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PRODUCTIVITY INCREASE AT SØRAL SMELTER

Terje Johansen*, Hans Petter Lange*, Rene von Kaenel**

*Sør-Norge Aluminium A/S
N-5460 Husnes, Norway

**Alusuisse Technology & Management Ltd
Technology Center
CH-3965 Chippis, Switzerland

Abstract

The Sør-Norge Aluminium A/S (SØRAL) smelter was started in 1965 with Alusuisse 100kA pre-baked anodes technology. In 1989 it was decided to bring the plant up to date, no modifications having been made since start-up. The objectives of the initial modernization project were quite modest : to increase the current level from 105 to 115 kA, current efficiency from 90 to 92 % and to decrease energy consumption from 15.3 to 14.7 kWh/kg Al. These goals were to be reached by introducing a new cathode shell and lining design, by making minor modifications to the busbars, and by installing new process control and point feeding. These changes improved performance and pointed the way to yet further improvements. Today Søral is operating both pot lines at 126.5 kA with a current efficiency of 93.6% and a specific energy consumption of 14.8 kWh/kg. Ten test cells have been operating for more than 17 months at 140 kA and, with the cooperation of the Alusuisse Technology Center Chippis, Søral is exploring the possibility of operating the cells at 150 kA. The ultimate goal is to operate the whole plant at 150 kA with 94% CE and a specific energy consumption of 14 kWh/kg by 2005. This paper presents the developments and methodology in detail, showing the results achieved to date and discussing possible future developments.

Introduction

SØRAL is located at Husnes near Bergen in western Norway, and was founded in 1962 with Alusuisse as the main shareholder. Alusuisse-Lonza (A-L) now owns 50% of the shares, Norsk Hydro A/S 49.9%, the rest being privately held.The Husnes site was chosen because it is easily accessible to big ships and has cheap hydroelectric power and a suitable labor force.

Construction began in 1964, full production being reached in 1966 with two potlines and 56,000 tpy. The Alusuisse 100 kA cells with prebaked anodes were regarded as being among the best technologies available at that time. Forty pots were added to one pot room during 1969 and 1970, increasing capacity to 68,000 tpy. Between 1970 and 1989, SØRAL invested in modern dry scrubbing equipment and hooded the pots so as to reduce environmental pollution.

In 1986 SØRAL started to plan a new line with Alusuisse EPT18 180 kA pots. The recession which started in the late 80's stopped that project, and it was decided in 1989 to retrofit the plant with EPT12 120 kA pots, a variant of EPT18. That retrofit was made in cooperation with the Alusuisse Technology Center Chippis (TCC), as have all the succeeding improvements.

Modernization Program

Before starting to modernize the whole plant, ten test pots were modified, with a booster to bring the current from 105 to 115 kA. The current was increased in steps of 5 kA, a measurement campaign being made at each step, in which the thermal balance of the cell, the side ledge, and the induction magnetic field were all measured and the stability of the metal-bath interface assessed.

These measurements were used to confirm that the corresponding predicted values from the mathematical models [1] used to design the modifications to the cells were accurate enough.

The ten test pots have been used systematically to pilot all the new developments at SØRAL. At each stage of development, the test pots are run for long enough to encounter most of the operational problems and find appropriate solutions before the corresponding modifications are made to both lines. In what follows, the modernization program will be described in 4 steps from its start in 1989 through the present to its planned end in 2005.

Step 1 (1990-1993)

As already mentioned, the goals for this stage of the modernization were rather modest: current increase from 105 to 115 kA, CE increase from 90 to 92% and energy consumption decrease from 15.3 to 14.7 kWh/kg Al. The major elements of the plan to reach these goals were:

- installation of point feeding and new process control
- new pot shells
- new lining and cathode blocks
- larger anodes
- minor modifications to the busbars

The pots were first rebuilt for point feeding, each pot being provided with one AlF_3- and two alumina-feeders. AlF_3 and alumina are brought to the pot by overhead pneumatic conveyor. At this same time, individual pot-controllers were installed, replacing the old system of control from a central computer with signal multiplexing and resulting in faster and more accurate control, which is essential for optimal calculation of the alumina feed. The introduction of point feeding and improved process control, together with improved standard operating practices, has made the pots more stable with a consequent reduction both in the frequency of anode effects and in gross anode consumption.

