A REVIEW OF FACTORS AFFECTING CARBON ANODE CONSUMPTION IN THE ELECTROLYTIC PRODUCTION OF ALUMINUM

Paul Rhedey

Abstract

Anode consumptions were determined in the laboratory in a miniature electrolytic cell in which the test electrode is fully immersed in the electrolyte. The test is carried out under conditions simulating those of industrial reduction cells, and the results parallel those of plant-scale tests. The correlation between the laboratory and plant consumption data is demonstrated. Laboratory studies led to better understanding of many factors affecting anode consumption. The mechanism is reviewed. Results are presented for (1) anode materials, (2) anode processing variables, and (3) cell operating practices. Of considerable interest are the consumption rates obtained with special cokes such as needle, fluid, and high-temperature cokes, and with coal-tar and petroleum pitches containing very low amounts of quinoline-insolubles. Anode consumption exhibits a minimum with increasing binder content. It can be significantly modified by the use of certain additives. Major changes in aggregate size distribution have marked effects on consumption in both the prebaked-type and Soderberg electrodes. The effect of electrolyte temperature and composition and some of the reduction cell variables on anode consumption are briefly discussed.

Paul Rhedey is head of the Carbon Section of Alcan Research and Development Limited's Electrometallurgical Division, Arvida, Quebec, Canada

Introduction

Alcan R & D: Arvida developed a laboratory test cell and has been using it over the past ten years for the determination of baked carbon anode consumption. (1) The laboratory anode consumption is measured on cored or machined samples of baked electrodes fully immersed in the electrolyte. The laboratory results therefore do not include the amount of carbon consumed by air oxidation or by secondary causes inherent to plant operation such as paste leaks or mechanical losses. A small amount of air oxidation of the sample occurs when it is withdrawn from the cell after the test. This was found to be 2% of the theoretical consumption and could be applied to the results as a standard correction. The laboratory baked anode consumption results may be expressed as a percentage of the theoretical consumption, theoretical being that corresponding to formation of CO at 100% current efficiency (0.112 g/Ah, or 0.247 lb/kAh).

The plant anode consumption may be considered as the sum of the following quantities: carbon consumed in the electrolytic reduction process at the anode face, carbon consumed by secondary reactions such as CO permeation, eroded carbon dust, mechanical losses through cracking and breakage, paste leaks or other losses, and carbon lost by air oxidation of the hot anode surface. It is believed that a major part of the excess consumption is usually due to the eroded carbon dust, while the role of secondary reactions is small. Air oxidation under certain conditions is appreciable. It is well known that the difficulty in determining the effect of any one variable on anode consumption in a plant-scale test lies in maintaining the numerous other operating variables at a constant value in a series of cells over a sufficiently long period of time. In order to achieve adequate accuracy a statistically designed experiment is necessary involving two sets of randomly selected operating cells, one set with the anodes to be evaluated, and another set with "control" anodes. The number of cells per set should be at least 24 or more, and the duration of test from 3 to 6 months. Under these conditions, provided that the smelter is equipped for such tests, a difference of 1 to 2% in anode consumption can be detected with acceptable confidence limits.

Many investigations have been carried out over the past ten years at Alcan R & D: Arvida on the different aspects of the laboratory baked anode consumption, and factors affecting it. Similarly many plant-scale tests have been conducted or observations made elsewhere at the Alcan smelters and affiliates with regard to anode raw materials, manufacturing and operating conditions. The paper gives an up-to-date review of factors affecting anode consumption based on both laboratory and plant-scale measurements.

Results

Effect of Anode Materials on Consumption

For commercial calcined cokes from various sources, baked anodes
The effect of partial oxidation and surface oxygen content was investigated in Soderberg test electrodes. There was no significant effect on consumption over a range of 5 to 25 wt% burn-offs. The effect of cooling the coke in inert gas (nitrogen) in contrast to direct water quench after calcination was also examined. No effect on anode consumption appeared.

Anode consumption of Soderberg test electrodes decreased with increasing sulphur content at a rate of 2.7% per 1% sulphur over the range of 1 to 6% sulphur in the calcined coke. A similar, but less significant correlation was found for prebaked test electrodes. The rate of decrease in consumption was 1.2% per 1% sulphur in the coke. The laboratory results are shown in Figure 2. Similar results were found in plant-scale tests, although the effect of sulphur appeared less pronounced there than in the laboratory.

Several types of petroleum coals have been evaluated in the laboratory. The properties of the coals are given in Table II. Needle coke gave slightly lower anode consumption (1 to 2%) in both Soderberg and prebaked test electrodes than sponge coke. The reduction in consumption clearly would not justify paying a premium usually associated with this type of coke, for the aluminum industry. Substitution of fluid coke in the aggregate decreased anode consumption of Soderberg test electrodes significantly. As Figure 3 shows the rate of decrease is 5% per 25% fluid coke addition. A 22-cell, 6-month, plant test of fluid coke additions to Soderberg paste was made. The results obtained agreed with the laboratory prediction, and it was concluded that use of fluid coke of acceptable purity is advantageous in Soderberg paste. At the present time such fluid coke is not available to Alcan. High-temperature fluid coke (coke deposited in a fluidized bed at high temperature) gave very high consumption results in the laboratory. The use of 25% to 60% unground or ground high-temperature fluid coke in the aggregate increased the consumption of Soderberg test electrodes by 10 to 15%. In prebaked-type test electrodes anode consumption was 15% higher than for regular delayed coke. The high consumption is attributed to the low reactivity of high-temperature fluid coke.

A comparative laboratory testing of samples of horizontal stud Soderberg paste made with pitch coke and petroleum coke revealed very little difference in anode consumption. The former gave slightly, but not significantly, lower (around 1%) laboratory baked electrode consumption.

A considerable amount of work was carried out on coal-tar pitch binders, both in the laboratory and in the smelters. The range of properties of coal-tar pitches tested in the laboratory is given in Table III. An increase in softening point was found to decrease the laboratory consumption of Soderberg paste and green prebaked electrodes. The decrease in paste consumption was 2% per 10°C increase in softening point over the range of 100 to 125°C. Paste binder requirement did not change with increasing softening point. It appears that quinoline-insoluble content between 6 and 16% does not affect consumption. Good