or even higher. Alumina based cements are therefore the obvious choice.

Much work still remains to be done on the development of cermet materials for high temperature in the steel industry.

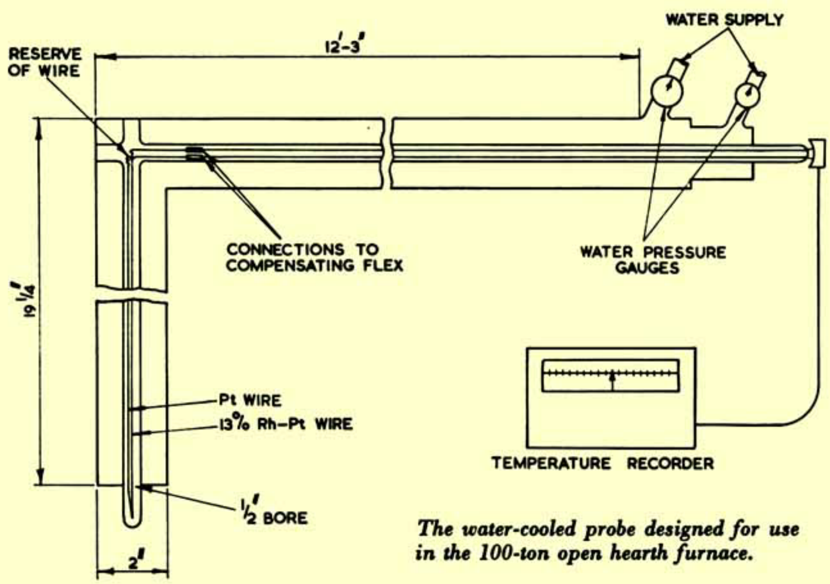
The Water-Cooled Probe

The probe used in the open-hearth furnace, shown below, was mounted on a trolley and inserted through an end door of the furnace. For regular use this would become a straight lance mounted through the back wall; it would thus be out of the way of normal furnace operation.

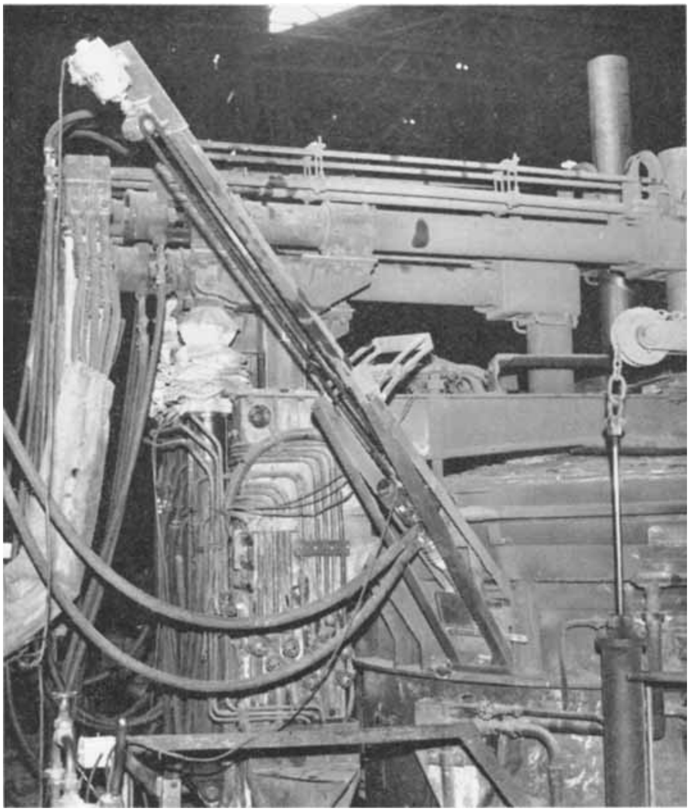
Construction of lance support equipment on the side of an eight-ton arc furnace is shown in the photograph over page. The water-cooled probe is straight and slides through a five-inch hole into the furnace.

Use in the Open Hearth Furnace

The continuous immersion couple was originally developed in an open hearth furnace, where prolonged immersion times were obtained. The technique is now available for regular use in an open hearth as a working proposition.



The water-cooled probe designed for use in the 100-ton open hearth furnace.