Figure 1 shows the AE frequency from January 1992 to July 1998, and figure 2 the gross anode consumption from January 1990 to July 1998.

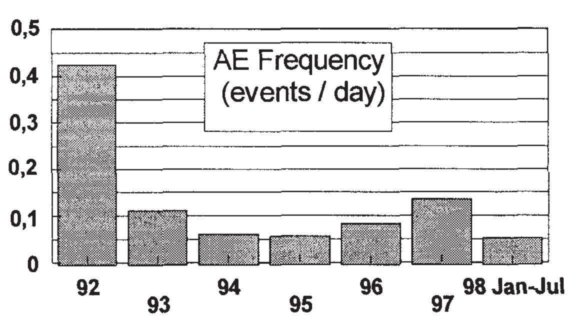

Fig. 1 : AE frequency from 1992 to July 1998

Experience with EPT18 pots led to the development of EPT12 pots, in which a cradle replaces the old box shell. Whenever old pots tapped out, they were replaced with EPT12 pots.

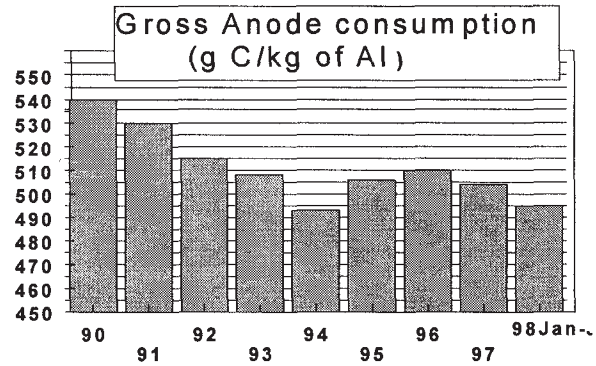

Fig 2 : Gross anode consumption from 1992 to July 1998

These pots had a steel shell with a new mechanical design. The old one was strong and stiff. Under thermal stress, the sides deflected away form the side blocks, creating an insulating airgap, causing the ledge to distort and shortening the life of the pot. The new shell was more flexible and the sides remained in good thermal contact with the blocks.

The EPT12 design also features a new lining and a different type of cathode block in which the rammed amorphous carbon was replaced with glued semigraphitic blocks.

The anode length was increased from 1150 to 1250 mm and the number of studs increased from two to three. This was done to improve the current distribution and maintain the same anode current density as before.

In 1989 the busbars were slightly modified to compensate for the magnetic influence from the adjacent potline. At the same time, 30 pots were added to one potline. Table I shows the change in some key numbers from 1989 to 1993.

Table I. Some key numbers at SØRAL, for 1989 and 1993

Year	1989	1993
Number of pots	250	280
Current Efficiency (%)	90	92
Line current (kA)	105	115
Production (tpy)	68,000	87,000
Number of employees	550	460
Productivity (tpy par employee)	123	189

Figures 3,4,5 and 6 show the progress in some important performance criteria from 1990 to July 1998. In all these four graphs, the shaded histogram gives the information for the test pots and the solid line that for the plant as a whole.

Step 2 (1994-1997)

The results of step 1 were so encouraging that higher goals were set for the second stage of the modernization program : current increase from 115 to 125 kA, CE increase from 92 to 93% with no change in energy consumption. The major elements of the plan to reach these goals were:

- graphitized cathode blocks
- SiC sidelining
- larger cathode blocks
- bigger anodes
- anode setting according to the metal surface contour
- reduced variation in the bath and metal levels

In 1991 SØRAL had started to test graphitized cathode blocks, which were expected to last longer than the semigraphitic blocks. It was found that the voltage between metal and collector bar (bottom voltage) was lower than before, but the higher thermal conductivity and reduced heat production in the graphitized cathode blocks meant that the ACD had to be increased to maintain temperature. This led to increased energy consumption but also to more stable operation of the pots, offering the possibility of further increasing the current. When measurements showed that the shape of the side ledge had also improved, the decision was taken to change both lines from semigraphitic to graphitized bottom blocks, and the size of the cathode blocks was increased so as to prepare the pots for a different side ledge at higher current.

