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Increased Current Efficiency and Reduced Energy Consumption at the TRIMET Smelter Essen using 9 Box Matrix Control

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Abstract

Energy consumption is one of the key issues in the production of primary aluminium. It is therefore a great challenge for aluminium smelters worldwide to increase current efficiency and at the same time reduce energy consumption. At the Essen Smelter a new type of energy and mass balance control algorithm has been developed and successfully implemented on an industrial scale. Central to this new strategy are superheat measurements. Supporting measurements include bath temperature and cathode voltage drop. Measurement data are input into a newly developed 9 box matrix control algorithm. The concept utilizes pot voltage adjustments as the primary control tool to drive the bath temperature into a predefined control band. As a secondary control, AlF_3 additions are based upon the liquidus temperature trend. Through combined stabilization of energy and mass balance a stable cell operation is achieved, leading to the benefits of higher current efficiency and reduced energy consumption.

1. Company Information

The TRIMET Smelter in Essen was commissioned between 1971 and 1973. Today the smelter produces 155,000 mt per year of primary aluminium The three potlines are Alusuisse technology end-to-end with prebake anodes, originally built for 140 kA (EPT 14). After a major modernization in 1986 the cells were equipped with point feeders and individual pot controllers. Currently, the line amperages are 158 kA in line 1 and 2 and 166 kA in line 3 (EPT 17 since 1998). Line 3 was modernized in 1998 with a new busbar system and modified pot shell structure.

2. Introduction

Aluminium reduction cells are controlled by the continuous monitoring of line amperage, cell voltage and periodic sampling for bath temperature and cryolite bath analysis. Less frequently measurements are taken for cathode lining voltage drop and samples are taken for metal pad analysis.

Continuous tracking of cell resistance has proven successful in controlling alumina feed-rate to achieve increased current efficiency. Furthermore, cell resistance tracking has provided a means of estimating Al_2O_3 concentration in the bath and enabled detection of excessive noise levels in the cell [1]. Whilst intelligent use of the electrical parameters has provided significant improvements in cell operating efficiency, the application of bath temperature and cathode lining voltage drop measurements have not changed significantly over the past few years. Since many modern smelters now regularly claim current efficiencies of 94-96%, it is suggested that the recent trend of achieving current efficiency gains through improvements in feeding technology alone is unlikely to continue. A cost-effective option might be to achieve smaller additional gains in current efficiency through the use of more accurate, reliable and faster sampling techniques coupled with alternative control strategies to assist in optimisation of process control.

Most smelters use either a multi-dipping thermocouple (Type K) or disposable thermocouple (Type S) every 1-2 days to monitor bath temperature [2] [3]. In addition, samples are taken every 2-4 days to control bath chemistry. Chemical additives (AlF_3 or occasionally Na_2CO_3) are added, depending upon a target composition or theoretical liquidus temperature (Liq). To determine the main bath constituents, excess AlF_3 and CaF_2, many smelters have invested in semi-automated sample preparation and XRD analysing equipment, in the belief that accurate analysis will be obtained. The main cause of inaccuracies in bath analysis however, is in the way in which samples are extracted from the bath. Sampling tongues provide good quality samples whilst they are kept cold but when the tongues become hot, the sample-cooling rate slows and the physical structure of the cryolite sample changes, thus giving differences in the XRD analysis [4]. Another problem with present methods of bath composition determination is the time delay of typically 6-10 hours between taking samples, having those samples analysed and the data finally being entered into the computer. The delay between sampling and the computer calculating the chemical additions prolongs the time at which the bath operates at non-optimal conditions.

Some smelters calculate superheat from bath chemistry and bath temperature measurements taken separately; liquidus temperature is then calculated using a theoretical liquidus equation [5-8]. In addition to the potential sampling errors outlined earlier, inaccurate liquidus data can be determined because not all the constituents in the bath are analysed or taken into account in the liquidus equation. Taking bath temperatures and bath samples separately can introduce further errors into the superheat calculation [4]. With the above potential errors in mind it is not surprising that some smelters occasionally observe apparent negative superheats [9]. Recent developments in direct measurement superheat sensors have raised serious doubts as to whether negative superheat actually exists [4, 10].

