NRC aids Canadian company — Electrochemical oxygen sensor

Research being conducted by a team of scientists at the University of Toronto is helping a Canadian manufacturing company involved in the production of electrochemical oxygen probes, devices which play a vital part in the manufacture of steel. Operating under a Special Project Grant of $147,000 from the National Research Council of Canada, the team, headed by Dr. C.B. Alcock, Chairman of the University's Department of Metallurgy and Materials Science, steadily has been devising improvements to the probe since early in 1971.

The work already has solved many of the problems which beset the devices since they were first introduced on an industrial scale in 1970. The University researchers are working in collaboration with Leigh Instruments Limited, and its member manufacturing company, Quality Hermetics Limited, of Toronto. Major Canadian companies who use the probes include the Steel Company of Canada Limited (Stelco), Dominion Foundries and Steel Limited (Dofasco) and Algoma Steel. Japanese steel manufacturers also have displayed great interest in the probes.

In order to understand and appreciate the importance of electrochemical oxygen probes, one must understand the basic processes which are involved in the production of steel. First, the molten pig iron which is produced in blast furnaces is poured into a basic oxygen furnace where oxygen is introduced through a lance to oxidize the carbon, along with the other elements contained in the pig iron, such as silicon, manganese, sulphur and phosphorus. Pig iron contains about four per cent carbon which must generally be reduced to less than one per cent in the production of steel. At this stage, knowledge of the oxygen activity gives a reasonable indication of the carbon content. After the oxidation process, the steel has a high oxygen content which must be lowered prior to solidification, usually by the addition of metals such as elemental aluminum, silicon or manganese. The final oxygen content is important since, to a large extent, it controls the structure of the steel cast from the molten metal.

Much of the steel production used to be carried out in open-hearth furnaces, a process which took anywhere from eight to 12 hours. Oxygen content then was monitored by removing a sample of the liquid steel which was cooled and taken to a laboratory for analysis. This rather lengthy procedure is unsatisfactory for basic oxygen furnace steel production which requires only about 45 minutes for a 100-to 200-ton batch, and a means of rapidly determining the oxygen content of the liquid steel is essential. The electrochemical oxygen probe being studied at the University of Toronto is filling this need. After insertion into the liquid steel, the probe takes five to six seconds to achieve thermal equilibrium and then provides an accurate and stable reading of the oxygen content for a further four to five seconds.

Team member Dr. Tom Etsell says of the operation of the device: "An electrochemical probe works on the same principle as an ordinary dry cell, the only difference being that instead of two different chemicals at the electrodes, the same chemical is present but at two different pressures. This creates an EMF (electromotive force or voltage) which is directly proportional to the difference in oxygen activities at the electrodes. Therefore, when the EMF is measured and the oxygen activity at one electrode and the temperature are known, the oxygen activity at the other can be easily calculated."

"In essence, we are establishing two different oxygen levels at the ends of the ceramic electrolyte and measure this difference in the form of an electromotive force. We know what one level is, and we can calculate the other level from the measured voltage difference," says Dr. Susan Zador, another member of the research team.

Many oxygen probes have been introduced into small induction furnaces during an extensive testing program conducted by researchers at the University of Toronto. The tests have been carried out at the Ontario Research Foundation and also at the Department of Energy, Mines and Resources in Ottawa. • De nombreuses sondes à oxygène ont été introduites dans de petits fours à induction, selon les directives données par l'Université de Toronto, au cours d'un programme d'essais étendu. La "Ontario Research Foundation" et le Ministère de l'énergie, des mines et des ressources, à Ottawa, ont fait les essais.

The probe itself, in manufactured form, is several feet long so it can be dipped into the liquid steel at 1600 degrees Centigrade. The actual sensor consists of an oxygen concentration cell involving an oxide ceramic electrolyte and a reference electrode of known oxygen potential. This cell, the main component of the probe, includes a piece of Vycor glass fused onto a stabilized zirconia electrolyte pellet in the shape of a cylinder, 2.8 millimeters (0.11 inch) in diameter and five millimeters (0.197 inch) long. The end inside the Vycor tube contains a small hole into which a platinum bead welded to a platinum wire is pressed to form the lead wire for the reference electrode. The outer lead for the probe is an iron tube separated from the Vycor by a ceramic insulator insert, the circuit being completed through the liquid steel. The leads are simply connected to a potentiometer, from which the oxygen readings are obtained, and a recorder.

The probe has a life span in the liquid steel environment