In 1994 sidelining with silicon carbide was introduced so as to make room for yet bigger anodes. The length of the anodes was increased from 1250 to 1300 mm in order to maintain the same current density as before.

Since the insertion height is calculated according to the anode burning rate, it is important to know how the metal height varies in the pot. In order to reduce the number of spikes, increase stability and reduce anode consumption, a new method of anode setting was introduced which took the metal surface contour into account. This method is described in reference [2].

Automatic correction of tapped metal was introduced, which together with improved equipment for measuring the metal and bath heights has reduced the variations in the amounts of both bath and metal in the pots.

During 1996 and 1997 forty more pots were added to one line. Table II shows the change in the key numbers from 1989 to 1997.

Figure 3 shows that the current reached target by the end of 1996, and figure 4 that CE was on target at the end of 1994 and remained stable through1996.

Table II. Some key numbers from 1989 to 1997

Year	1989	1993	1997
Number of pots	250	280	320
Current Efficiency (%)	90	92	93
Line current (kA)	105	115	125
Production (tpy)	68,000	87,000	109,000
Number of employees	550	460	420
Productivity (tpy par employee)	123	189	260

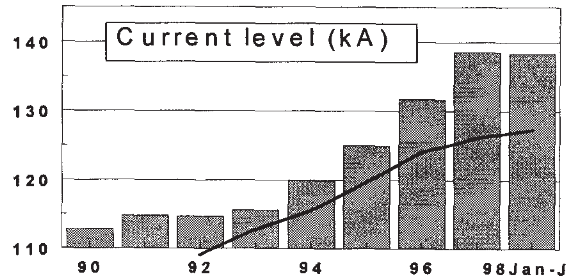

Fig. 3 : Current level for the test pots and the rest of the plant from 1990 to July 1998.

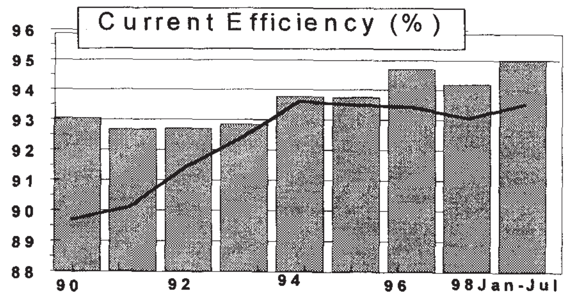

Fig. 4 : Current efficiency for the test pots and the rest of the plant from 1990 to July 1998

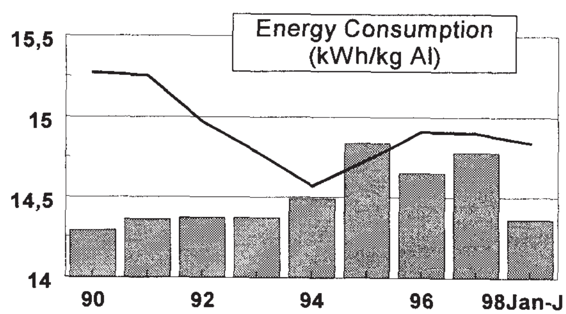

Fig. 5 : Energy consumption for the test pots and the rest of the plant from 1990 to July 1998

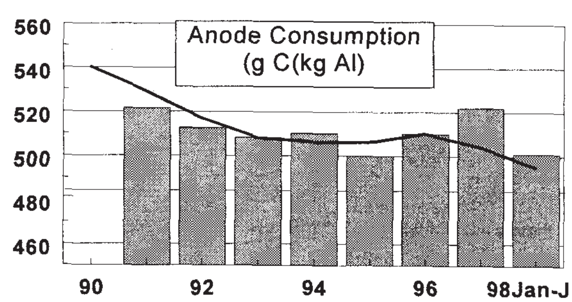

Fig. 6: Anode consumption for the test pots and the rest of the plant from 1990 to July 1998.