In the current project at the TRIMET smelter frequent measurements were taken of bath temperature (Tb) and liquidus temperature (Liq) using the Heraeus Electro-Nite disposable "superheat" sensor. [11, 12, 13]. The use of this type of sensor replaces traditional bath temperature measurement techniques;

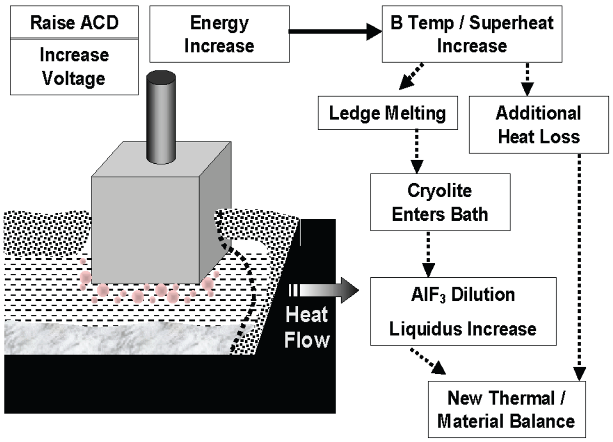

Figure 1: Cycle of cell imbalance caused by increased energy input.

and the requirement to take bath samples for chemical analysis no longer exists. Additional disposable sensors were used for making combined measurements of bath temperature and cathode voltage drop (CVD) in order to monitor sludge formation [14].

3. Heat and Mass Balance

Changes in thermal balance and material balance influence the stability of a cell. Among other parameters, thermal balance is affected by the energy input to a cell and changes in thermal balance affect the stability of the ledge (Figure 1). Chemical additives affect the material balance and changes in the material balance also affect the stability of the ledge (Figure 2). Thus, two components that have a significant impact upon the stability of a pot, thermal balance and material balance are intrinsically linked together due to the dynamic effects of ledge melting and freezing [15-18].

The liquidus temperature (melting point of the bath) is determined by the bath composition. The superheat (ΔT) is defined as the temperature difference between the bath temperature and the liquidus temperature. Superheat controls the thickness of the ledge (Figures 1 and 2) and provides the heat for heating up and dissolution of the alumina. Therefore the superheat should not be too low [10, 19].

4. 9-Box Control Algorithm

The objectives of an improved process control strategy are:

- Reduce the variation in bath temperature, liquidus temperature and superheat across the potline.
- Change to a more beneficial operating point, i.e. lower liquidus temperature, bath temperature and superheat, without running the risk of de-stabilising the pot.

Lowering the liquidus temperature will increase current efficiency because of the higher AlF_3 concentration in the bath. This effect is linked to the reduced metal solubility in the electrolyte. Lower bath temperature and superheat will reduce heat losses and decrease the energy consumption [10, 19, 20].

Higher excess AlF_3 concentration reduces the alumina solubility

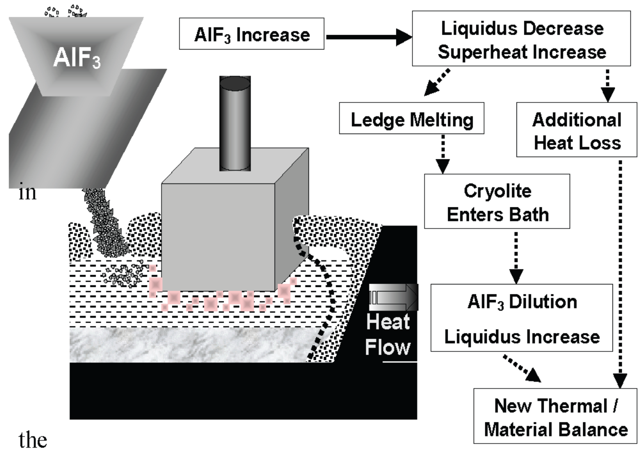

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Figure 2: Cycle of cell imbalance caused by increased AlF_3 addition

bath, which increases the risk of sludge formation, therefore it is necessary to closely monitor sludge formation with regular CVD measurements. Excessive sludge can lead to various problems during cell operation; one problem being noise due to disturbance of the cathodic current distribution. A further problem of operating pots at higher acidity levels is that it becomes more difficult to operate the pot in a stable manner [10, 19, 20].

The basic strategy of the 9-Box concept is governed by firstly, selecting a target bath temperature (e.g. 960°C) and applying control limits (e.g. 955 – 965°C). Secondly, selecting a target liquidus temperature (e.g. 950°C) and applying control limits (e.g. 945 – 955°C). The liquidus temperature is actually expressed as a 4 point moving average. By applying these control limits, 9 distinct boxes or zones are identified as shown in Figure 3.

Primary Control: - Voltage adjustments based upon bath temperature deviation from target. Where superheat permits, voltage is increased or decreased periodically to a new level. Based upon the voltage step response relationship; maximum limits are set for increase or decrease in voltage. Use of voltage as a control tool has also been postulated elsewhere [17, 18].

Secondary Control: - AlF_3 stepwise increase or decrease in addition depending upon the liquidus trend (4 point moving average) – initial additions are based upon the age of the pot. Maximum and minimum addition limits are set.

