Rapid Determination of Carbon in Steel-Making

AN EXPENDABLE PLATINUM THERMOCOUPLE CARTRIDGE

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Carbon content is the controlling factor in operating a steel-making furnace, and fast and accurate carbon determinations can yield fuel and time savings that lower production costs. This article describes an expendable device incorporating a platinum:rhodium-platinum thermocouple which gives carbon contents extremely rapidly by thermal arrest point determination.

The steel-making process at all stages is governed almost entirely by the carbon content of the steel, and a rapid method of analysis for carbon is, therefore, essential to the efficiency of the process in terms of fuel consumption and time. A recently introduced method of fast carbon analysis is based on the measurement of the liquidus temperature of molten steels by means of an expendable cartridge containing a platinum : rhodium-platinum thermocouple. All the alloying constituents of a steel or cast iron affect the temperature at which the liquidus phase change occurs, but the element which has the greatest effect on this temperature is carbon.

Liquidus temperatures of molten metals can conveniently be measured by the use of thermocouples which have junctions of low thermal capacity and therefore give rapid response to temperature change. As a method of analysis this has been used for some time in cast iron founding (1), where the tolerance on carbon content is less critical and the process less dependent on an accurate knowledge of the level of this element. Steel-making normally involves carbon contents up to 0.6 per cent, and the tolerance on carbon determinations must be of the order of ±0.01 to 0.02 per cent. In terms of the change of liquidus temperature this tolerance requires that any temperature measuring system used must read to an accuracy of ±1°C over the range 1450 to 1550°C.

Fig. 1 The Leeds & Northrup Tectip S cartridge for the rapid determination of carbon in liquid steel. The platinum: rhodium-platinum thermocouple can be seen through the transparent quartz tube fitted into the bottom of the sand mould

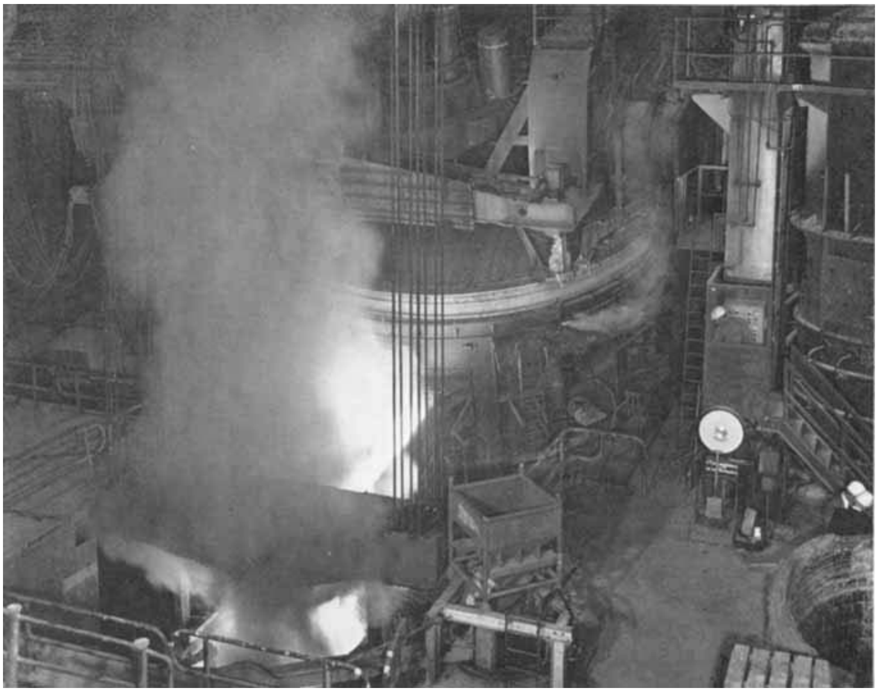

Fig. 2 After a lengthy evaluation of the expendable cartridge technique in the electric arc furnaces at Steel, Peech & Tozer three sets of equipment have been installed and substantial time savings have been made in routine working

The need for such extreme accuracy in temperature determination has, until recently, precluded the use of thermal arrest measurements as a means of analysing for carbon in steel. However, it is now possible to obtain thermocouples of platinum against 10 or 13 per cent rhodium-platinum that can provide temperature measurement to within $\pm 0.5°C$ in this temperature range. This improved accuracy has led to the introduction by Leeds & Northrup Ltd of a procedure for quick carbon analysis by the use of an expendable cartridge.

