

16th September, 1981.

METHOD FOR CONTROLLING SLOPPING AND PHOSPHOROUS CONTENT
OF THE B.O.F. STEEL MAKING PROCESS

In the B.O.F. process a method is proposed for adjusting oxygen lance positions and oxygen blowing pressure to achieve suitable phosphorous reduction in the melt without inducing slopping of the slag outside the vessel.

The method is based on the monitoring of electrical characteristics associated with the flame as it emerges from the vessel. In particular, with a direct electrical low resistive connection between the oxygen lance and the hood of the vessel (which is at earth potential), a particularly useful measurement is that of the electric current in the connective link.

The monitored electrical current derives primarily from the ionization in the turbulent flame surrounding the oxygen lance and extending to the hood (earth) of the vessel. The electrical signal fluctuations indicate to some extent the state of turbulence and ionization in the flame which in turn reflects the state of the decarbonization process, the dephosphorization process, the slopping potential of the slag, and the nature of the turbulence of the melt. With sufficient knowledge of these aspects of the steel making process, for the duration of a heat, together with available a priori information in the charge, the lance height and oxygen flow rate can be suitably adjusted throughout the heat to achieve the required steel specifications with virtual elimination of slopping and associated yield loss.

Specific claims about the method.

1. The measurement of the "short circuit" current between the lance and the hood (earth) can be achieved by measuring the voltage

across a linkage with a resistance of the order of 1 milliohm between the lance and the hood. This current can be of the order of tens of amps which flows primarily through the ionized flame between lance and hood (earth) where the voltages are generated. By measuring this particular current, second order electrical effects such as currents through the refractory to earth produced by contact potentials between melt and slag, lance and slag, melt and refractory, etc., are virtually eliminated from the measurement. This is so since the conductive pathways to earth, alternative to the ionized flame pathway, are relatively high in impedance - see Appendix.

Earlier related research and patents focussed on measurement of the "open-circuited" voltage between lance and earth and purported to measure voltage across the slag melt interface, see [1-3]. This measurement has been termed the lance e.m.f. even though no particular effort is suggested to insulate the lance completely from earth for such a measurement. Typically, resistances to earth of a lance may be orders of magnitude higher than suggested in our method.

2. The lance current signals can be characterised according to their sign and their fluctuations. The latter can be parameterized by their magnitude and "duty cycle". With a positive current and low duty cycle, achieved with soft blowing and high lance heights phosphorous is efficiently removed from the melt. This is termed Regime 1. With a positive current and high duty cycle, achieved with harder blowing, the predominant reaction is decarburization. This is termed Regime 2. Likewise with a negative current achieved with even harder blowing. This is termed Regime 3. Slopping of the slag and thus yield loss occurs in passing from Regimes 2 or 3 to 1 in all but the latter part of a hood. Such situations can be avoided by suitably increasing the hardness of the blow when indicated in the lance current signal patterns. Refinements

to the above control strategy are not detailed here.

The lance current slopping potential indication is distinct from that of earlier patents using the sign of lance emf signals in that it claims to more closely indicate the nature of the process. Experimentally it appears to be considerably more reliable, virtually eliminating slopping under a wide range of conditions and yet achieving steel specifications.

Originality

The measurement apparatus was first conceived and demonstrated by H.G. Kemlo of B.H.P. [4]. The method of recognition of current signal patterns so as to suitably control the B.O.F. also originated with K.G. Kemlo [4]. The interpretation of the signals in terms of the flame properties and thereby of the process behaviour was developed by Professor John Moore.

The ideas of both K.G. Kemlo and J. Moore were worked out in collaboration with Dr. Neil Molloy.

In earlier patent investigations, not sufficient novelty in the measurement set up of K.G. Kemlo was seen to justify a patent application. This indicates that the interpretation of the measurements as distinct from those in an earlier patent is not obvious to workers in the field. Also misleading to workers in the field are results on experimental furnaces which do not create the same flame conditions and high lance electrical current intensities as in the full scale version. Thus it is claimed here that the techniques, their application, their interpretation, and significance are sufficiently novel to warrant patenting.

The idea to measure electrical currents within the B.O.F. flame when the lance and hood are essentially short circuited, first originated with Professor J. Moore and Dr. N. Molloy on 12th September, 1981. This idea is distinct from the earlier patented idea [3] of measuring potential between lance and slag.

To establish a date for the claims reported in this preliminary patent note, we sign this report in the presence of two witnesses.




J.B. Moore.



N. Molloy.

16/10/81

Witnesses.