Superheat determines whether the control actions should be energy or material balance driven. For simplicity, the control algorithm is represented as a 9-box matrix (Figure 3). The central zone (Box 5) indicates the pots working limits.

Superheat sensor measurements determine in which of the 9 boxes, the pot is currently operating within. Depending upon the superheat level, each box has a diagnosis to either adjust voltage or AlF_3 addition rate in order to move the cell towards the central box (Box 5). The objective is to drive as many pots as possible into or close to Box 5.

5. Preliminary Optimisation of 9-Box Parameters

Before 9-Box Control can be introduced it is necessary to carry

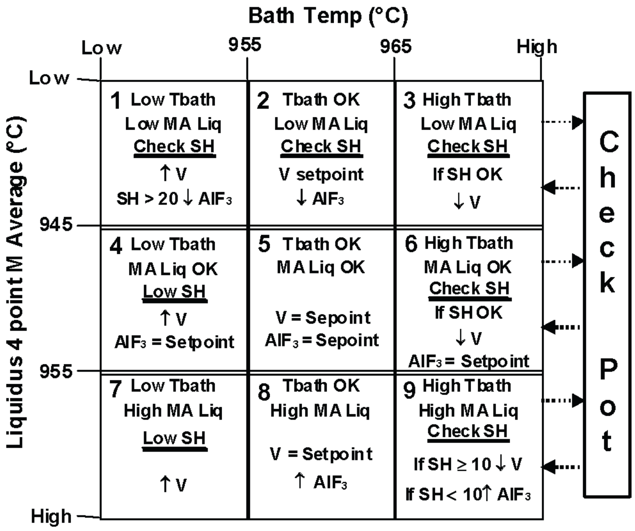

Figure 3: 9 Box Control Algorithm

out some preliminary investigations to determine the influence of voltage changes, changes in AlF_3 addition rates and pot disturbances on bath temperature, liquidus temperature and superheat. These investigations provide an understanding of how the pot reacts during normal operational disturbances, e.g. anode change or alumina feeding.

5.1 Influence of Anode Changing

The influence of anode change was investigated for a single anode (anode 17) and a double anode change (anode 12+4), as shown in Figure 4. Two pots were tested for each anode change schedule. The main purpose of this test was to identify the influence of an anode change on the bath and liquidus temperature as well as the recovery time for the pot to return to stability after anode change. It was assumed that the anodes closest to the measuring location would have the biggest influence on the measurement data.

Figure 5 shows the response of bath and liquidus temperature after changing Anode 17. Bath and liquidus temperature immediately fell on the introduction of the cold anode. Approximately 5 hours after the anode change, superheat had recovered, but it took 10 hours for bath temperature and liquidus to recover to their values prior to anode setting.

Table 1 shows that pots reacted differently depending upon whether a single or double anode was changed. Pot 2058 indicates that carrying out tapping just prior to anode changing

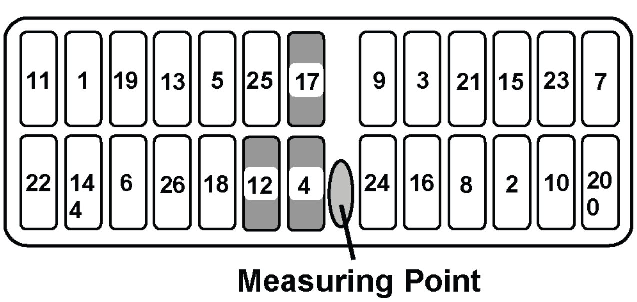

Figure 4: Anode Setting Pattern

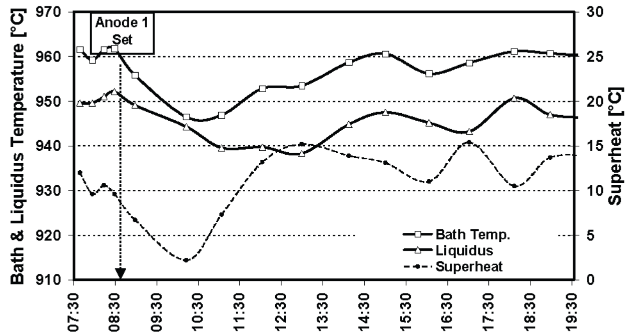

Figure 5: Bath temperature, liquidus and superheat response after the change of anode 17 for pot 2066

might have a beneficial effect on the recovery time. In this case the pot was tapped late, very close to scheduled anode setting. Summarizing the results for anode changing, a minimum of 12 hours between anode change and superheat measurement is recommended.

