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TECHNICAL RESULTS OF IMPROVED SOEDERBERG CELLS

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In recent years Mitsubishi Light Metal Industries Limited (MLI) has been enjoying excellent technical results in the Söderberg operation which can well compete with that of the prebake anode operation.
The level of power consumption is lower than 13,000 kWh/ton-Al and the paste consumption less than 500 kg/ton-Al in our Naoetsu Plant. This is the result of improving the anode property of pitch coke basis material and the development of computer controlled pot operations.
The present anode techniques consist mainly of optimizing the paste producing conditions and lowering the pitch content of the anode.
Pertaing to the cathode block, a pitch coke basis semi-graphite carbon has been developed for it.

Introduction

At the Naoetsu Plant of MLI, the first potline started in 1963, followed by the second one in 1966, the third one in 1968 and the fourth one in 1970, thus reaching the maximum annual capacity of 160,000 metric tons.

In the reduction plant, we started with the pots designed by Aluminum-Pechiney, afterward we introduced the technologies of "Dry anode" and "Automatic Crust Breaker". And simultaneously, we proceeded with our studies of our own technologies, such as the simulation technique of pot's design and pot's condition, the improvements of the anode properties and the cathode capability, and the development of computer control technique. Step by step, we have applied those techniques to whole potlines, and have obtained the excellent technical results which can well compete with that of the Prebake type operation.

Due to the oil crisis, however, we decided to close down even such an efficient reduction plant.

In this report, we will show the technical results that have been actually observed in Söderberg operation in our Naoetsu Plant.

Operational Results

The transitions of the improved direct current power consumption and the improved anode paste consumption are shown in Figure 1. After 1976, those results were improved rapidly because of introducing the dry anode and the automatic crust breaker, and then after 1978, were improved dramatically by the technologies of MLI. Those technologies are as follows;

1, The pot design technique which consists of a magnetic field (1),(2), the thermal distribution (3), the potential distribution and the pot's condition (4),(5) by computer simulation at the Research Laboratory of MLI.

2, The anode paste manufacturing technique.

3, The improvement of cathode lining materials.

4, The operational technique which is based mainly on a computer control system.

The operational results of the different cathode type pots in 1981 are shown in Table I.

The Essence of the Improvement

Improvement of the Anode

With the dry paste Söderberg anode, we call the bulk of anode block "primary anode", and the anode under the spikes "secondary anode".
The qualities to be required for the anode are: lower anode voltage drop, lower consumption, and stability avoiding loss, etc. It is known that the quality of the anode carbon depends on the filler coke composition.

