

Preheat and Start-up Practice of SAMI SY 300 kA Prebake Pots at ETI Aluminium

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Abstract

This article gives a complete introduction for preheating and starting up of Shenyang Aluminium and Magnesium Institute (SAMI) SY 300 kA electrolysis potline in Turkey. As a key point, the article in particular analyzes and compares different methods of preheating and starting up cells and discusses in detail the improvements and practices of key technological aspects. It makes a scientific design for controlled changes of technical conditions of the cells after start up. The procedure implements new findings and is of special significance as reference for the start-up of prebake pots.

Keywords: SAMI SY 300 Smelter, preheating and start-up of pots, prebake electrolysis potline, cathode lining.

1. Introduction

In recent years, in the rapid development of aluminum electrolysis, the productive capacity of aluminum exceeded demand seriously; furthermore, the speed of economic growth slowed down and the pressure on economy intensified. Aluminum price has been continuously low and loss of money has become a difficult problem for the whole industry. In order to reduce cost and transform the loss into profit, aluminum industry has developed many new technologies, the technology development enterprises have made many useful trials in the process. Just to see from the stage of preheating and starting up, in order to reduce energy consumption, the preheating time has been shortened from 4 days to 3 days, and even shorter; it seems that the use of high voltage and three days of preheating time has become the common practice in the industry. Whether this is scientific and reasonable or not, there are really few people who review and think about these practices.

2. Conventional Start-up of Prebake Pot

Nowadays, most of Chinese aluminum smelters pour bath and have no start-up anode effect (AE) by preheating with coke. The pure calcined coke or a mixture of graphite and coke are used as heating resistance. The thickness is commonly from 1.5 to 2.5 cm. The charging material in the sidewall channels is composed of sodium carbonate, a small quantity of cryolite and bath lump material. Some companies even use a small quantity of magnesium fluoride or calcium fluoride. Before energizing, shunts must be mounted on all pots. In some companies, larger and smaller size of shunts are used simultaneously and use only part of the potline current and high voltage to preheat; the common preheating time is approximately 3 days. During the

preheating, phenomena such as uneven rate of temperature increase in different position and carbon burning may frequently occur. The data measured before bath up indicates that the abnormal temperature increase in cathode collector bars and potshell side may happen now and then, therefore, the use of compressed air is a common to decrease the temperature and guarantee a safe start up.

3. Preheat and Start-up of Turkish 300 kA Electrolysis Pot

The 300 kA electrolysis pot of Turkish ETI Aluminum is a large capacity advanced electrolysis pot, designed and developed by Shenyang Aluminium and Magnesium Institute (SAMI). It has integrated many new ideas and technologies. The service for starting up and operation management was undertaken by CHALCO Liancheng Branch. The potline began the start-up on 26 May 2015 and finished the start-up on 22 August 2015. During the whole start-up process, the pot preheating was smooth and good and no phenomena such as crust surface collapse and red stubs ever happened. During the start-up nearly none of the cathode windows had yellow smoke, the preheating temperature was even and the middle channel showed bright yellow colour with liquid bath. During start-up, there was no leakage and all 94 pots were started up smoothly and successfully and were changed over to normal operation and production quite well.

3.1. Preheat and Start-up Method

Electrical preheat was used and pouring liquid bath to start up without AE. The preheating time was 4 days.

3.1.1. The Choice and Proportion of Coke and Graphite Material

- (1) Choice of material: Both graphite and coke were purchased from Germany; the particle size was approximately 2 – 4 mm, the resistivity of graphite was 80 $\mu\Omega\text{m}$ and that of coke was 355 $\mu\Omega\text{m}$.
- (2) The proportion of graphite and coke:
During start up, two proportions of carbon material were used for preheat as follows:
 - Graphite to coke, 2:8, with resistance of the mixture of 290 $\mu\Omega\text{m}$;
 - Graphite to coke in the ratio of 1:9, with resistance of the mixture of 320 $\mu\Omega\text{m}$.
- (3) Laying out coke
The thickness of the mixture material was 2 cm; multi mesh positive cone sifter was used to lay out the bed. The contact surface area between anode and carbon bed was above 95 %.