Table 1: Anode setting summary

Pot	Anode change	Time to recover
2066	17	10 hours
2067	17	12 hours
2058	17 + tapping	7 hours
2053	12/4	8 hours
2055	12/4	10 hours

5.2 Influence of Feed Cycle

Two pots were measured for bath temperature, liquidus and superheat every 10 minutes throughout two consecutive feed cycles. Figure 6 shows the typical response during a complete feed cycle; (e.g. 70% underfeed, 120% normal overfeed and 192% accelerated overfeed). Bath and liquidus temperature reacted in the expected manner when cold alumina was added to the pot, i.e. bath temperature reduced followed by a fall in liquidus due to the change in bath chemistry. Table 2 summarizes the results obtained during the trial. It can be seen that bath temperature changed up to 5°C during one feed cycle whereas

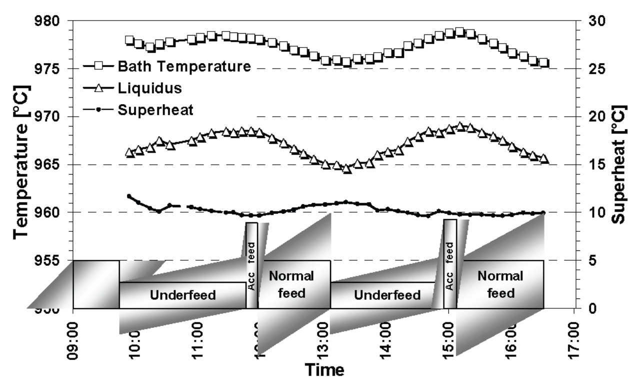

Figure 6: Response to Alumina feed cycle (70% underfeed, 120% normal feed and 192% accelerated feed)

liquidus temperature varied by 7°C due to the change of the heat balance and chemistry of the bath. It was concluded that the measurement of the bath and liquidus temperature could be taken at any time in the feeding cycle without having a major influence on the 9-box control strategy.

Table 2: Alumina feeding response

Pot	Minimum Tb	Maximum Tb	Difference
2041	972.4°C	975.9°C	3.5
2043	974.4°C	979.4°C	5.0
Pot	**Minimum Tliq**	**Maximum Tliq**	**Difference**
2041	955.6°C	962.9°C	7.3
2043	963.1°C	969.9°C	6.8
Pot	**Minimum SH**	**Maximum SH**	**Difference**
2041	11.9°C	17.4°C	5.5
2043	6.7°C	12.1°C	5.4

5.3 Influence of Voltage Step Response

Voltage step response tests were carried out in steps from +/- 50, 100, 150, 200 and 300 mV deviation from the set point voltage. Two pots were selected for each test and voltage was applied / reduced for a 24 hour period. The results of these tests were analysed to determine equations for the response of bath temperature and superheat to voltage addition and reduction. Table 3 summarizes the results of the voltage step response tests. The results indicate that the bath temperature is influenced greater by a voltage change than the liquidus temperature. The response of the liquidus temperature is more closely linked to the ledge dynamics and, therefore, more time related than the response to rapid energy changes. In summarizing, the step response tests, a change of +/- 100 mV voltage addition / reduction resulted in approximately +/- 7°C bath temperature change and +/-3°C superheat change over 24 hours.

Table 3: Voltage step response in 24 hours

Voltage Change	Tb change °C	SH Change °C
+ 100 mV	+ 7	+ 3
- 100 mV	- 7	- 3
+ 300 mV	+ 21	+ 9
-300 mV	- 17	- 8

5.4 Influence of AlF_3 Addition

The response to AlF_3 addition was tested over a 4-week period, where standard additions (std) (~23kg/day depending upon pot age) were made during the first week, followed by varying AlF_3 additions during the second week from ½ std, std, 1½ std and 2x std. During the third and fourth weeks all pots reverted back to standard additions. All pots received daily additions of AlF_3. Bath temperature, liquidus and superheat were measured daily to monitor the influence of AlF_3 addition rate. Table 4 shows the liquidus temperature response to changes in AlF_3 addition. From the tests it was observed that liquidus temperature is mostly influenced by the gradual change of bath chemistry, whilst the bath temperature is slowly following the liquidus. When AlF_3 addition was reduced to half the amount of the standard addition, it was observed that liquidus temperature increased by about 2°C/day. It was also observed that there was a time delay of some 3-4 days before the full effect of an AlF_3 addition was realised by the liquidus temperature. Due to this time dependent lag, the use of 4 point moving average for the liquidus temperature (LMA) is recommended. It was decided from the trials that changes in AlF_3 addition per day should be gradual and in discrete 6 kg steps.

Table 4: AlF_3 addition step response

Designation	Addition in kg / pot day	Tliq shift °C / day
0	0	4.0
0.5	11	2.0
1 (base)	23	-0.3
1.5	34	-1.6
2	46	-3.0

6. Implementation of 9 Box Control

6.1 Field Test on 40 Pots

A minimum validation period is needed during which time the 9 Box Control algorithm is fine-tuned on a section of test pots. In October 2001 a test campaign began with 40 pots (2041-80) in Line 2. These pots were assigned to operators from a special measurement group who were used to carrying out special tasks as part of routine production.