Step 3 (1998-2000)

New and yet more ambitious goals were set for the third stage of the modernization program : current increase from 126.5 to 137 kA, CE increase from 93 to 94% and a reduction in the energy consumption from 14.8 to 14.5 kWh/kg Al. The major elements of the plan to reach these goals were:

- major modifications to the busbars of both potlines
- additional rectifier equipment
- reduced variation in the bath temperature
- quality teams
- improved preventive maintenance
- upgrading the skills of the operators
- organizational changes
- changing anodes two at a time

In 1997 a major change was made to the busbars of the ten test pots, which have since been run at nearly 140 kA for 17 months [3], as can be seen in figure 3. For the test pots, figure 4 shows that CE is already 1% above target while in figure 5 the energy consumption is on target. These results are so promising that it has been decided to make the same modifications to all pots in both lines.

During the modifications to the busbars of the test pots, a technique was devised to have one pot out of operation for four to five hours during welding, while the rest of the potline kept running. This technique has been improved further, and today it takes three hours to do the welding for one pot, while the whole line is without current for less than one minute. The plan is to have both potlines fully modified by the end of 1999.

The original busbar design had three busbars at each side. The main modification to a pot is to introduce a new busbar at one side and two new busbars under the pot. The old and new busbar layouts are shown in figure 7.

Today there are 4 rectifiers which each can give 40 kA, so as to ensure uninterrupted operation at 120 kA even if one rectifier shuts down. To maintain this degree of reliability for current levels above 120 kA one more rectifier is to be installed for each line.

A temperature model has been installed in order to decide the frequency and amount of the AlF3 feed, and to adjust pot voltage when necessary.

The pots have no center channel, so that as the length of the anodes was increased from 1250 to 1300 mm they became more asymmetric. Experience in operating the test pots at 1350mm showed an increase in the frequency of anode breakage during anode changing to a point which would be unacceptable in full-scale operation. To reduce this, the length was put back to 1300 mm while to keep current density unchanged the width of the anodes was increased by 20 mm to 540 mm, which meant that the distance between the anodes of one pair became very small. There is now inadequate space available to make corrections in case of problems with the crust breaker at the tapping and measuring holes. The plan is to change each pair of anodes at the same time so as to minimize this difficulty. Crust lying on one of the neighboring anodes will be avoided and there will be more space to position the anodes. Double anode changing will also reduce the emission of fluoride from the potroom.

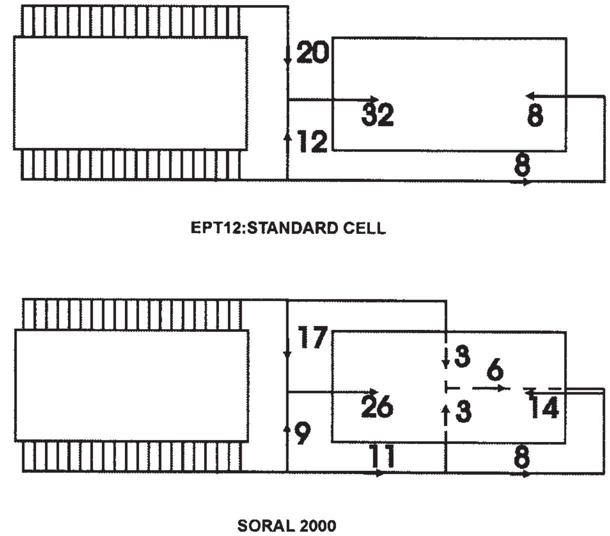

Fig. 7: Old (EPT12 standard cell) and new (SØRAL 2000) busbar layouts.

