Discussion:
The mode of current transfer between electrode and slag in the submerged-arc furnace

by W. P. CHANNON, R. C. URQUHART, and D. D. HOWAT

J. MEINTJES*

I have read the paper with much interest, and I should like to make a few observations.

(1) The experimental work deals with resistance heating by an electrode immersed in a slag, and the conclusion is drawn that arcing resulting from electrode current density in excess of a critical value is undesirable, owing to decrease in power at a given voltage and owing to imbalance in rate of heating should an arc be struck at only one of the electrodes. These conclusions are applied to the submerged-arc furnace for the design of which it is noted that current density appears to be chosen so as to avoid arcing.

In submerged-arc furnaces for the production of, for example, ferroalloys and carbide, arcing from the tips of the submerged electrodes is the normal state of affairs, and current transfer takes place partially through these arcs and partially through the contact resistance between the charge and the higher parts of the electrodes. Heating imbalance will result from the cessation in contrast to the initiation of arcing at one or two of the electrodes. Arcing is absent usually only in abnormal circumstances such as during the baking of a green Soderberg electrode on low load when the furnace must necessarily be operated under conditions of extreme imbalance for extended periods.

Electrode current density is fixed from considerations of electrode consumption and possible breakage, power density, and peripheral resistance. Avoidance of arcing is not a factor in its choice.

(2) The authors omit the values of ϕ and E_m used in calculating, from the equation on p. 4, the theoretical current curve of Fig. 2 (d). Although ϕ can be estimated from Fig. 2 (c), I have not checked the calculations. Inspection of the curve as drawn gives a zero value for i at the end of the negative half-cycle at 0,02 s, whereas, on the positive half of the cycle, i at this time is still only approximately $-2{,}5$ A and reaches zero only at 0,0215 s. The curve will not be the smooth one depicted, but discontinuous. The anomaly results from the use of different data for calculations in the two half-cycles.

(3) Modification of the equation for current if it is to be applicable or, alternatively, critical re-examination of the experimental results is suggested when note is taken of the fact that the theoretically calculated i lags behind the voltage while the actual measured i leads the voltage. How this can happen is indeed puzzling, as it indicates that somehow there was introduced into the circuit a capacitance that more than compensated for the inductance present in the circuit during the measurements with low current density. Does the arc itself create the capacitance?

(4) Finally, I should like to point out that the increase in burden resistance resulting from the striking of an arc is an advantage in submerged-arc operation for the production of carbide and ferroalloys. It is true, of course, that at *constant* voltage power input will decrease but this is not important. By increasing the voltage, the same current as before can be passed and the increased resistance will give increased power dissipation at a higher power factor of

Power$=3\ I^2\ R$, where I and R are the phase amps and resistance.

For the same current, power increases with resistance.

$$\text{Cos } \alpha = \frac{R}{\sqrt{R^2+X^2}} = \frac{1}{\sqrt{1+\frac{X^2}{R^2}}},$$

where X is the phase reactance (constant), i.e., as R increases, $\frac{X^2}{R^2}$ decreases and cos α increases.

AUTHORS' REPLY

We thank Mr Meintjes for his critical analysis and helpful comments arising out of his study of our paper. Possibly we should emphasize at the outset that our experiments all related to the conditions in which the lower portion of the electrode was immersed in molten slag. We believe, however, that our results are also applicable, in a measure at least, to conventional submerged-arc furnace operation, although we accept that the application may be very slight in the case of processes that do not normally involve the production of slag, e.g. carbide and ferrosilicon production.

As indicated in our paper, considerable uncertainty still appears to exist about the predominant manner of heating in the submerged-arc furnace, some authorities such as Volkert and Frank believing that arc heating is predominant and others favouring the assumption of resistance heating. Persson goes as far as to say that 'although arcing may occur in the submerged-arc furnace the heating is mainly resistive'. We believe that our findings support the view that arcing should be eliminated as far as possible. Mr Meintjes agrees with the views of Volkert and Frank that arc heating is probably the predominant mechanism for power dissipation.

*Rand Carbide Limited.