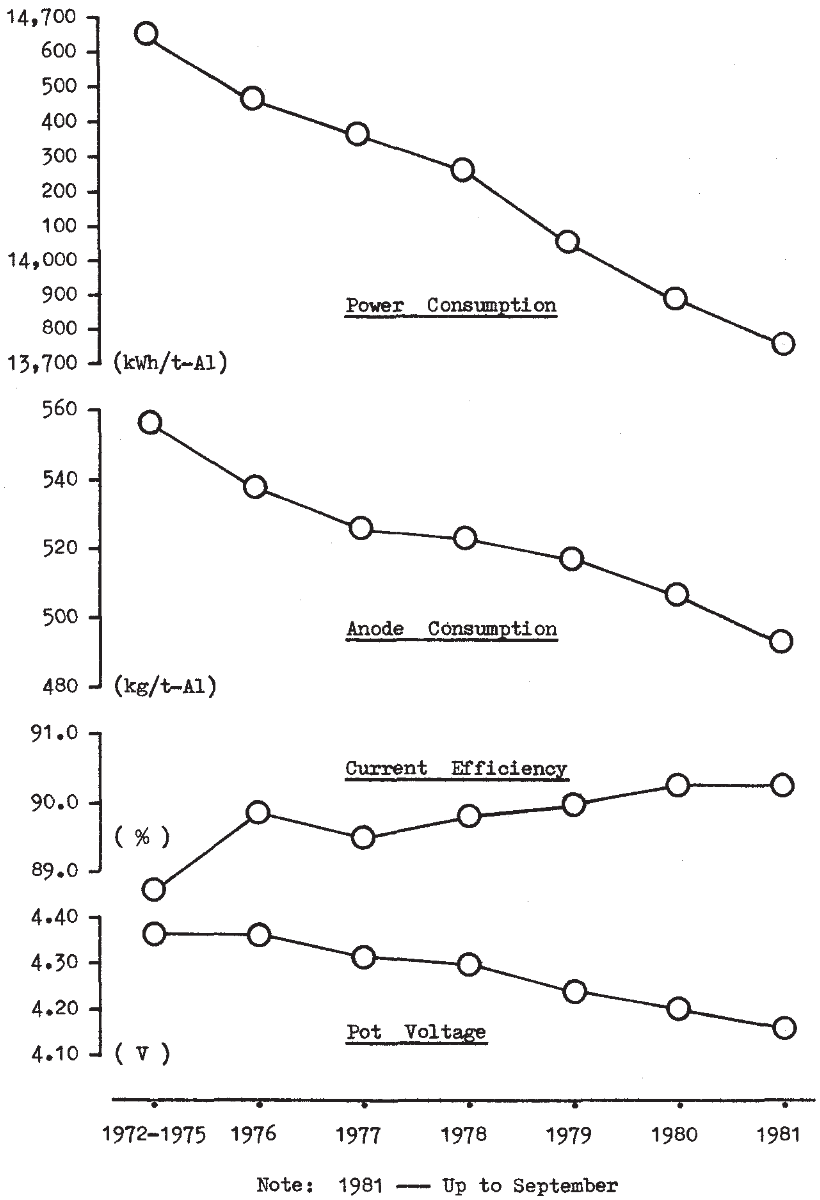


Figure 1. Technical Results in Naoetsu Plant

TABLE I. OPERATIONAL RESULTS IN 1981

	Type 1	Type 2	Type 3	Type 4	Newest test
Anode Voltage Drop (V)	0.46	0.46	0.46	0.46	0.37
Cathode Voltage Drop (V)	0.40	0.32	0.26	0.20	0.20
Total Voltage (V)	4.26	4.20	4.10	3.99	3.90
Current Efficiency (%)	89.6	90.8	91.7	91.7	92.0
Power Consumption (kWh/t)	14,200	13,800	13,350	13,000	12,650
Anode Consumption (kg/t)	490	490	490	490	480

Type 1 : Using anthracite bed carbon.

Type 2 : Using semi-graphite bed carbon based on oil coke.

Type 3 : Using semi-graphite bed carbon based on pitch coke and improved collector bars.

Type 4 : Using semi-graphite bed carbon based on pitch coke and further improved collector bars.

Primary Anode The first step to improve the primary anode was to develop an experimental method in order to obtain samples having properties similar to the actual anode. Then, using this experimental method, 150 or more tests were performed by radically changing the granulometric composition in each fraction.

From these studies, we have discovered optimum filler coke compositions which dramatically improve the quality of the primary anode. The facts obtained through these studies are as follows:

1, The consumption of anode is minimized in the filler coke composition which minimized the binder pitch content for forming the paste. And the quantity of the fine fraction mainly affects the binder pitch content.

2, The effects of the quantity of coarse fraction are usually known as: The greater the amount of coarse fraction, the lower the ratio of expantion-shrinkage, but the mechanical strength, such as crushing strength, tends to grow weaker. But to the contrary, the following result has been obtained through the MLI studies: The coarse fraction can be increased within the range of crushing strength value above 400 kg/cm^2.

3, The electrical resistivity of the anode carbon depends on the degree of compactness of coke particles. According to our studies, the lowest value of electrical resistivity has been obtained when the ratio of medium fraction per fine fraction is optimum.

