Essential Readings in Light Metals: Electrode Technology for Aluminum Production.
Edited by Alan Tomsett and John Johnson.

EVALUATION OF THE UNIFORMITY OF BAKING IN HORIZONTAL AND VERTICAL FLUE RING FURNACES

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The uniformity of final baking temperature, as determined by the mean crystallite thickness of petroleum coke samples, was measured in both horizontal and vertical flue ring furnaces.

The effect of the uniformity of final baking temperature on the properties of anodes was evaluated.

Introduction

Both horizontal and vertical flue ring furnaces are used for baking electrodes in the aluminum industry. At Alcan smelters, furnaces of both types have been installed.

One of the most important criteria of the operation of these furnaces is the range of final baking temperatures attained by the electrodes. Generally, a minimum temperature is specified. The target average baking temperature, which is a parameter for furnace control, is then set such that all electrodes in the furnace reach temperatures equal to or higher than the minimum baking temperature.

The uniformity of the final baking temperature is a very important aspect of the design and operation of the ring furnaces. Variations in final baking temperature result in variations in physical properties of the electrodes and ultimately affect the electrolytic cell operation. With a higher non-uniformity in final baking temperatures the average and the maximum baking temperatures must be increased to maintain the same minimum temperature. This results in both increased fuel costs and accelerated refractory deterioration.

It is relatively easy to measure the distribution of final baking temperature in a horizontal flue furnace by placing thermocouples in the electrode charge, but it is extremely difficult to do so in a covered vertical flue furnace. In order to determine the uniformity of the final baking temperature in such a furnace, it is necessary to determine some other property which correlates with the baking temperature and is easily measurable.

This paper presents studies of the uniformity of final baking temperatures in oil fired horizontal and vertical flue baking furnaces, based on measuring the mean crystallite thickness of petroleum coke samples dispersed throughout the furnace. The properties of the anode blocks were measured as a function of baking temperature, determined by the mean crystallite thickness of these petroleum coke samples.

Experimental

Studies of the uniformity of final baking temperature were carried out in vertical flue and horizontal flue ring furnaces when baking anode blocks.

Samples of a commercially produced petroleum coke, precalcined to 800°C to remove volatile matter, were placed in graphite containers 38 mm diameter and 38 mm high. During charging of the furnaces, the sample containers were inserted into the anode stud holes. After baking, the sample containers were retrieved and the mean crystallite thickness determined by X-ray diffraction analysis.

The correlation between baking temperature and mean crystallite thickness of coke samples was determined in the laboratory. Results obtained for a retention time of 44 hours are presented in Figure 1.

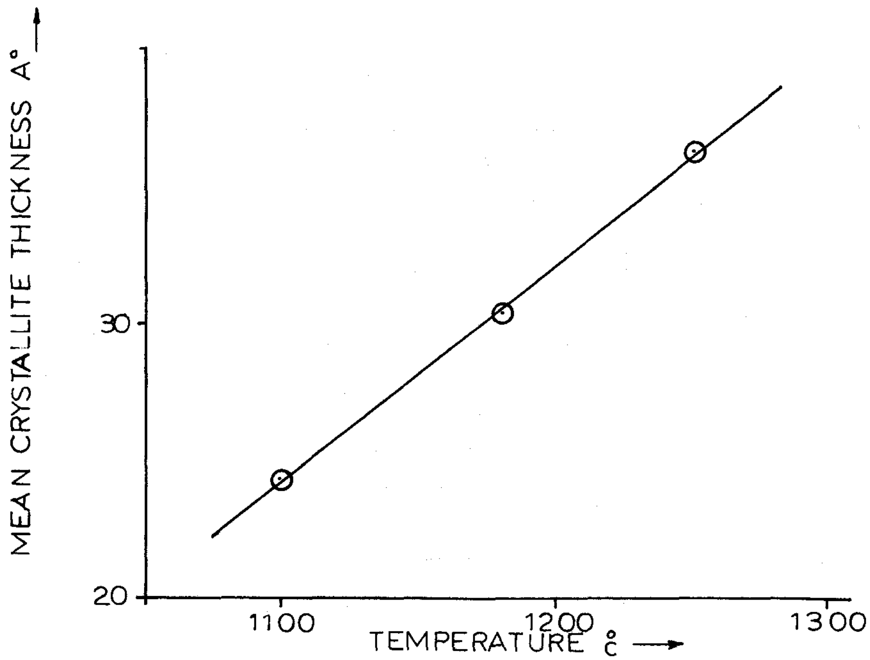

Fig. 1 - The relationship between mean crystallite thickness and temperature of petroleum coke samples.

