Retrofitting Older Aluminum Reduction Cell Lines—A Way to Extend Productive Life

Halvor Kvande

Retrofitting older alumina reduction cell lines may be an alternative to a complete line shutdown and replacement with new, modern cells. This may, in turn, extend the time that aging cell lines remain cost effective and profitable, and may also help meet today’s more stringent environmental protection regulations. In this article, practical examples of improvements achieved by cell retrofitting are discussed.

INTRODUCTION

Because the primary aluminum industry has grown rapidly, many different types of cells have been developed. Today, there may be about 180 smelters in operation worldwide, with possibly 200-300 different cell designs and constructions operating in the range of 30-300 kA, with a large variation in performance. The oldest cell line still in operation is probably the Volkov smelter, built in 1932 near St. Petersburg in Russia.

Figure I shows the start-up period of the total worldwide aluminum smelter capacity that was operational in 1991, according to Keller and Fischer. About 20 percent of this capacity was installed before 1960, and about 50 percent was installed before 1970. Thus, an estimated one-half of worldwide annual aluminum production is presently being made in cell lines that are more than 25 years old.

An alumina reduction cell line may have a lifetime of 30-40 years, but sometimes it takes only 10-20 years before the technology is outdated. In view of the technological advances made in the aluminum smelting process in the past 25-30 years, plant retrofitting (i.e., the incorporation of aspects of new and advanced technology to upgrade an existing smelter) may be viewed as an interesting economic alternative to a complete conversion to new, modern cells. These changes are made to take advantage of recent technological developments and improved knowledge and understanding. The improvements in cell design, construction, and operating procedures are usually achieved through extensive use of computer modeling and large-scale development work conducted on test cells.

Retrofitting may have three main results. It can make the cell line more cost effective, thereby, remaining competitive (e.g., higher amperage, improved productivity, increased current efficiency, lower energy and anode carbon consumption, and increased cell life); extend the economic lifetime of the existing cell line to avoid building a completely new line, if availability of capital is a severe constraint; meet current, more stringent environmental protection regulations; and improve working conditions, emission control, and fluoride recovery.

Retrofitting may be done in a variety of ways. The new technology that has mainly been employed to retrofit old cells is:

- Alumina point feeding (install or upgrade automatic feeders)
- Bath-chemistry modification (additives to reduce bath temperature)
- Cathode design improvements (better construction materials and lining practice)
- Anode size modification (larger)
- Busbar system (improved magnetic compensation)
- Improved process control computerization

Each of these may contribute to improving operational results. In addition, some modification is sometimes done to the cell superstructure (e.g., hooding and the installation of hoppers for alumina and aluminum fluoride). Furthermore, the introduction of new or improved mechanical equipment for cell operation is also considered to be an important part of the retrofitting process.

ALUMINA POINT FEEDING

Technology

Alumina feeding has developed considerably during the last 30 years. Important advances came in the 1960s with the introduction of a vehicle with a crust-breaker wheel for feeding alumina along the sides of the cell and when central-bar-breaker feeders and hoppers were built into the superstructure of some cells. The most important development—the point feeding of alumina—came in 1961 and has proven to be a major breakthrough in alumina-feeding technology.

Point feeding consists of punching small holes in the crust successively at two to five positions along the center line of the cell and subsequently adding about one kilogram of alumina in each dump. The crust breaking is done by a single piercing rod mounted at the end of a fast-acting pneumatic cylinder. The volume of alumina added each time is the same, while the time interval between additions can vary considerably.

At present, point feeders are an important feature of all modern cells; however, there are still many older cell lines that do not use this superior feeding method. The main advantages of small additions are that the alumina concentration in the bath is kept more constant, there is less thermal disturbance by the addition of cold alumina, fewer anode effects will occur, and uncontrolled overfeeding and sludge formation may be avoided. Process conditions may then be maintained more constant and closer to optimum, which may improve the cell performance considerably. For example, the point feeding of alumina permits improved bath chemistry through lower bath ratio (i.e., a higher content of AlF) and, thereby, lower bath temperature.

Case Studies

In the literature, several interesting papers concerning conversion to point feeding may be found. Johnson and Guello discussed the application of the new technology in plant retrofit programs. Early in the 1980s, Kaiser Aluminum decided not to construct new facilities with their 195 kA cell tested in Tacoma and Chalmette because of capital-spending constraints. Instead, the technology developed for these prototype cells was applied to existing cells in their older plants such as the Anglesey smelter in Wales.

The biggest stumbling block preventing Anglesey from changing the bath composition to higher AlF and lower bath temperatures was the fact that the plant was equipped with centerfeed, half-break cells. These generally exceed alumina solubility limits at high AlF contents because of the large quan-
ties of alumina fed at one time. Capital-spending limits precluded the installation of point-feed cylinders and breakers, so a conversion of the existing breaker beam and alumina hopper to a relatively low-cost point-feed system was adopted. At the same time, the excess mass percent AlF$_3$ content was increased from 9% to 11%, and the bath temperature dropped from 970°C to 960°C. A gain in current efficiency from 90% to 92.5% was achieved.