3.1.2. Charging the Pot

- (4) Charging material included: High cryolite ratio (CR) cryolite, sodium carbonate and crushed bath, including 7 tonnes of cryolite, 14 tonnes of crushed bath, 3 tonnes of sodium carbonate, a total of 24 tons.
- (5) Charging method: Charge material by keeping central channel empty while laying between anodes and side blocks with different layers. Along the cathode surface of the central channel, only 5 cm thickness of cryolite was laid out in order to avoid oxidation of the cathode surface. Between anodes and side blocks, sequentially, from downstream to upstream, cryolite, sodium carbonate and crushed bath were charged. The thickness of material on anode top surface was 10 cm.

3.1.3. Conductive Path of the Anodes

The electric conduction path of 40 anodes and the anode beam was through preheat flexibles. This allowed anodes to adapt under their own weight and move upwards or downwards during preheating process and thus assured an even anode current distribution. The flexibles should be dismantled two hours before bath-up.

3.1.4. Mounting of the Shunt

In order to ease the impact of intense current to pot at the initial stage of energizing, the choice should be made whether to install shunts or not; this depends on the specific resistance of mixture of coke and graphite and on initial impact of pot voltage when the pot is energized. Install 3 groups of shunts if pot is laid out with pure coke (install shunts on risers 1, 3, 5 separately). Control initial impact pot voltage below 4 V. During preheating process, start to dismantle shunts as soon as voltage is below 3.5 V, normally shunts should be dismantled within 2 hours. Shunts are not required for pots which are laid out with mixture of coke and graphite.

Table 1. Situation of initial voltage for pots without shunts.

Proportion		Initial voltage		
		Average	Minimum	Maximum
Graphite: coke	2:8	3.49	3.318	3.870
	1:9	3.78	3.204	4.276

3.1.5. Preheat

Full current was used to preheat the pots which were laid out with a mixture of coke and graphite. Preheating time was 96 hours. Preheating temperature and anode current distribution are shown in Figures 1 and 2.

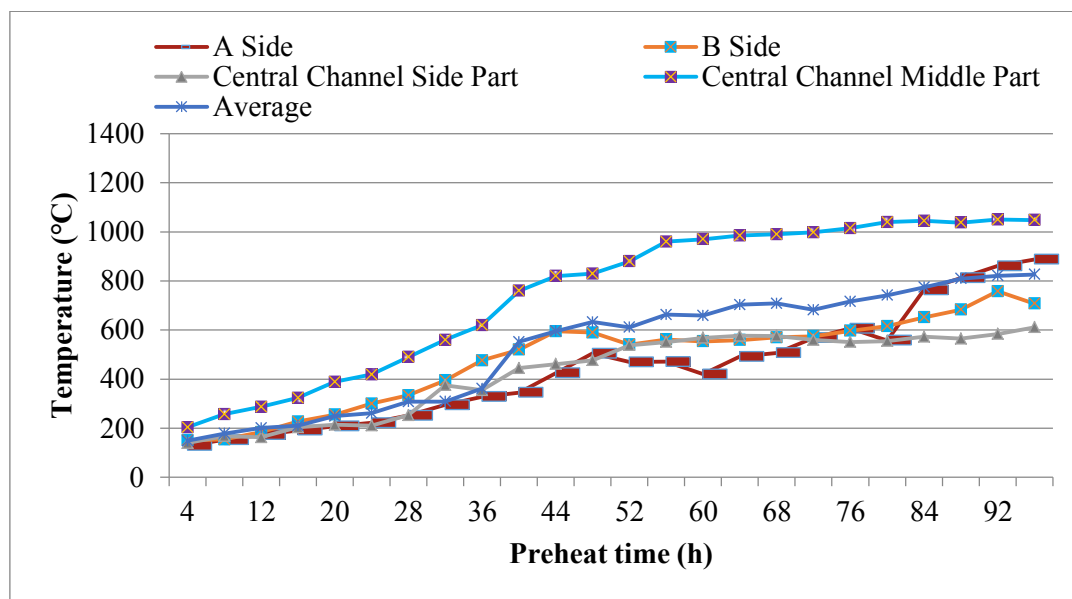


Figure 1. Preheat temperature.