These results were confirmed by comparing the temperature measurements in the horizontal flue ring furnace using thermocouples, with those computed from mean crystallite thickness of coke samples placed in the same location.

The placement of the anodes and coke samples in the vertical and horizontal flue furnaces is shown in Figure 2.

Core samples were taken from the baked anodes and their physical properties were determined. These included: apparent density, electrical resistivity, compressive strength, pseudo-tensile strength, air permeability and the electrolytic consumption index.

Results and Discussion

Variation of the mean crystallite thickness (L_c)

Typical results obtained in the vertical and horizontal flue furnace pits are shown in Figure 2.

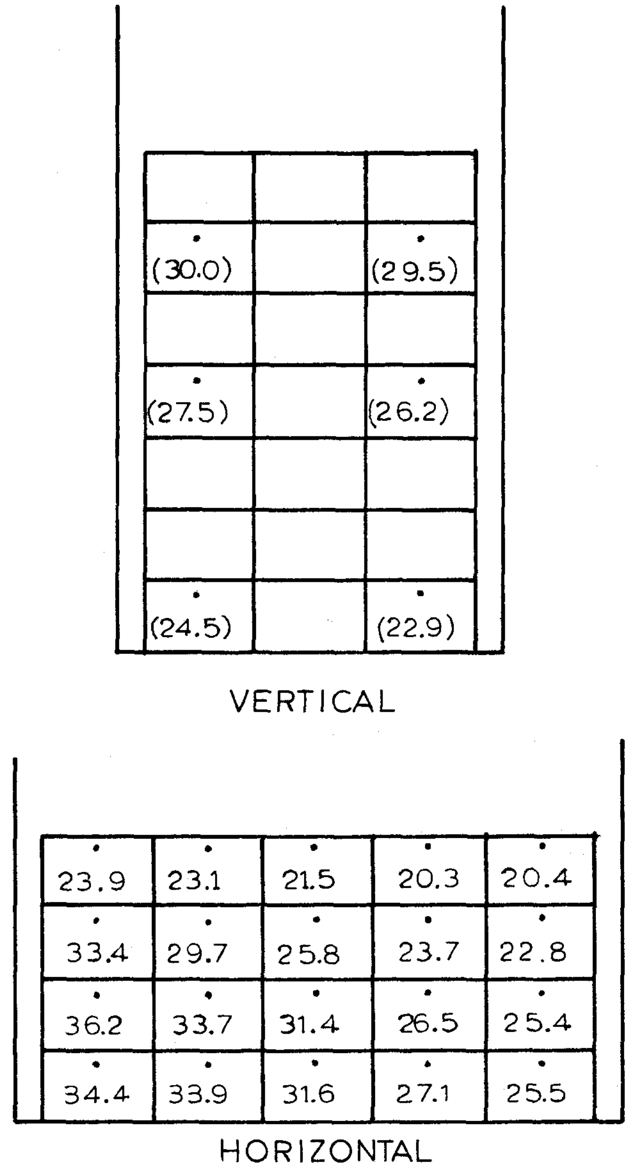

Fig. 2 - Location and L_c of petroleum coke samples placed in vertical and horizontal flue furnaces.