The Expendable Cartridge

The cartridge, known as the 'Tectip S', consists basically of an expendable sand mould A thermocouple, approximately 2 inches long, made from platinum and 10 per cent rhodium-platinum wires 0.005 inch in diameter, is first spot-welded together at the hot junction. This thermocouple is protected by a fused quartz U tube cemented inside the sand mould, which has a capacity of 4 to 5 cubic inches. The platinum and 10 per cent rhodium-platinum wires are joined to copper-nickel and copper compensating leads of larger diameter which emerge from the base of the sand mould to form contact points. The cartridge is shown in Fig. 1, in which the thermocouple can be seen through the transparent quartz tube fitted into the bottom of the mould. This unit is expendable and inexpensive; it is used for one thermal arrest point determination only.

The cartridge is plugged into a permanent stand, shown in Fig. 3, from which compensating lead cable runs to a rapid response recorder, of the type shown in Fig. 4, calibrated in 0.5°C intervals over the range of interest. The narrow range of chartered temperature is necessary to achieve maximum sensitivity to carbon content, and the recorder must have a high chart speed, in the region of 4 inches per minute.

In order to take a reading, molten steel is

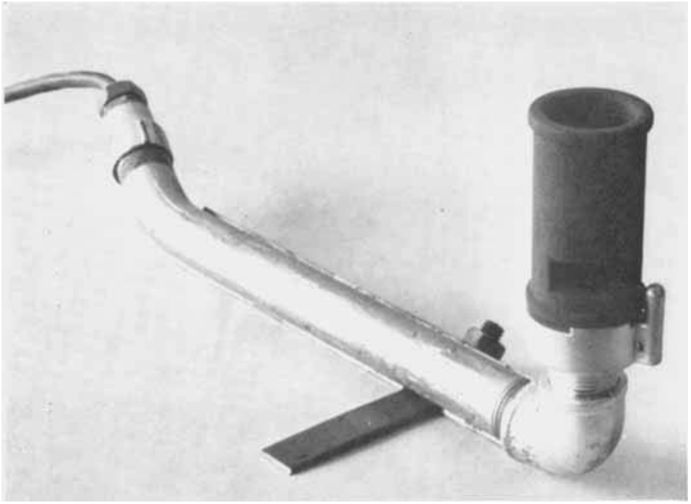

Fig. 3 In order to make a determination the cartridge is mounted in a metal stand to enable the thermocouple to make contact with the compensating cable linking it to a temperature recorder

spooned from the bath, deoxidised with aluminium wire, and poured into the mould, as shown in Fig. 5. A certain skill is required in pouring the sample to ensure that the steel is at just the right temperature to give a thermal arrest point in 20 seconds, since if the pouring temperature is too high or too low freak curves may result. The thermal arrest temperature can then be converted to a carbon content by reference to the appropriate calibration graph.

Apart from carbon, the other alloying constituents in steel also depress the liquidus temperature, although to a lesser degree. Each constituent affects the liquidus temperature by an amount proportional to its content and independent of the presence of other alloying constituents. This effect of the alloying constituents is compensated for by prior knowledge of the level of each of these constituents. It is not necessary to know the levels of these elements accurately, because their affect on the liquidus is much less than that of carbon, and compensation can be made by the use, for example, of the depression values given by Roeser & Wensel of the National Bureau of Standards (2).

Field trials of the Tectip S for determining

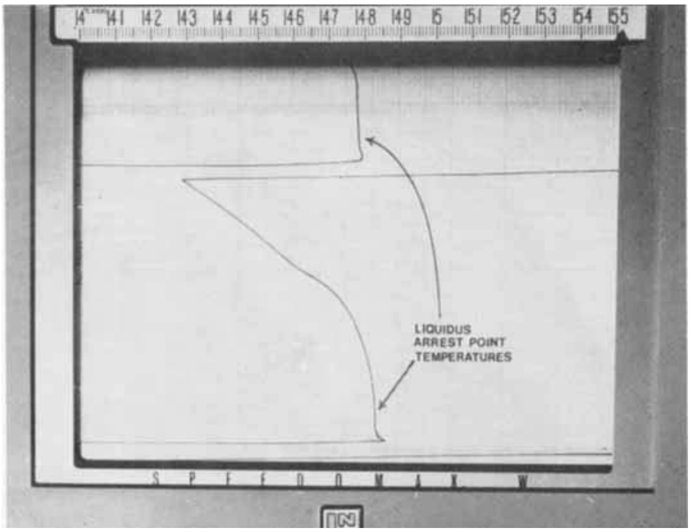

Fig. 4 A rapid response type of recorder is used, calibrated over as narrow a temperature range as possible to give maximum sensitivity and to ensure coverage of the carbon range