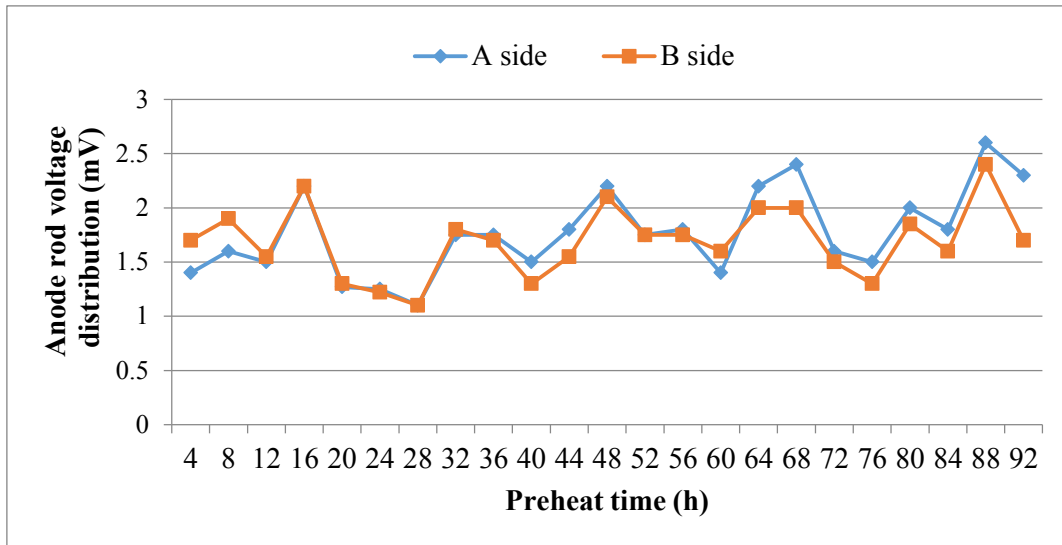


Figure 2. Anode rod voltage distribution during preheat (mV).

3.2. Start-up

3.2.1. Confirmation of Start-up Conditions

When preheat temperature at pot side reaches above 700 °C and at central channel reaches above 900 °C, the pot is ready to be bathed up.

3.2.2. Start-up

The process of starting up is composed of five steps: pouring liquid bath, melting of material, raising temperature with AE, skimming carbon dust, self-adaptive control in semi-automatic mode. The length of time is approximately 8 - 10 hours.

1) Pouring liquid bath

The total volume of liquid bath needed for pouring in a pot is 20 t. At the beginning, use two vacuum crucibles to pour liquid bath continuously, and must guarantee more than 5 t; it is quite important to increase the voltage during pouring liquid bath. Liquid bath flows to duct end through central channel, and when the liquid bath level rises to 30 cm down from the pot deck plate, start increasing voltage by raising the anodes. At first, increase the voltage to 3.5 - 4 V; for this anodes are raised more than 3 cm, then increase voltage accordingly following the pouring of liquid bath. Pay attention that during the raising of the anodes, the depth of anode immersion in liquid bath is more than 15 cm. At the end of pouring liquid bath, the voltage should be kept at 8.5 – 9 V and the distance from the level of liquid bath to pot deck plate is 25 - 30cm. The relationship between the amount of poured liquid bath (t), anode-cathode distance (ACD) (cm) and voltage during start-up (V) is shown in Figure 3.

2) Melting of materials

This is the most time-consuming stage during startup, and also a stage to be treated carefully by operators. The main three tasks are:

- At first, as per the situation of melting of material, push the material from the surface of anode into the pot, especially add material at these places when and where the melting rate is high in order to ensure an even temperature rise everywhere in pot;
- Secondly, regulate pot voltage dynamically to 8.5 to 9 V;

- Thirdly, skim carbon dust dcontinously at tap end (TE), duct end (DE) and awatch-hole or at corners.

