ESTIMATION OF BYPASS CURRENT IN A BIPOLAR ELECTRODE STACK - MAGNESIUM BIPOLAR CELL

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ABSTRACT

A theoretical model based upon cell configuration (Resistive Network Model) is adopted for calculating the bypass current for a stack of bipolar electrodes used in molten salt electrolysis. A simplified bypass current calculation is also made by using experimentally obtained current and potential in the magnesium cells. The results obtained from both the models are compared and discussed paticularly for two different electrolyte compositions.

Key words: magnesium bipolar cell, by-pass current.

INTRODUCTION

It recent years, the light metals industries have shown increasing interest in using bipolar cells for fused salt electrolysis. The outstanding examples are the ALCOA aluminium chloride process cells [1] and the ALCON [2] and Ishizuku [3]. The problem with such cells is the bipolar current leakage are corrosion phenomena, losses in current yields and a contamination of the electrolysis products, often with the formation of explosive mixtures [4]. These effects should be taken into account when designing industrial bipolar electrlyzers and planning electrolysis plants equiped with them inorder to

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minimise detrimental effects and secure safe operation of the equipment with technical and economic performance figures. Hence a comparative study has been made to estimate the current bypass from current-potential curves (i-E) and Resistive Network Model (RNM) for a magnesium bipolar cell.

THEORETICAL TREATMENT

The current loss in bipolar cells can be measured by solving a set of linear equations [5], or finite difference equations [6], or a Laplace equation [7].

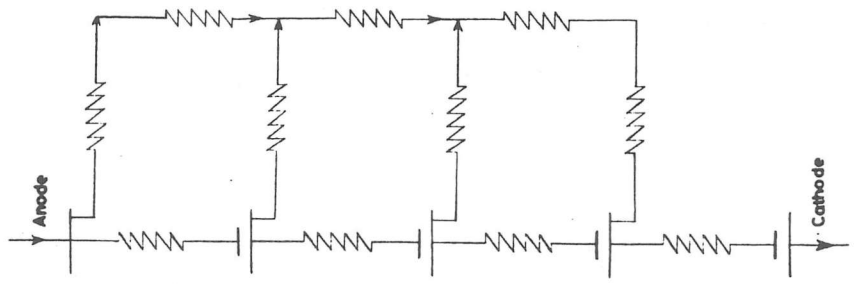

Fig.1 Equivalent circuit of the bipolar electrode stack to RNM model

In the RNM, the bypass current was calculated by using the equation,

$$k1 = ko - \frac{j\lambda [\lambda^{1} + \lambda^{n-1} - 1 - \lambda^{n}}{[\lambda^{n} - 1]\,[\lambda - 1]} \qquad \ldots\ldots\ldots\ldots (1)$$

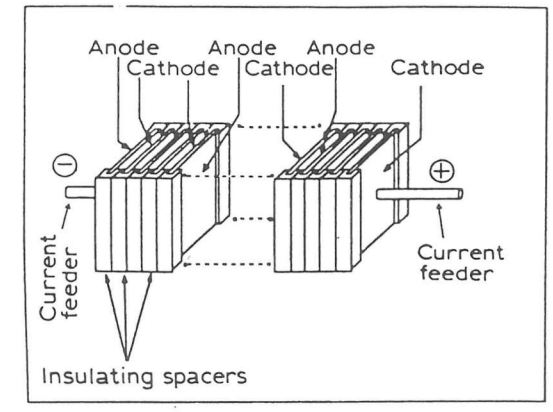

Fig.2 Schematic representation of the bipolar cell stack to i-E model

The estimation of current bypass from i-E curves,

$$ib = \frac{nE_1 - E_n}{nE_1 - E_o} \qquad \ldots\ldots\ldots\ldots (2)$$

where the notations in equation (1) and (2) are described elsewhere [8] and [9],respectively.