The conversion from open side-worked cells to hooded point-feeder cells (138 kA) at Albras in Brazil was described by de Carvalho et al. Point feeding contributed to an increase in current efficiency from 88.3% to 91.5% without any simultaneous change in bath composition (9% AlF$_3$, at 967°C).

Niven and Cornford$^7$ gave a description of the conversion from bar-breaker to point-feeder technology in the cells at Boyne, Australia. Equipment was developed to enable the cell superstructure to be changed on-line. A special frame was designed to hold the anodes in place and to permit the superstructure to be exchanged with the cell off-load for only one hour, with a relatively small disruption to cell operation. Knapp$^4$ gave further details of the retrofit program at Boyne. Development of the point-feeder design and testing of its reliability took nearly two years. Similar to the experience of other smelters, the wear of air-cylinder seals was claimed to be the biggest problem, but their goal of two years' seal life is now exceeded.$^8$

A radical change has taken place in Hindalco's small 58 kA cell line that was initially installed in 1962. Alumina feeding was done manually by breaking the center crust with poker bars every 80 minutes; therefore, there was no proper control of the quantity of alumina added to the bath. Point feeders were developed in order to feed a small, measured quantity of alumina at short intervals. Higher AlF$_3$ content than the previous 5% AlF$_3$, composition was used, but the exact value was not given by Chaudhry and Prasad.$^9$ Current efficiency increased from 87% to 93%.

Stefanidis and Georgantonis$^{10}$ reported results from a conversion from side feeding to point feeding of 70 kA and 90 kA cell lines of Aluminium de Grece. A 2% increase in current efficiency was obtained, together with lower energy consumption and improved cathode life.

**BATH CHEMISTRY**

**Technology**

The introduction of point feeding has permitted significant improvements in bath chemistry. The trend is clearly toward lower NaF/AlF$_3$ bath ratios (or higher AlF$_3$ contents), which reduce bath temperature and improve current efficiency and energy consumption. Modern cells are typically operated with baths containing 10–13% AlF$_3$, and these bath compositions have also been the target in smaller, retrofitted cells. The use of point feeders is an important factor for maintaining almost constant bath composition, which is required for stable and consistent cell operation.

**Case Studies**

One example is the Mead smelter of Kaiser Aluminum,$^{11}$ at which the AlF$_3$ content was increased from 5.5% to 12.5% in small 68 kA cells. Together with improvements in anode size and shape and cathode design, current efficiency was increased from 86.2% to 91.9% in these cells with a center-break alumina feeding system.

At Boyne,$^4$ the AlF$_3$ content in the bath was increased from 7% to 13.4%. This resulted in a bath-temperature reduction of 25°C to 950°C and a 4% rise in current efficiency to 92.7%.

In a retrofit program for 170 kA cells (Kaiser P-69) in Dubai, United Arab Emirates, the bath composition was increased from 5–9% to 7% AlF$_3$, Dhameja and Sachan$^{12}$ claimed that this gave a 2.5% improvement in current efficiency. Intalco has also spent a significant amount of effort on improving bath chemistry.$^{13}$ However, they changed from 6–7% AlF$_3$ to a lithium-modified bath composition, which reduced the bath temperature from about 970°C to between 940°C and 955°C. Hawkins$^{14}$ reported that Intalco's 137 kA cells operated very well at about 92.5% current efficiency with a bath composition of 8% AlF$_3$ and 2% LiF.

**CHATHODE DESIGN AND CONSTRUCTION**

**Technology**

Improvements in cathode design are usually established through computer modeling, which may give a precise prediction of thermal performance. These changes may have the objectives of reduced heat losses, reduced cathodic voltage drop, improved cell stability and operation, and increased cell life. Significant gains in voltage drop can be achieved with the use of semigraphitized cathode blocks. In order to preserve heat balance and not lose voltage savings, heat must be conserved in the cathode. This means an increase in thermal insulation in the lower sidewall and under the blocks. The thermal resistance of the upper sidewall needs to be decreased.$^{15}$ (Less insulation is necessary in those parts of the cathode.)

The use of penetration barriers will inhibit the rate at which bath and vapor impregnate and slowly degrade the bottom insulation. It is also very important to improve the quality and longevity of the seals around the current collector bars to inhibit the ingress of air into the cathode lining. Stuffing boxes at the entries for the collector bars may prevent air burn of the backside of the carbon sidewall.$^{16}$ Stronger steel shells provide less shell distortion. More retrofits of cathodes should be expected in the face of increasing costs and the availability of energy.$^{13}$

Autopsies are sometimes conducted on young cells removed from operation. These autopsy results may help to ensure optimum heat balance and the correct location of the liquidus isotherm by the use of cost-effective construction materials.$^4$