Temperature measurements were taken on a daily basis in the shift prior to scheduled anode changing. A four-day cycle of measurements was followed:

- Day 1 Combined bath and liquidus temperature
- Day 2 Bath temperature only
- Day 3 Combined bath and liquidus temperature
- Day 4 Combined bath temperature / CVD.

On the days when liquidus temperature was not measured, liquidus and superheat was predicted using the superheat equations derived in the voltage step response work in section 5.3. Based upon the latest bath temperature measurement, the previous liquidus measurement and the anticipated changes in superheat since the last liquidus measurement, superheat and liquidus were predicted. Any errors in the prediction were corrected 24 hours later when new liquidus measurements were taken.

Cathode voltage drop was measured every 4^{th} day, always between the metal pad and a fixed connection to the external busbar. CVD results reflect the ageing of the cathode lining as well as the cell conditions regarding sludge and/or bottom freeze formation. To correctly quantify these effects it was necessary to distinguish between long and short-term variations. Long-term increase in the CVD base level is associated with sodium / AlF_3 intercalation of the carbon lining, particularly during the early lifetime of a cell. Short-term swings in CVD (days to weeks) are caused by sludge and/or bottom freeze formation [14]. The 9 Box control logic links the CVD measurements to the energy balance. When CVD exceeds a preset upper limit, the algorithm automatically increased the bath temperature control band by 5°C and liquidus 4 point moving average control band by 3°C. The average increase in the superheat from 10–12 °C resulted in an increased energy input to the cell, thus raising the liquidus temperature and reducing acidity. This reduced bath acidity promotes an increase in the alumina solubility, thus reversing the tendency to form sludge. When the CVD value returned below the preset CVD limit, the algorithm automatically lowered the bath temperature and liquidus control bands to their original values.

Using the 9-Box Control algorithm each pot was treated as an individual in terms of energy input and chemical composition of the bath. This means that if the heat and mass balance of the pots are individually controlled then it is possible to operate a large number of pots in a stable manner and maintain the production of every pot at its individual optimum. This philosophy of controlling pots is rather new to many in the aluminium industry.

Computer software was developed which contained the 9-box algorithm and individual pot data for 40 pots. After the measurements were completed, the results were pasted into the software and, based upon the equations generated in Section 5, the program calculated the target voltage and AlF_3 additions for the next 24 hours. Each pot had its own set point data to keep the pot within or close to its control band of Tb and LMA. Once the pot reached Box 5 the pot was considered to be in a stable heat and mass balance. If the pot drifted out of the control bands the program would respond with either a voltage addition or reduction (provided sufficient superheat) for a constant heat balance. Similarly, step-wise (6 kg steps) increase or decrease of the AlF_3 addition was made to achieve a constant mass balance. Daily results were displayed on a report sheet. This sheet contained easily interpreted information and advice to enable the operator to carry out the pot adjustments quickly and efficiently. The information given in the report page are illustrated in Figure

							1	0	0	
Report Date:	12/11/2001						0	15	1	
							0	1	2	
				Report For :			12/11/2001			
Pot #	Bath Temp	Liq. Temp	S/heat	Liq. MA	Box#	Consec. Repeats	Target Voltage	AlF3 (Kgs)	Pot Age	Comments
2041	964	951	13	950	5	1	4.28	19	1621	; Pot in control limits
2043	953	937	15	944	1	1	4.43	19	2595	
2045	962	945	16	946	5	7	4.28	21	498	; Pot in control limits
2047	958	937	20	945	5	1	4.28	25	1248	; Pot in control limits
2049	956	941	16	947	5	1	4.28	25	1429	; Pot in control limits
2051	959	947	12	949	5	1	4.28	27	1110	; Pot in control limits
2053	973	964	9	959	9	2	4.28	31	1506	; Check Pot
2055	960	958	2	959	8	1	4.28	41	1834	
2057	969	964	6	957	9	1	4.28	33	893	; Check Pot
2059	965	952	13	951	5	2	4.33	27	2567	; Pot in control limits
2061	964	954	10	951	5	8	4.28	27	1156	; Pot in control limits
2063	966	955	11	954	6	1	4.19	27	1422	; Check Pot
2065	965	952	13	950	5	11	4.33	25	1102	; Pot in control limits
2067	962	952	10	954	5	6	4.28	25	1150	; Pot in control limits
2069	964	951	13	952	5	2	4.33	25	2685	; Pot in control limits
2071	964	950	14	951	5	1	4.28	23	1901	; Pot in control limits
2073	960	948	11	948	5	2	4.28	25	900	; Pot in control limits
2075	961	952	9	953	5	7	4.38	25	1002	; Pot in control limits
2077	959	948	11	947	5	12	4.28	23	1933	; Pot in control limits
2079	963	952	11	955	5	1	4.28	25	1426	; Pot in control limits

Figure 7: Daily results displayed on report page

7.