4, The properties of experimentally baked carbon, which has optimum filler coke composition, are shown in Table II. From this result, we expected the improved results of a decrease in the anode voltage drop of more than 20 mV, and a decrease in the consumption of the anode to about 20 - 25 kg/ton-Al.

Table II. Properties of Experimentally Baked Carbon

	Optimum compositions	Previous compositions
Room temperature electrical resistivity (.cm)	6,300	7,000
Ratio of expantion-shrinkage (%)	0.15	0.35
Crushing strength (kg/cm^2)	480	490
Apparent density (g/cm^3)	1.62 - 1.63	1.61
Electrolytic consumption (%)	122	126

N.B Electrolytic consumption is the ratio of actual consumption per theoretical consumption.

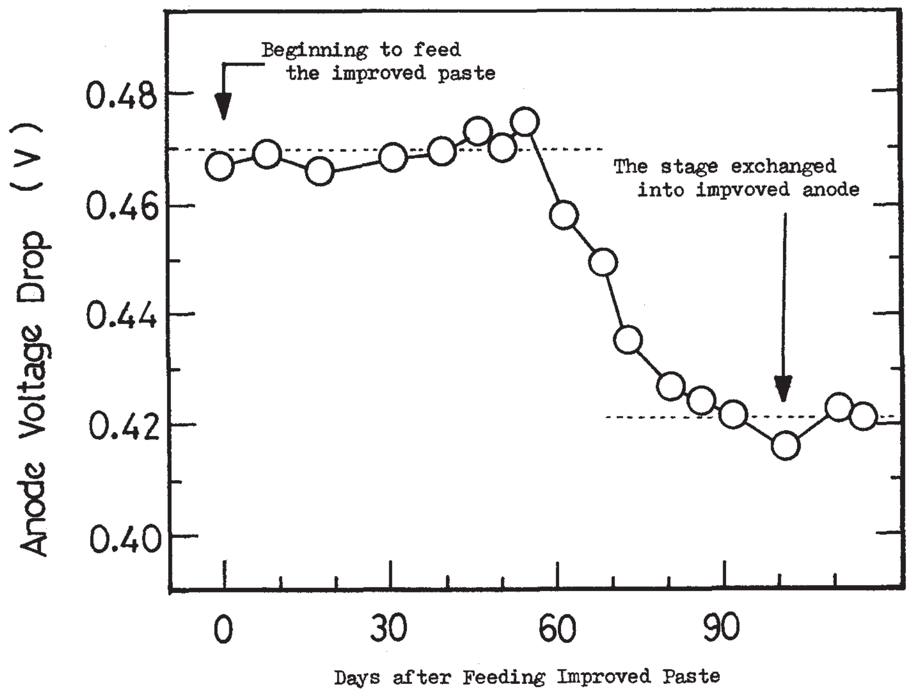


Figure 2. Anode Voltage Drop using Improved Primary Paste

From *Light Metals 1982*, J.E. Andersen, Editor

The paste formed with the obtained optimum filler coke composition has been used in thirty pots. It has been confirmed that the anode voltage drop has reduced by 50 mV, and the consumption of the anode decreased 25 kg/ton-Al as was expected.

As for the anode voltage drop, we have confirmed that the deviation from the expected value was caused by the low contact resistivity of spike-carbon due to the low expantion-shrinkage ratio.

The improved anode voltage drop is shown in Figure 2.

Secondary Anode As for the secondary anode, we have improved it with two steps. The schematic drawing of the secondary anode is shown in Figure 3.

First step: For decreasing the anode voltage drop, we have examined the sample of actual secondary anode, and have improved the filler coke composition to fill the clearance between the spike and the primary anode with a much richer filler coke.

We have already applied this secondary anode paste on the whole potlines and have obtained an anode voltage drop which is 50 mV lower than the previous type.
This decreased anode voltage drop is resulted from the primary anode sticking tightly to the spike.
The decreased anode voltage drop in whole potlines is shown in Figure 4.