In this connection, a comparison can be drawn between the conditions obtaining in the melting of steel scrap in an electric furnace and those obtaining in a ferro-alloy furnace and a furnace used for melting copper-nickel matte, where the slag resistances are of the order of 1 to 2 Ω/cm and 4 Ω/cm respectively. In the case of steel melting and refining, the charge has a very low resistance and heating is predominantly by arcing. At the Quebec Iron and Titanium Corporation, the smelting of titaniferous iron ore is done in open-arc conditions necessitated by the very low resistivity (about 0,01 Ω/cm) of the high-titania slag produced.

We readily admit that the curve predicted by the theoretical equation is not in exact agreement with the experimental results, but this is possibly due to changes in the electrical parameters arising from experimental factors over which we had no control. For this reason, the curve was drawn as a broken line and, like the trace measured during the experiments, is not meant to be continuous.

However, we feel that the theoretical equation does give a reasonable prediction of the circuit current in view of the fact that such parameters as the gap between the electrode and the slag, together with the atmosphere prevailing in this gap, have a profound effect on the arc and these parameters are by no means constant. We accept Mr Meintjes' suggestion that the arc in the circuit behaves as a capacitor in that it appears to cause the current to lead the voltage.

We had assumed that, under any given conditions of burden, a correctly designed furnace should be operated at its maximum voltage for maximum power utilization. Under these conditions, any increase in resistance must decrease the power dissipated. Mr Meintjes postulates that the increased resistance arising when the arc is struck may be counteracted by raising the voltage, so maintaining the current constant and thereby increasing the power dissipated. In addition, an ancillary benefit, as indicated by Mr Meintjes, is that the power factor is increased. Obviously this must be a question of the overall economics of the process.

Termination of membership

In accordance with By-Law 7.6.1. of the Constitution of the Institute, the names of the undermentioned members have been removed from the membership register.

Fellows

A. G. Raper, W. H. Wise.

Members

D. de W. Marais, C. R. S. Needes, P. K. Pech, K. A. Ullerstam.

Associates

J. de F. Agrella.

Graduates

P. J. Delaney, J. K. MacLean, J. Marais, D. A. Nolte, E. Pothas, D. J. Theron.

Students

G. K. H. Anderson, J. H. Ashton, H. J. Engelbrecht, J. W. Jordaan, W. K. Lawson, K. L. McDonald, K. J. Merz, C. Mills, M. A. Pascall, J. L. Pretorius, J. C. Roegiers, T. Schmoll, L. A. J. Skinner, C. M. Wintersteen.

Colloquium and General Meeting

A General Meeting and Colloquium on 'Heavy-medium separation and ore sorting' was held on 18th September, 1974, at 09h15, in Kelvin House, Johannesburg.

Dr R. E. Robinson (Vice President) was in the Chair.

The colloquium was attended by 200 delegates and was opened by the Vice President at 09h20.

Minutes

The minutes of the Special General Meeting and General Meeting held on 22nd May, 1974, as published in the August issue of the *Journal* were confirmed.

Obituaries

Mr K. Richardson, Fellow.

In memory of the deceased and in sympathy with the bereaved, the delegates rose and observed a few moments' silence.

Membership

The Vice President: I have much pleasure in announcing that the undermentioned candidates, whose names have been published in accordance with By-Law 5.2.2. have been elected to membership of the Institute in the following grades:

Members

H. H. Gielen, J. R. F. Leszczynski, G. J. Rees.

Associate Members

E. F. Dennis, D. G. Nicholson, J. H. Proctor.

Graduates

R. le Marchant, N. J. Pursell.

Associates

N. Mauer, J. A. McLernan, D. H. Stevenson, L. G. Ullyett.

Students

D. W. Butcher, K. Dewer, G. J. Dyason, N. F. Philpott, C. E. van der Bergh.

Transfers

To Member

A. J. Michau, J. C. van Rooyen.

To Graduate

M. E. Dingle.

I welcome the newly elected members to the Institute, and congratulate those who have been transferred to a higher grade.

General

The Vice President extended the gratitude of the Institute to Mr B. S. Dykhouse and to S.A. Cyanamid Ltd for their generosity in offering to sponsor the lunchtime refreshments, and to Hoechst (S.A.) Ltd for sponsoring a cocktail party for the delegates at the conclusion of the colloquium.

The meeting ended at 09h30.