All process relevant long term data, e.g. bath temperature, liquidus temperature, superheat, pot voltage, additional voltage, anode effect data, noise, cathode voltage drop, metal pad height and AlF_3 content were stored within the program. To assist in the supervision of the pots on an individual basis, and as a tool for further development of the 9 Box algorithm, the data was graphically displayed over a 2 –3 month period for each pot.

All the recommendations, advice and graphical presentations within the software helped the operators to react quicker when disturbances and abnormalities occurred. Recommendations were for example, the periodic measurement of the anodic current distribution, a historical check of temperature stability, noise development and an improved spike-tracking rate. The check for spikes was initiated when the superheat became greater than 18°C. At the same time that the new control strategy was introduced the pot tending procedures were also changed. During anode change for example, the anode cavity was cleaned more

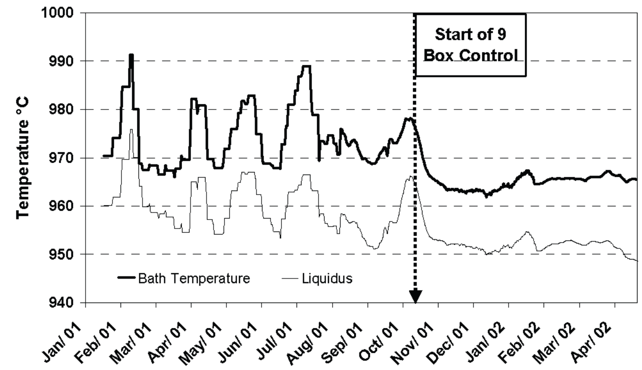

Figure 8: Bath temperature and liquidus performance using old and new control strategies

thoroughly than in the past, to ensure removal of lumps of frozen crust. This was a necessary step for the successful implementation of voltage reduction.

Due to the individual control of every pot it was possible to reduce the swing in the process variables, such as bath temperature and liquidus variation (Figure 8). The standard deviation for bath temperature also decreased on average from about 12 to 7. As a consequence of controlling the liquidus temperature at a lower level and within relatively tight limits, the AlF_3 content increased from 12% to 13.5% with average values of 4.8% CaF_2 and 2-3% Al_2O_3 (Figure 9). The better control of the chemical composition of the bath and higher AlF_3

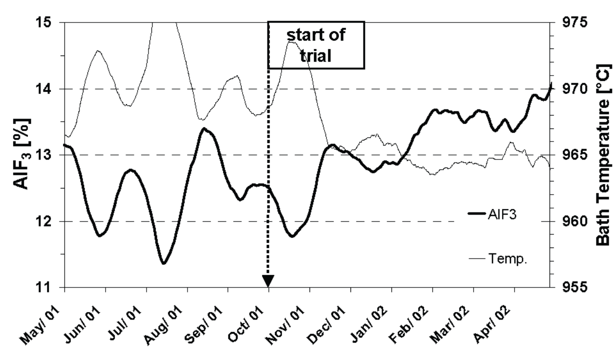

Figure 9: Development of the AlF_3 excess in the bath for the 40 test pots (30 days moving average)

concentration coupled with the greater ledge stability led to a higher current efficiency. The increased risk of sludge formation and bottom freeze was monitored with frequent CVD measurements.

Figure 10 shows the average pot voltage for 40 pots and average alumina consumption over a 12-month period. Since the start of the trial, the cell voltage reduced more than 100 mV whilst the higher alumina consumption indicated increased Al production.

Average superheat was reduced from values greater 15°C with the old strategy to 10-12°C with the new 9 box strategy (Figure

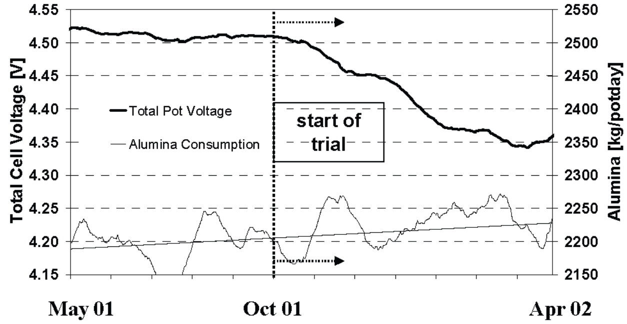

Figure 10: Cell voltage and Al2O3 consumption for 40 test pots (30 day moving average)