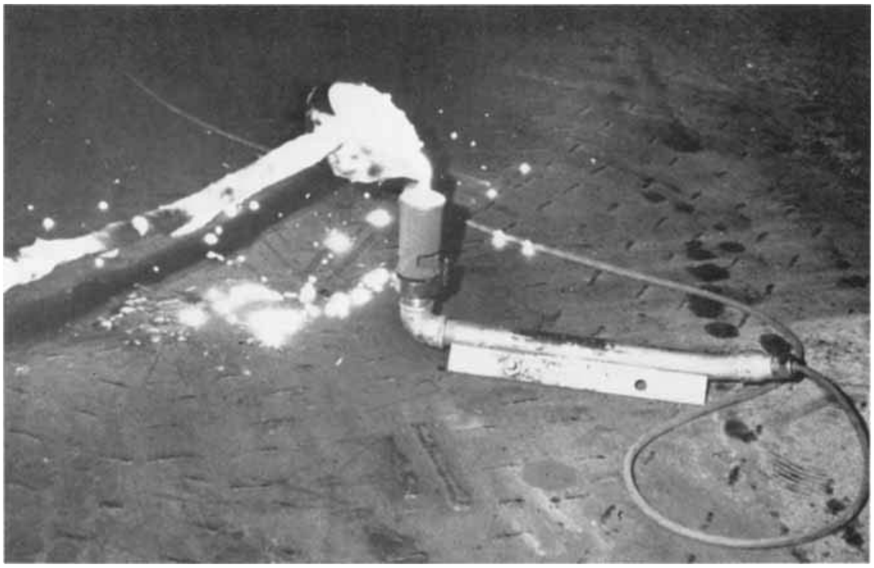

Fig. 5 In order to take a reading a sample of molten steel is poured into the Tectip cartridge. The thermal arrest point is recorded within twenty seconds, and the carbon content can then be read from a conversion graph fully corrected for the effects of other elements

the carbon level at all stages of the steel-making process have recently been described by P. B. Dunnill and H. Atkinson (3), of Steel, Peech & Tozer's Rotherham Works. They found that 96 per cent of results were within ±0.03 per cent carbon and 87 per cent within ±0.02 per cent carbon when compared with conventional induction heating rapid analyser results.

Comparison with Conventional Techniques

Other methods of carbon analysis at Steel, Peech & Tozer involve a time lag of five minutes between sampling and availability of results, whereas the Tectip S provides an answer in thirty seconds. Because it is necessary to know the carbon level at a number of stages during steel-making, the total time saved in this plant was 10 to 15 minutes per cast. This time-saving alone justified the introduction of the Tectip S as a regular means of melt control.

The apparatus is well suited to shop floor operation by relatively unskilled personnel. The total cost of the equipment differs by orders of magnitude from that of the direct reading instruments, which have usually to be installed away from the melting shop and must be operated by more highly skilled workers. The accuracy of the method is slightly less than that of the more sophisticated methods, but, as a procedure complementary to these more accurate methods, the Tectip undoubtedly offers the steel maker a means of reducing his production costs.

In the United States the Tectip method is now being used as a routine production tool, and some thirty steel works are making a total of about 100,000 Tectip carbon determinations per month. Among the users are Bethlehem Steel Corporation, Republic Steel Corporation, Kaisers and Colorado Fuel and Iron.

In the United Kingdom ten companies are carrying out development trials and some are using the method in place of other carbon determination methods for intermediate sampling of heats; a few have used it on tapping samples.

References

1 *Platinum Metals Rev.*, 1962, **6**, 20
2 W. F. Roeser and H. T. Wensel, *J. Res. N.B.S.*, 1941, **26**, (April), 273
3 *Steel Times*, 1968, **196**, (January), 13