EXPERIMENTAL

The electrode stack contains two bipolar electrodes. The dimensions of both graphite and mild steel are 18x28x2.5 cm and 18x28x1.5 cm, respectively. In a bipolar electrodes the graphite and mild steel are kept at a distance of 3.0 cm giving each anode (cathode) a total area of 504 cm^2 for the three cells stack. $MgCl_2$ was added to the NaCl + KCl mixture in two different concentrations (20 and 25 %). At regular intervals tne

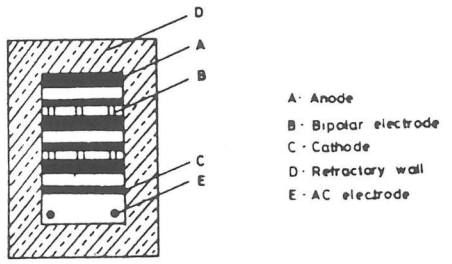

Fig.3 Schematic diagram of the bipolar cell

concentration of $MgCl_2$ was analysed. Though the normal working electrode temperature is 983 + 10 K, temperatures up to 1013 K were employed. Adding too a high concentration of $MgCl_2$ reduces the electrical conductivity of the electrolyte and increases the amount of $MgCl_2$ lost in the sludge.

RESULTS AND DISCUSSION

Figures 4 and 5 represent current density - cell voltage plots corresponding to one element cell at 1003 + 10 K and a bipolar stack with three cells. In current-potential relation the transition is observed from non linear above 0.2 A/cm^2. This is due to the fact that the electric field inside the bipolar cell is not sufficiently high to polarise all the bipolar electrodes.

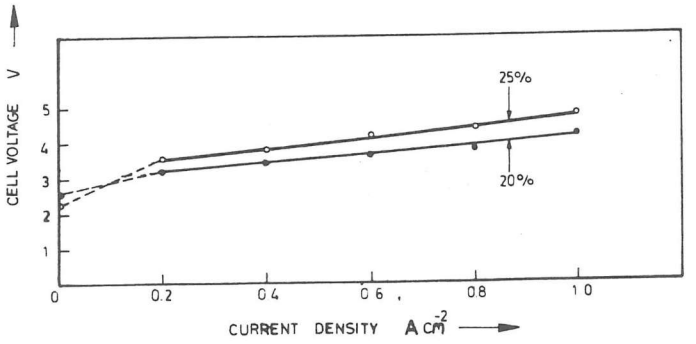

Fig.4 c.d Vs Cell voltage
One element cell

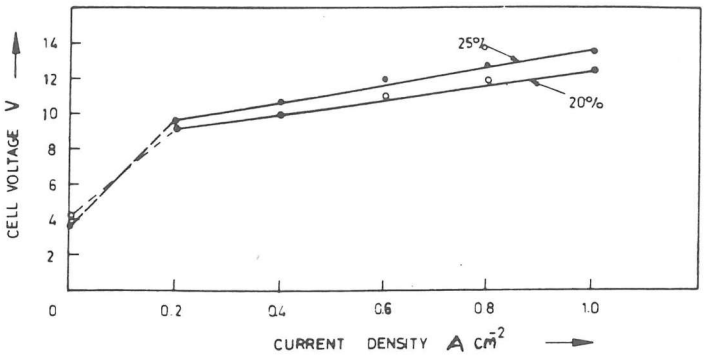

Fig.5 c.d Vs Cell voltage
Bipolar stack

The cell voltage was observed even at zero current density. The similar observations were noticed for both the one element cell and bipolar stack with three cells. Figures 6 and 7 show the variation of individual bipolar voltage with the current density. Hence the cell voltage increases with the current density for both the concentrations of $MgCl_2$. Also from (A) in figure 6 and 7, the cell voltages of 2.6 and 1.8 V were observed even at zero current density. Similarly, the voltages measured between bipolar one and bipolar two (B) and bipolar two and cathode (C) were 1.2 and 0.9 V for the electrolyte containing 25% $MgCl_2$. But for 20% $MgCl_2$ concentration, the cell voltages were 0.8 V for both the cases. The potential distributions corresponding to the anode to bipolar one and bipolar two to cathode were the same for both the cocentrations. But the voltage between bipolar two to cathode is slightly higher for the current density greater than 0.4 A / cm^2. The bypass current (i_b) for different current densities (0-1 A /cm^2) were calculated by using the equation (2).