Second step: In order to conquer the environmental problems, such as pitch fume emission, we have developed the preformed secondary anode, which consists of the cannon bullet type of secondary paste and the molten paste to fill the space in the spike hole.

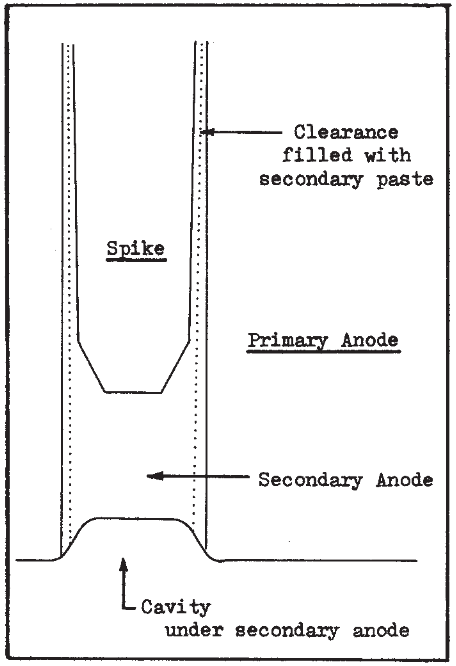


Figure 3. Schematic Drawing of Secondary Anode

The spike changing operation is done in such a way as to insert the preformed secondary paste and the molten paste into the same hole, instantly after pulling out the spike, then the new spike is replanted.
This saves the time usually required to melt the secondary paste in the spike hole.

The preformed secondary paste is formed as green anode pressed at about 350 kg/cm^2, and the molten paste is made up of more of the fine coke fraction, which makes the spike to stick tightly in both the preformed secondary paste and the primary anode. Consequently, the quality of the secondary anode is nearer to those of primary anode, and the anode problems such as froth carbon and the anode voltage drop can decrease. With the MLI test of the preformed secondary anode, the anode voltage drop decreased 50 - 70 mV due to the lowering of the spike. In this case the reconstruction of the spike pulling crane is necessary.