Operator skills at SØRAL are upgraded by training programs developed in collaboration with other Norwegian aluminum plants. The operators are competent and have the responsibility and the freedom to take independent action to correct operational problems. A new training program is at this moment being prepared that will further improve their skills and help them to better understand the changes and manage the resulting new challenges. It will take an operator two years to get through this part-time course, which includes the principles of Statistical Process Control (SPC) and modern techniques of Quality assurance (QA) and of problem solving.

In preparation for the third stage of the modernization plan, quality teams were set up for the various operations : tapping, anode changing, pot operation and so on. Each of the potroom shifts has a member in each team. The teams discuss and solve present operational problems and problems that are likely to arise when the current is increased. Each member of the group is responsible for informing his shift as to what decisions have been taken and why. He will also be a resource person when the new procedures are put into practice. The quality team for anode changing has since January 1998 been improving standard operating practices to reduce the emission of fluoride, with good results so far, as can be seen in figure 8.

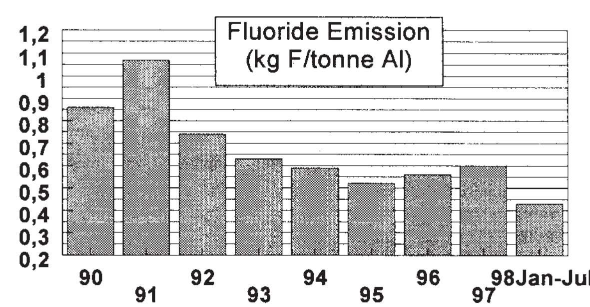

Fig. 8 : Emission of Fluoride from 1990 to July 1998

The more complex operating conditions require not only very well trained and self-motivated operating people but also a flatter organization with maintenance integrated into production. team-building will be a key factor in attaining the improved communication between people and the high level of self-motivation which are vital preconditions for reaching the new goals.

Step 4 (2002-2005)

The measurement campaigns for the test pots have shown that at 140 kA they are both thermally and magnetohydrodynamically stable. It has therefore been decided to increase the current yet further, and the mathematical model predicts that it will be possible to reach 150 kA. The goals for the fourth stage are thus to increase the current in both pot rooms from 137 to 150 kA while keeping the CE at 94%, and to reduce energy consumption from 14.4 to 14.0 kWh/kg Al. The major elements of the plan to reach these goals are:

- new anode rod, revamp the anode rodding shop
- new butt cleaning station
- bigger anodes
- continuing to change anodes two at a time

Increasing the current from 137 to 150 kA will require lengthening the anodes from 1300 to 1400 mm so as to keep the same current density. This in turn necessitates new rods in order to make the anode symmetric to the studs again. New rods make it necessary to revamp the anode rodding shop and build a new anode cleaning station.

Table III shows the goals for the key numbers at SØRAL for 1999-2005.

Table III. Key objectives at SØRAL for 1999-2005

Year	1999	2000.	2002.	2005.
Number of pots	320	320	320	320
Current Efficiency (%)	94	94	94	94
Line current (kA)	130	137	145	150
Production (tpy)	115,000	121,000	128,000	133,000
Number of employees	420	415	410	410
Productivity (tpy per employee)	274	292	312	324

Results And Conclusions

Results

The SØRAL smelter was built thirty years ago. An aggressive program of modernization has been carried out over the last nine years, requiring capital investment that is slight compared to that for building new capacity. As a result of this, production has increased by 60% while at the same time productivity has doubled and fluoride emissions halved, with corresponding improvements in all the usual criteria of operating efficiency.

Conclusions

It is possible to increase the production of a thirty-year old smelter by means of a modernization program, at small expense compared to that required for building new capacity.

An effective strategy for bringing this about is to apply modern methods of mathematical process modeling to predict the effect of modifications to pots, in conjunction with painstaking measurement campaigns on a relatively small number of test pots to confirm the predictions of the models at each stage of modernization. Operating these test pots over a sufficient period of time also makes it possible to anticipate and solve practical operational problems before modifications are applied at full scale.

Not least, well-planned training courses provide the basis for keeping the operators up to date with the technical advances, while the creation of quality teams mobilizes their resources to solve the practical problems they live with day by day.

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