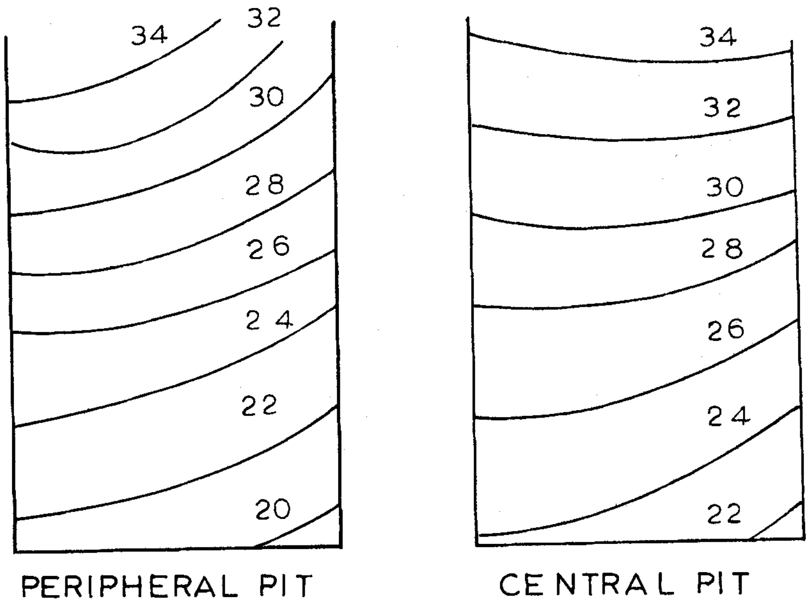

Fig. 3 - ISO-L_c contours in vertical flue furnace.

Figures 3 and 4 show the nature of the iso-L_c contours for the two types of furnaces. These graphs are obtained by interpolating and extrapolating the data of several pit surveys. The average and the standard deviation of the L_c was around 26.5 A° and 3.6 A° respectively in the horizontal flue furnace and 26.4 A° and 3.7 A° respectively in the vertical flue furnace. The overall range of the L_c in the two furnaces was nearly equal. The variation of L_c within a pit, between pits and between sections of the two furnaces is given in Table I. In the vertical flue furnace, the variations were mainly in the vertical direction while they were in both horizontal and vertical directions in the horizontal flue furnace.

Table I. Variation of L_c of petroleum coke samples within vertical and horizontal flue furnaces

	Vertical flue		Horizontal flue	
	SD (A°)	n	SD (A°)	n
Within pit	3.54	6	3.48	24
Between pits	0.45	4	0.15	2
Between sections	0.93	3	0.54	2
Overall	3.70	72	3.60	96