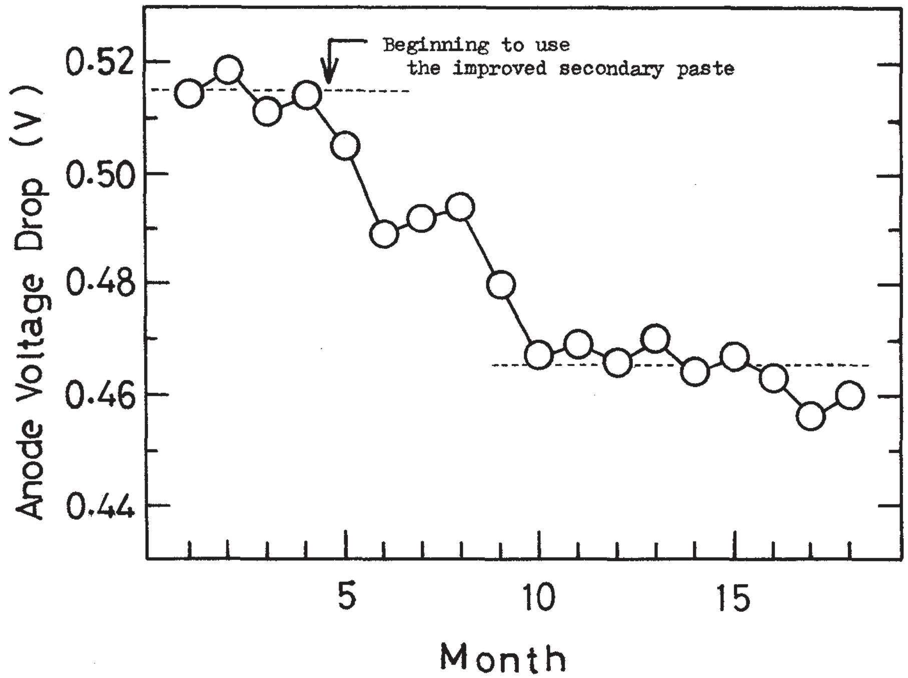


Figure 4. Anode Voltage Drop using Improved Secondary Paste in whole Potlines

Improvement of the Cathode

For decreasing the cathode voltage drop and extending the pot life, we havé developed the semi-graphite bed carbon, based on the pitch coke and the particular collector bars. And we have also developed the prebaked carbon block for large jointing part instead of the stamping paste. This prebaked carbon block which avoids the crack and the osmosis of the bath in the large jointing part is beneficial to keep the stable performance of the cathode.

From this combination, it has already been confirmed that the cathode voltage drop became lower than 0.20 volts, and the pot life extended from 4 - 5 years to 7 - 8 years. Without any difficulty we achieved the cathode design, including the thermal insulation corresponding to this combination, by computer simulation.

Development of Computer Control

In the operational technique, which depends mainly on the technique to keep the pot's condition stable, the computer control of the potline is usually used. The items for the usual computer control are:

(a) An alumina feeding control based on the prediction of anode effect.

(b) A pot voltage regulation.

(c) Control of the pot voltage swinging.

A deviation from the stable condition is caused mainly by a short circuit between the anode and the cathode, and the instability of the surface of cathode aluminum metal which is intensified by alumina sludge. Because of this, in addition to the usual computer control system, we have developed two of the most unique methods of computer control and the method of rapid data treatment that is most important for the control of the potline.

Diagnosis of Pot Condition It is known that the short circuit of the anode and the catode is detected by the voltage when the anode effect (A.E) occurs. And the variation of thermal balance in the pot is detected by the variation of the cathode shell temperature which means the variation of the frozen bath.

In many pot conditions, we have examined the A.E voltage and the cathode shell temperature, and we get the diagnosing diagram which shows the classified pot conditions as shown in figure 5.
With this method, the computer can give the instruction to the operator, and anyone can quickly examine the pot condition on the TV screen.

Additional Voltage Control In order to dissolve the alumina in the bath, a high heat quantity is required. In a continuous alumina supplying system, a constant heat quantity is required, which means to control the constant pot voltage. But in Söderberg pots, the supply of the alumina is periodical. In this case, the constant heat quantity causes the bath temperature to fall considerably, and results in the poor ability of the alumina to dissolve in the bath. Consequently, the chance for the alumina deposit on the cathode increases.