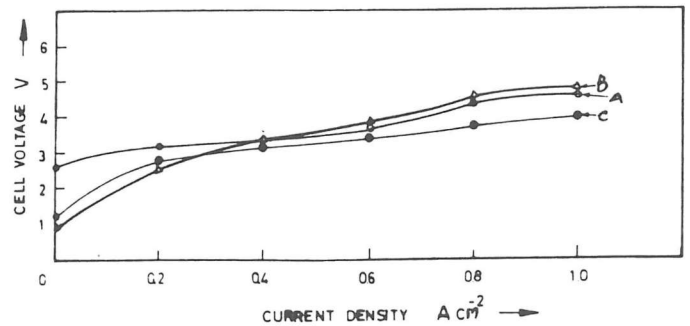

Fig.6 c.d Vs Cell voltage
Bipolar cell with 25% $MgCl_2$

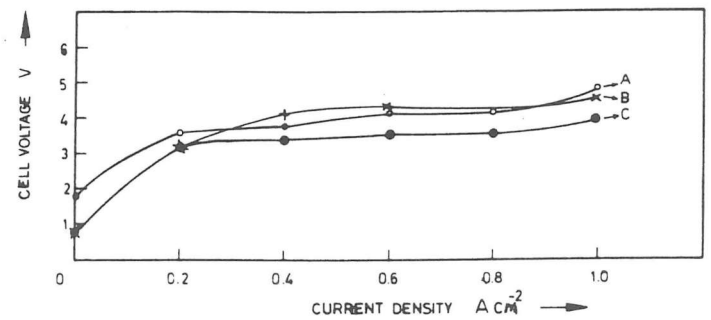

Fig.7 c.d Vs Cell voltage
Bipolar cell with 20% $MgCl_2$

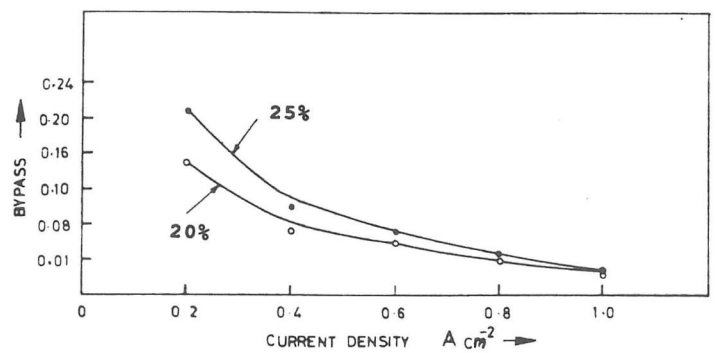

Fig.8 c.d Vs Bypass current

Figure 8 shows i_b - current density plots for the two concentrations of $MgCl_2$. As the current density increases i_b decreases at low current density. i_b is very high for both the concentrations. For comparission, i_b estimated from the RNM and also the i-E curves is given in table-1. From the table -1, ib calculated from i-E curves is nearly five times higher when compared to the value which are estimated by using RNM.

Table-1 : Comparison of bypass current

Current density A cm^{-2}	ib		
	i-E curves		RNM
	25%	20%	
0.2	0.208	0.1500	0.03350
0.4	0.103	0.0741	0.01836
0.6	0.075	0.0650	0.01330
0.8	0.047	0.0430	0.01080
1.0	0.024	0.0370	0.00930

CONCLUSIONS

All the patents on design of multipolar/bipolar electrolysers now recognize that the design must take provision for minimization of leakage currents. The obtained results indicate that i_b estimated from i-E curves and also RNM are varying from 20% to 2% and 3 to 1%, respectively, with the increase in current density.

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A NEW APPROACH TO CURRENT EFFICIENCY CALCULATION IN MAGNESIUM ELECTROLYSIS

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SUMMARY

Energy consumption in an electrolytic process is mainly governed by current efficiency and voltage efficiency. Hence an accurate calculation of the current efficiency will greatly help in evaluating energy data precisely. An attempt has been made in this study to perfect an alternate method for calculating the current efficiency (C.E.) from the chlorine gas liberated at the anode during magnesium chloride electrolysis. The anodic current efficiency (A.C.E.) thus obtained has been compared with the cathodic current efficiency (C.C.E.) calculated by metal basis. A difference between the two values has been observed and the reasons for such differences have been analysed in this paper.

KEY WORDS: current efficiency, anode product, magnesium cells, chlorine gas analysis.

INTRODUCTION

Energy conciousness in electrometallurgical industries has necessitated a fresh appraisal of the existing technologies, inorder to update them for more clean and economical

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