SD = standard deviation of L_c - n = number of observations

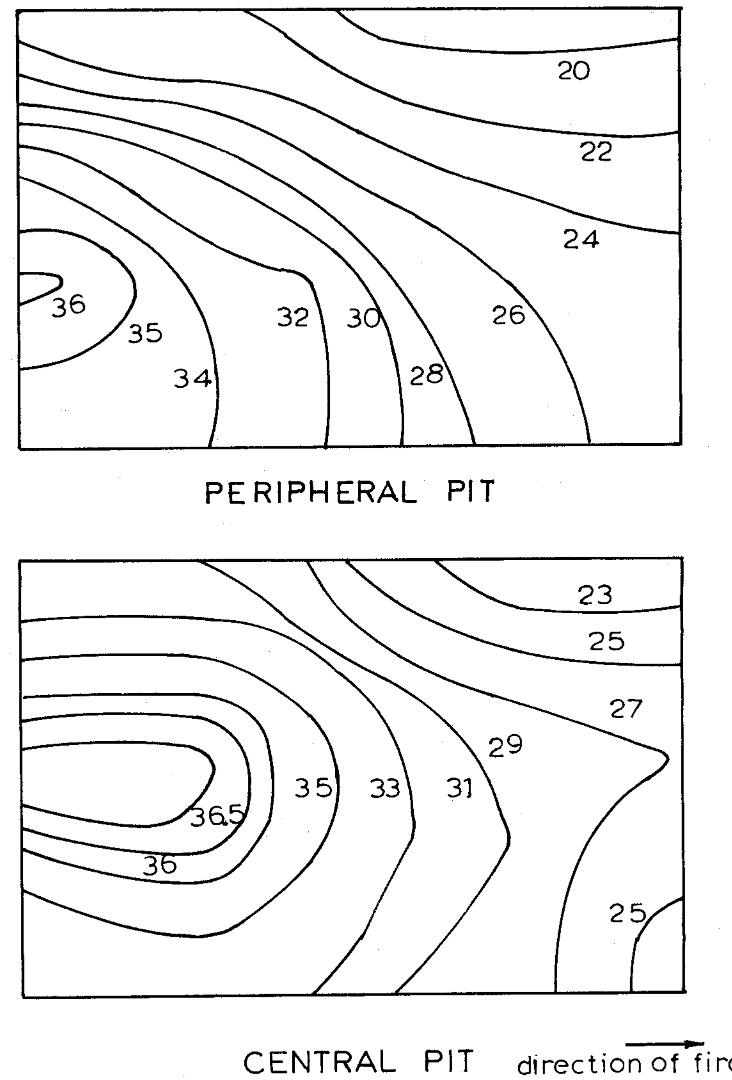

Fig. 4 - ISO-L_c contours in horizontal flue furnace.

The results of the temperature distribution given here apply strictly to the two furnaces in which it was measured. In general, the temperature range will be affected by both furnace design and operation. However, these results are fairly typical of those obtained in oil fired furnaces operated within Alcan.

Variation of properties

The effect of baking temperature, as described by L_c of coke samples from the same location, on anode properties is given in Table II. As can be seen from this, the effect of variations in baking temperature is most significant in case of anode consumption which decreases with increasing baking temperature. To a lesser extent, the baked apparent density is also seen to be a function of maximum temperature obtained. Other properties such as electrical resistivity, compressive strength and air permeability are not found to be significantly affected by the baking temperature.

Table II. Variation of properties of anodes as a function of L_c

		Mean Crystallite Thickness: L_c A°					
		Average 30.4	SD 2.34	Average 26.3	SD 1.8	Average 22.5	SD 1.38
Green apparent density	Mg/m^3	1.566	0.007	1.563	0.008	1.566	0.010
Baked apparent density	Mg/m^3	1.503*	0.004	1.504	0.009	1.512*	0.003
Compressive strength	MPa	31.0	2.6	28.7	4.2	34.9	3.7
Pseudo-tensile strength	MPa	3.48	0.66	3.79	0.85	3.82	0.75
Air permeability	cm^2/s	9.8	2.4	9.4	2.1	8.3	0.7
Electrical resistivity	µΩm	65.3	6.1	65.0	3.2	66.0	1.5
Electrolytic consumption rate	%	113.3**	1.0	114.1	0.5	115.8**	0.3

* difference significant at 95% confidence limit

** difference significant at 99% confidence limit

SD: standard deviation

In Table III, the properties that are found to be affected by the variations in baking temperature, i.e. electrolytic consumption index and baked apparent density, are compared for anodes baked in the horizontal and vertical flue furnaces. The very similar range and standard deviation of the properties for anodes coming from both furnaces, is a further corroboration of the data of Table I, which shows the temperature distribution in the two furnaces to be very similar.

Table III. Variation in properties of anode baked in vertical and horizontal flue furnaces.

		Vertical			Horizontal		
		Average	SD	Range	Average	SD	Range
Green apparent density	Mg/m^3	1.565	0.008	0.023	1.567	0.003	0.008
Baked apparent density	Mg/m^3	1.507	0.009	0.019	1.498	0.011	0.026
Electrolytic consumption rate	%	114.3	1.2	4.1	114.1	1.4	4.0

Conclusions

The variation in the final baking temperature as recorded by the measurements of L_c, was very similar for the two types of furnaces as operated by Alcan. However, the gradient was mainly across the vertical direction in the vertical flue furnace and both the horizontal and vertical directions in the horizontal flue furnace.

The effect of the variation in the final baking temperature was most pronounced in case of the electrolytic consumption. Other properties were affected either to a lesser extent or not at all.

Improving the uniformity of final baking temperatures should be considered to be an important aspect of both design and operation of carbon baking furnaces.