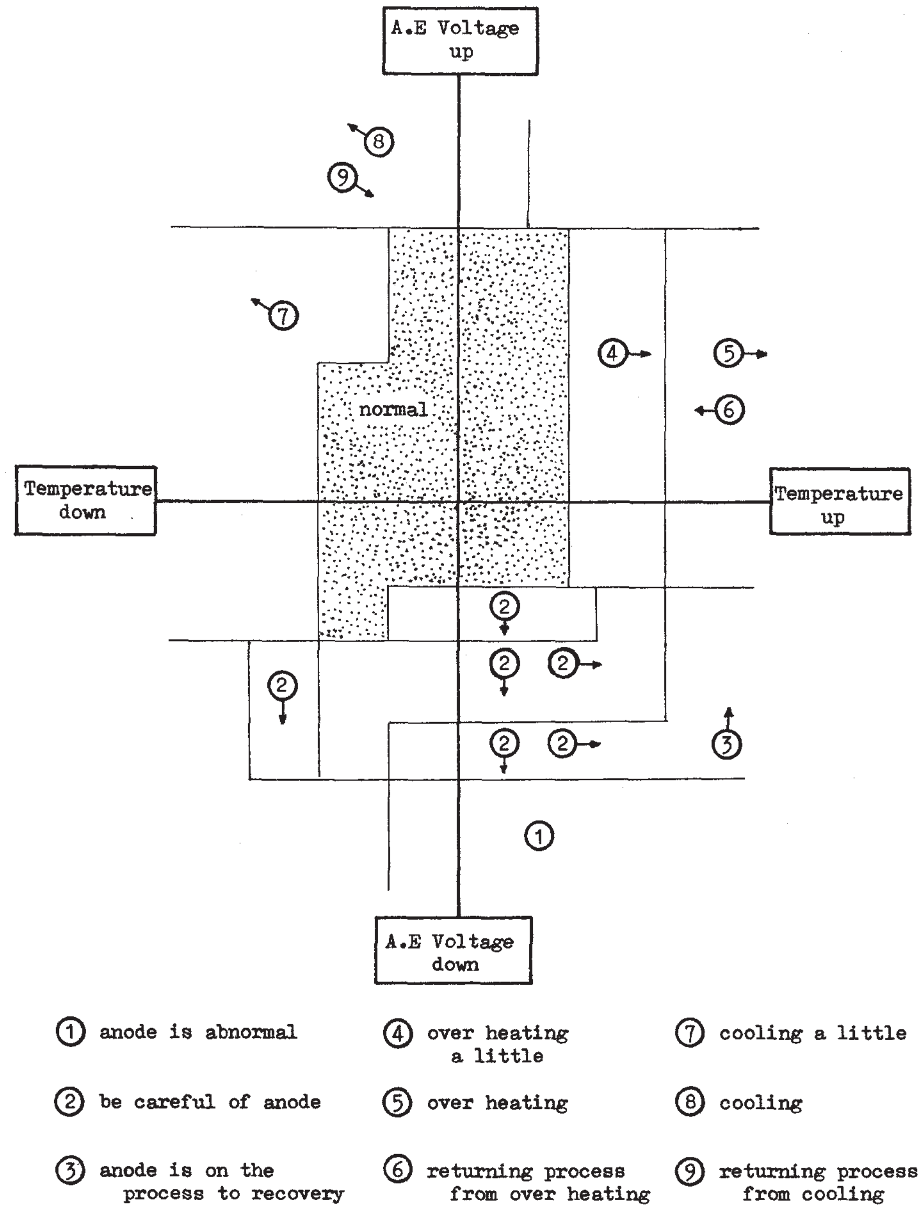


Figure 5. Diagnosis of Pot Condition

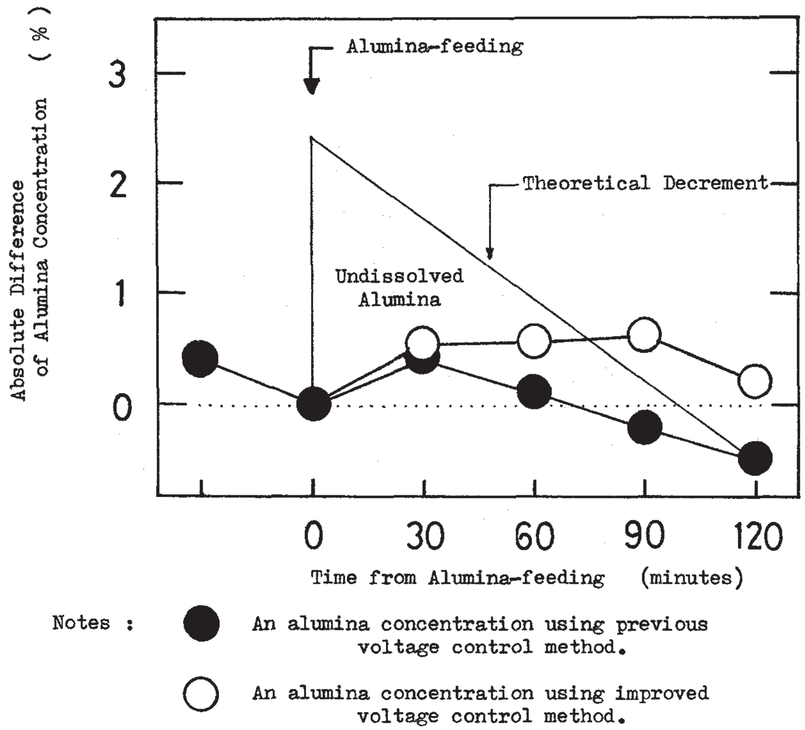


Figure 6. Actual Alumina Concentration

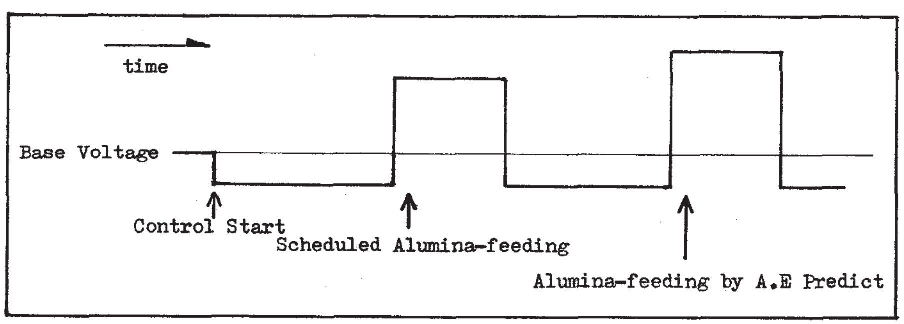
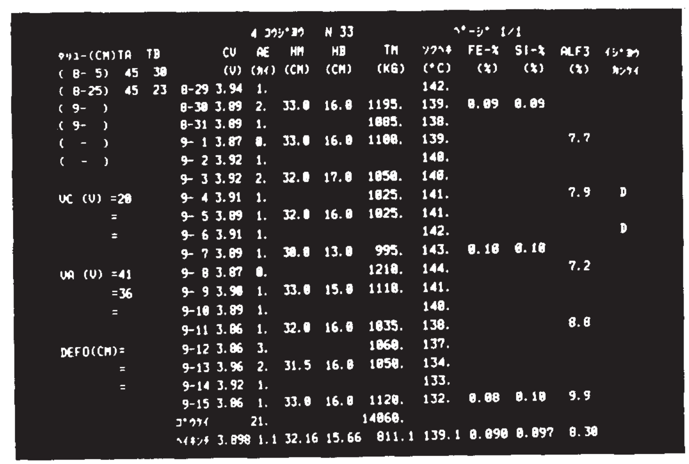


Figure 7. Conceptual Improved Pot Voltage Control

Figure 8. Operating the Keyboard



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ﾀｯｼｭ-(CM)	TA	TB		CV (V)	AE (ｶｲ)	HM (CM)	HB (CM)	TM (KG)	ｿｸﾍｷ (°C)	FE-% (%)	SI-% (%)	ALF3 (%)	ｲｼﾞｮｳ ｶﾝﾁｲ
(8- 5)	45	30											
(8-25)	45	23	8-29	3.94	1.				142.				
(9-)			8-30	3.89	2.	33.0	16.0	1195.	139.	0.09	0.09		
(9-)			8-31	3.89	1.			1085.	138.				
(-)			9- 1	3.87	0.	33.0	16.0	1100.	139.			7.7	
(-)			9- 2	3.92	1.				140.				
			9- 3	3.92	2.	32.0	17.0	1050.	140.				
VC (V) =20			9- 4	3.91	1.			1025.	141.			7.9	D
=			9- 5	3.89	1.	32.0	16.0	1025.	141.				
=			9- 6	3.91	1.				142.				D
			9- 7	3.89	1.	30.0	13.0	995.	143.	0.10	0.10		
VA (V) =41			9- 8	3.87	0.			1210.	144.			7.2	
=36			9- 9	3.90	1.	33.0	15.0	1110.	141.				
=			9-10	3.89	1.				140.				
			9-11	3.86	1.	32.0	16.0	1035.	138.			8.0	
DEFO(CM)=			9-12	3.86	3.			1060.	137.				
=			9-13	3.96	2.	31.5	16.0	1050.	134.				
=			9-14	3.92	1.				133.				
			9-15	3.86	1.	33.0	16.0	1120.	132.	0.08	0.10	9.9	
			ｺﾞｳｹｲ		21.			14060.					
			ﾍｲｷﾝﾁ	3.898	1.1	32.16	15.66	811.1	139.1	0.090	0.097	8.30	