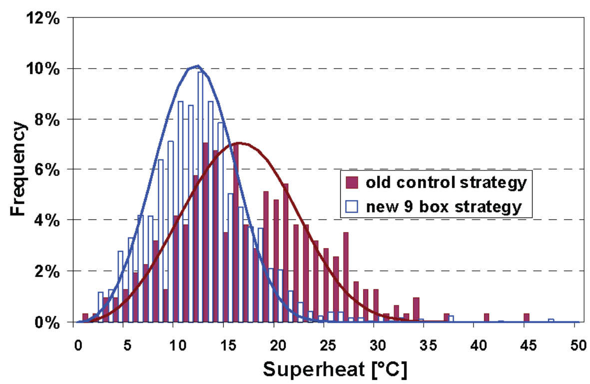

Figure 11: Superheat distribution for 40 pots in the test section for 2 month; July-August 02 - old control strategy and November-December 02 – new 9 box strategy

11). In addition, the average superheat distribution narrowed with the implementation of 9 Box control. Reaching superheats around 10°C with the current Essen system of pot shell isolation and feeding technology can be considered a good achievement because the pot is prone to sludge formation and bottom freeze. To reduce the average superheats below 10°C would require further development of the pot shells and feeding system.

Since 9-box control was introduced the current efficiency increased by more than 1%, whilst the specific energy consumption per kg Al was reduced by about 0.6 kWh/kg. For a smelter geographically located in an area where energy is expensive (coal-fired power plant), the potential energy savings, if achieved across the whole plant, provide a major justification to implement 9 Box control.

6.2 Full Implementation of 9-Box to Line 2

The final stage of the development was to expand the test of the new control procedure to an industrial scale of pots over a longer period of time in order to evaluate potential cost savings. Based upon the increased current efficiency and reduced energy consumption from the 40 test pots, the decision was made to expand the 9-Box Control over the whole of Line 2. 120 pots were gradually taken under control with the new strategy. The time schedule was as follows:

- **October 2001 40 pots – 2041-80 (11 month control)**
- **April 2002 40 pots – 2081-120 (5 month control)**
- **June 2002 40 pots – 2001- 40 (3 month control)**

Before expanding 9-box to the whole line it was decided to provide training in the form of a course for all shift leaders and foremen. The purpose of the course was to inform and educate the smelter personnel to capture interest in this potentially cost saving project. The course provided basic information about the new measuring equipment, the basic concepts of 9 Box Control and the perceived benefits to the smelter. This work was considered necessary because the new strategy was breaking with the traditional concepts for the control of bath temperature and bath chemistry.

A major milestone in transforming the project from a pilot scale to industrial scale was the development and programming of a databased software package of the 9-box algorithm into the plant computer. The plant software gave a new dimension to the control strategy compared to earlier versions of "stand alone" software used for the 40-pot trial. Pot voltages, anode effect data and noise data was fed "live" into the plant computer software enabling the early recognition, diagnosis and elimination of disturbances and abnormalities.

Development of new, semi-automated, user-friendly equipment for superheat measurements was considered essential if the new technology was to be embraced by the production operators. Figure 12 shows the semi-automated measuring device used for liquidus measurements. This vehicle contains batteries, an industrial PC for data analysis and an easily driven and less physically demanding immersion lance. The availability of such a device made it relatively easy to convince the operators of the need to change their job routines.

Figure 12: "Manipulator" equipment for easy liquidus measurements

The performance of Line 2 was evaluated over a 12-month period with various sections being introduced to 9-box control over the evaluation period. Figures 13-15 illustrate potline performance in terms of % current efficiency, specific energy consumption and average pot voltage during the stepwise conversion of Line 2. The section where 9-Box trials started (11 month control – pots 2041-80) shows the best performance with the highest current efficiency, lowest pot voltage and lowest energy consumption over an 11-month period. The section controlled longest with the old strategy, (3 month control with 9 Box – pots 2001- 40), shows the poorest performance. Comparison data in Table 5 show the production figures from June to August 2001 for the **old control strategy** compared to June to August 2002 for the **new control strategy,** all data taken from the 120 pots in Line 2. It can be seen that the introduction of 9-Box Control across the whole of Line 2 has given a similar 1% increase in current efficiency and reduction (0.6 kWh/kg Al) in energy consumption to that achieved in the earlier pilot test of 40 pots.