REFERENCES

- [1] S.P. Parinov, V.P. Loktionov and S.A. Dubrovskii, "Monitoring oxygen content in slag in controlling basic oxygen steel making", Investiya VUZ Chernaya Metallurgiya, Dec. 1978, (12), 144-148.
- [2] S.V. Kolpakov, V.P. Loktionov, S.V. Radilov, B.N. Kozheonikov, M.M. Kataev and A.M. Pozbivanov, "Author Certificate 502948 cl, S2155/30", Otkrytiya, Izobr, Prom. Obrax, L. Tov, Zneki, 1976, (6), 66.
- [3] C. Ya Zarvin et al., "EMF signal study of converter melting", Staleplavil'noe Proizvodstvo, 1975, pp. 84-90.
- [4] K.G. Kemlo, "Dynamic control of the B.O.F. using an electrical signal generated from the reactions occurring during the refining operation", B.H.P. Report PQC 16, Dec. 1978.

APPENDIX I

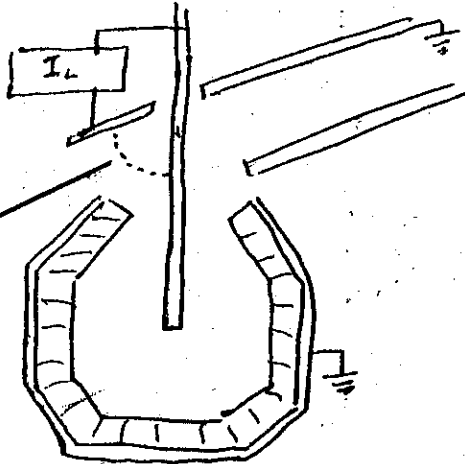
Two possible current loops.

1. Via Plasma to Hood

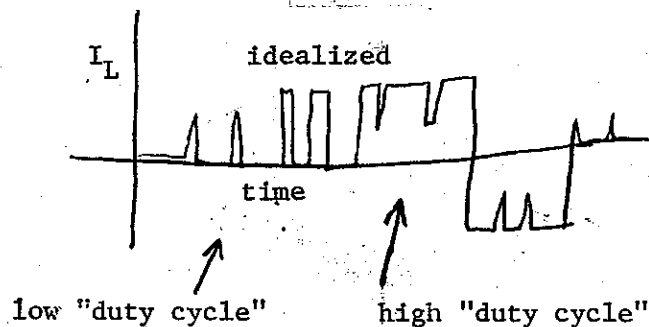
Current measurement 10's amps.

Flame voltage source with low internal resistance.

Not critically dependent on path length.



(milli ohms $.1 \rightarrow 25 \text{ m}\Omega$)



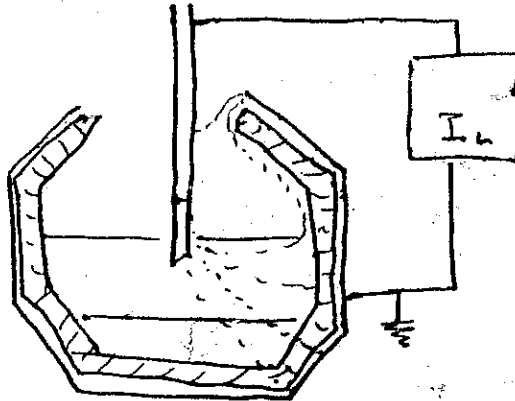
- (i) I_L depends on ionization level - chemi-ionization **
due to $2C + O_2 \rightarrow 2CO$

different from
Regimes 1, 2
and 3.

enhanced by Alkali seeding (K, Na,
thermionic C-O₂?
Thermal ionization (temp)
etc.

- (ii) turbulence - movement of large structure in flame.

2. Via Refractory to vessel shell



- I_L depends here on (i) conductivity of refractory. Suggest not high enough to carry 10's amps down to fractions of a volt.
- (ii) potentials at interfaces or within plasma/slag refractory.

APPENDIX II

Theory or conjectures.

Regimes 1 and 2

The flame is intermittent in its properties (conductivity due to ionization and current generation capacity). The intermittency is largely due to turbulence in the melt, chemical reactions, slag and flame. The flame is however, broadly speaking uniform at the mouth of the vessel and the electrode relative areas determine the sign of the electrical currents. The saturation currents to electrodes is proportional to area, so that when the effective area of hood is greater than that of the lance then the lance is positive with respect to the hood - attracting less electrons which are the most mobile of the charge carriers.

Regime 3

The flame is concentrated in the vicinity of the lance so that the lance effective area is now greater than that of the hood. The lance therefore is negative with respect to the hood, collecting more electrons.

The initial transients in lance current on ignition is due to flame front passages.

The negligible currents subsequently for a few minutes is due to the fact that Si oxidation takes place rather than C oxidation. The former is insufficient to achieve the chemi ionization necessary to achieve low flame conductivity and sufficient current generation in the lance.

The winding down of the decarbonization at the end of the blow signals reduced ionization within the flame.

At the slag rises in the vessel, the effective area of the lance is reduced so that its saturation current falls. Its continued fall

suggests slopping in the immediate future. This effect may be enhanced by reduced decarbonization giving less ionization in the flame.

When the lance current flow is negative and highly intermittent and slop occurs, one envisages slag flowing over the rim making electrical connections to the vessel rim, yet regime 3 is still there.