Figure 9. Displayed Data on TV Screen

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    81. 5...81. 8       A      4ｺｳｼﾞﾖｳ       ***      ｼﾖｳﾋ***
   +----+----+----+----+----+----+----+----+----+----+----+
   I   3   2   7  14  22  34  31  16   2   4   2 I
   +----+----+----+----+----+----+----+----+----+----+----+
   I                     S76                     I
   I                     S68                     I
   I                     S55                     I
   I                     S52 S79                 I
 30+                     S39 S75                 +
   I                     S37 S74                 I
   I                     S32 S69                 I
   I                     S31 S67                 I
   I                     S26 S65                 I
 25+                     S16 S57                 +
   I                     S 9 S53                 I
   I                     S 8 S48                 I
   I                 S73 S 6 S41                 I
   I                 S71 S 2 S36                 I
 20+                 S70 N77 S30                 +
   I                 S66 N73 S29                 I
   I                 S61 N64 S28                 I
   I                 S50 N62 S27                 I
   I                 S47 N61 S25 S78             I
 15+                 S46 N60 S19 S56             +
   I             S64 S45 N58 S17 S40             I
   I             S63 S38 N50 S 7 S34             I
   I             S58 S33 N49 S 1 S21             I
   I             S51 S23 N47 N75 S14             I
 10+             S43 S12 N44 N66 S13             +
   I             N79 S 5 N41 N59 S11             I
   I             N68 N55 N36 N56 S 4             I
   I         S59 N67 N48 N33 N54 N65             I
   I         S42 N27 N34 N28 N51 N63             I
  5+         N78 N25 N32 N21 N45 N57             +
   I         N72 N22 N24 N16 N40 N52     S35     I
   I S60     N53 N18 N10 N15 N38 N42     S 3     I
   I S54 N70 N35 N13 N 9 N 3 N31 N 6 S77 N43 S24 I
   I N23 N26 N12 N 8 N 7 N 1 N19 N 4 N69 N14 N74 I
   +----+----+----+----+----+----+----+----+----+----+----+
 MM    13.00     13.40     13.80     14.20     14.60     <
     <     13.20     13.60     14.00     14.40     14.80
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Figure 10. Printed Data of Histogram on Printer

(Anode Consumption Rate - mm/day -)

Therefore, in the acutual pot operation we have developed a new pot volage control system which responds to the supply of the alumina.

The transitions of the acutual alumina concentration in both the previous pot voltage control system and the improved pot voltage control system are shown in Figure 6, and the conceptual improved method of the pot voltage control is shown in Figure 7.

Data Banking and Displaying Online data, offline data, derivative data, total data of 190 items are sampled, gathered, calculated and stocked. The summarized and analyzed results are indicated systematically and quickly at real-time by request on the printer or the TV screen.

With this data treatment system, the time required for collecting and analyzing the various data decrease drastically. And we can quickly decide the operational policy of the potline and of the individual pot. Samples of the display are shown in Figure 8, 9 and 10.

Conclusion

Now, it has been proven that the technical results of Söderberg type operation can well compete with that of Prebake type operation. And the power consumption close to 12,500 kWh/ton-Al will be likely to be obtained with the Söderberg type operation.

In the Naoetsu Plant the reduction plant has been shut down, but from now on the need to save energy for the aluminum smelting operation will surely increase. We hope that this report will be usefull for aluminum smelters of the Söderberg type in the world.

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