The water-cooled probe installed in an arc furnace. Entry and withdrawal, governed by electric motor, are effected through a 5-inch diameter hole pre-cast in one of the dolomite blocks used for lining the side wall of the furnace

The circumstances that stimulated its development originated from the use of oxygen lances in the open hearth furnaces and from the introduction of modern methods of analysis. In many melting shops the final analysis of the bath sample takes fifteen to twenty minutes and during this period it is usual to adjust the metal temperature to the correct tapping level. Now with the possibility of obtaining an accurate result in less than five minutes, the furnace may be delayed tapping because the temperature is not correct. If the temperature of the metal is known continuously, the melter has a better chance of achieving correct metal analysis and temperature together. In these days of automatic controls it would be quite possible to use the information from the probe to control the fuel input to the furnace. Something similar is already done in many works by controlling the fuel input from the roof radiation pyrometer.

Above all, irrespective of the steelmaking method, a continuous knowledge of the steel temperature will increase our understanding of the steelmaking reactions.

Use in the Arc Furnace

Work in the open hearth furnace proved that such a technique was practical, and the initial task in the arc furnace was to make a probe that would stay in the furnace for any required length of time and give an accurate reading of metal temperature. It was also necessary to find a position of entry to the furnace that did not obstruct normal furnace working. This last feature meant a new hole being cut in the side wall, and as pre-cast dolomite blocks are being used, this has meant a hole being left in the block by the makers especially for this work.

An 8-ton arc furnace was used for the first trials. Initial dips were made on reducing slags, these being considered less likely to attack the sheath and also providing opportunities for high temperature. Lance coating techniques have had to be evolved to enable the lance to be freely withdrawn from the furnace and coatings have also been used on the sheath to prolong their life. This was especially necessary when immersion commenced on oxidising slags. This has proved successful, although immersion throughout oxygen lancing has not been tried very often.

In a routine operation the probe will be introduced to the furnace soon after clear melt, and removed for lancing and slagging off. The lance will then be reintroduced when the reducing slag has been made up, and not withdrawn until tap. The melter will know throughout the cast the temperature of the steel and at the end the sheath should be perfectly satisfactory for a further cast.

The current work is based on the iridium: iridium-rhodium thermocouple and its development for high temperature work. Arrangements are being made to use this technique on the new 120-ton arc furnaces at Steel Peech and Tozer, where considerably longer immersion times will result. It will also be possible to use the temperature of the steel to control power input to the furnace.

Acknowledgements

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References

1 J. D. Sharp .. .. Continuous Temperature Measurements of Liquid Steel. *Iron and Steel*, 1962, Dec.

2 J. Ravenscroft .. .. Programming and Automatic Control of Electric Arc Furnaces. *Iron and Coal Trades Rev.*, 1960, 955

3 J. A. Stevenson .. .. Temperature Measurement with the Expendable Immersion Thermocouple. *Platinum Metals Rev.* 1963, 7, (1), 6.

Polarisation of Platinum Electrodes

IMPEDANCE IN CHLORINE-CHLORIDE SYSTEMS

The reactions at platinum electrodes in aqueous solutions of halides when an alternating potential is imposed are complex and have been a continuing source of interest for many years to J. Llopis and his collaborators at the Instituto de Química Física "Rocasolano" in Madrid.

In their most recent paper (*Electrochemica Acta*, 1963, **8**, 163–174), Llopis and M. Vázquez report the results of a study of the changes in electrode impedance in aqueous solutions prepared from mixtures of 0.5 M perchloric acid saturated with chlorine, 0.5 M perchloric acid, and hydrochloric acid. The working electrodes were platinum wires carefully arranged in the axis of a cylindrical ancillary electrode of platinised platinum to ensure regular distribution of the current flow.

Measurements of impedance were made of a special hermetically-closed cell having a very small gas volume at frequencies ranging from 20 to 20,000 cycles/sec and the results were analysed in an attempt to determine which of a series of equivalent resistance-capacity networks (the components of which are shown to correspond to different types of electrode reactions) best approximated to the observed results.

One clear conclusion was that in the system Cl_2/Cl^- surface oxidation of the platinum electrode hinders establishment of the equilibrium potential. It is still not clear, however, whether this effect is due simply to loss of active adsorption sites through the blocking of part of the surface by oxidation, or whether the values of the free energy barriers which control the electron-transfer process at the electrode interface are changed.

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