Table 5: Comparison of production figures for Line 2

	Current Efficiency	Energy Consumption	Average Pot Voltage
June 01 – August 01	91.3%	14.81 kWh/kg	4.53 Volt
June 02 – August 02	92.8%	14.18 kWh/kg	4.40 Volt

On the basis of the industrial trial, it was considered that the introduction of 9 Box Control together with improved pot tending work practices had made a major contribution to the increased productivity and lower energy consumption at the plant. As a consequence of this the decision was made in 2002 to extend 9-Box Control to all 3 potlines (360 pots) at the TRIMET Essen smelter. It is also planned that more theoretical training will be given to the operators in order that they gain a better understanding of the process operation and at the same time inspire a higher motivation level.

Reduced energy consumption is the biggest benefit of the new 9-Box Control strategy at TRIMET Essen, because of the high energy costs in Germany. This new control philosophy will however, maintain the competitive edge of the smelter at a time when energy costs, particularly in Europe, are increasingly determining the viability of an aluminium smelters future.

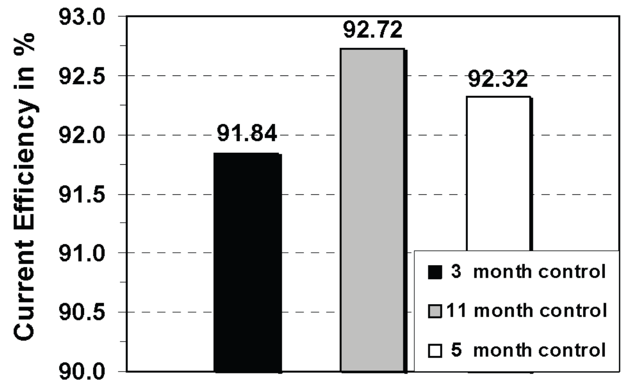

Figure 13: Current Efficiency 11 month average from October 01 to August 02 (3 month pots 2001-40; 11 month pots 2041-80; 5 month pots 2081-120

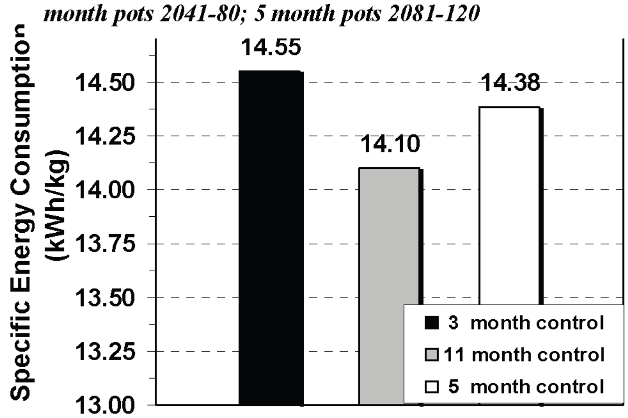

Figure 14: Specific energy consumption 11 month average (October 01 – August 02)

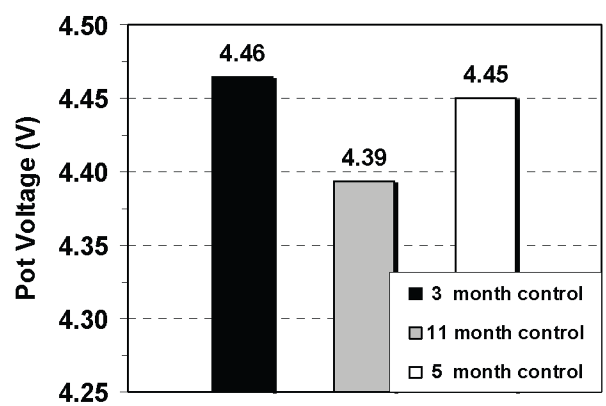

Figure 15: Pot voltage 11 month average (October 01 – August 02)

7. Conclusions

A new control strategy which links energy and mass balance control has been successfully developed and initially tested on 40 pots at the TRIMET Essen smelter in Germany. Subsequently, the control strategy was implemented across the whole of Line 2 (120 pots). Crucial to the success of 9-Box Control is:

- Use of accurate, reproducible sensors for thermal measurements coupled with reliable transfer of data from potroom to process computer.
- Development of new software for algorithm implementation together with improved visual graphics to analyse for pot parameter trends.
- Education and training of production personnel to enable an understanding of the changes being implemented.
- Improved pot tending work practices to accommodate the new measuring techniques and control system.

As a result of the above changes and approximately 12 months operation of 9-Box control, the perceived benefits to the TRIMET Essen smelter are:

- More stable pot operation and improved performance.
- Less variation (swings) of process parameters.
- Approximately 1% increase in current efficiency.
- Approximately 0.6 kWh/kg Al lower specific energy consumption.
- Optimum use of chemical additions to maintain stable composition control.

Following improved pot performance, the TRIMET Essen smelter is now committed to introducing 9-Box Control across the whole plant by the end of 2002.

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