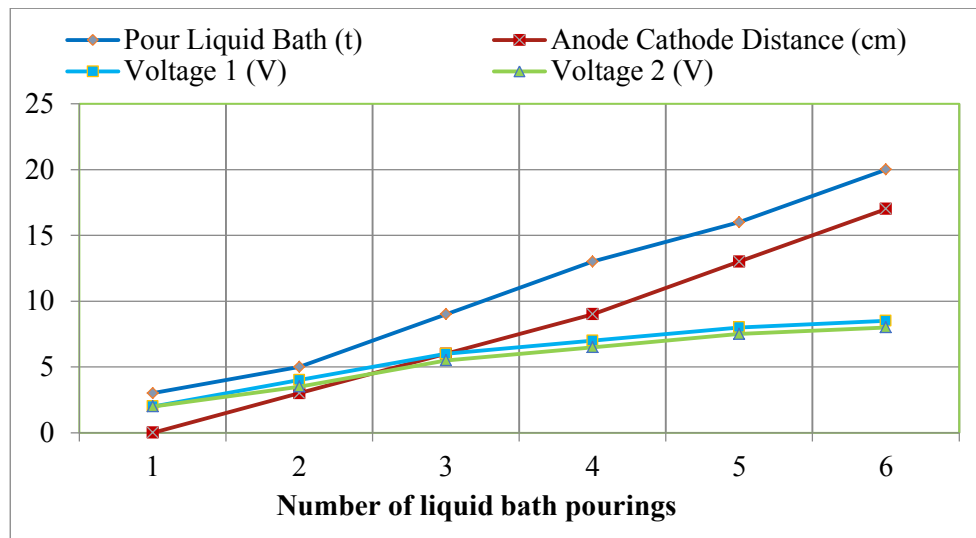


Figure 3. The relationship between amount of poured liquid bath (t), anode-cathode distance (ACD) (cm) and voltage during start-up (V).

3) Raise temperature by A.E.

When the materials in the pot essentially melt, raise voltage to 13 – 15 V to provoke an AE; keep the pot on AE in order to melt materials in the pot and increase temperature of liquid bath further. AE lasts about 30 - 40 minutes. When the temperature of liquid bath reaches 1000 – 1050 °C, quench AE by manually feeding alumina and decrease voltage to 7 - 7.5 V and keep it at this level.

4) Skimming carbon dust

Skimming carbon dust is a very important work during startup. Because the quantity of coke which was charged into pot during laying out of the coke and hanging the anodes is about 700 – 800 kg. If skimming is not well done during start up and too much of it remains in the pot, this will cause many troubles later; furthermore, it may make the pots sick, with anode spikes, etc. Thus, skimming must be paid high attention and must be done completely and carefully.

Skimming carbon dust is divided into four stages:

- At first, skimming carbon dust at the watch-hole of TE and DE after pouring liquid bath;
- Secondly, in the process of materials melting skim carbon dust at TE, DE or corners and other positions where the material is melting fast and carbon dust concentrates;
- Thirdly, after melting of material in pot and before manual AE, skim carbon dust from four sides of pot and the middle channel, this is the main skimming stage;
- Fourthly, skim after AE, at this stage there is a little carbon dust on the surface of liquid bath, and may skim at relevant positions.

5) Self adaptive control in semi-automatic mode

When voltage drops to 7 - 7.5 V and after the last skimming of carbon dust, switch pot to self-adaptive control in semi-automatic mode. At this time, alumina concentration is automatically controlled and voltage is manually controlled; this is the end of start-up.

3.2.3. Pouring Liquid Metal

The liquid metal needed for one pot is 17 tonnes, and will be poured into the pot twice. The first 9 tonnes will be poured at 16 hours after cover material melts and AE is quenched, the second pouring of 8 tonnes will be done 24 hours after cover material melts and AE is quenched. After the second pouring and when the surface of liquid bath forms crusts, put covering material and this is the start of early operation of the pot.

4. Regulation of Technological Parameters After Start-up and in Early Operation

4.1. Technological Data

(1) Set voltage

The rate of set voltage decrease with time is given in Table 2.

Table 2. Rate of decrease of pot voltage.

Time interval for voltage decrease		Voltage, V
1 day	After start up	6 - 6.5
	After first pouring liquid metal	5.5
	After second pouring liquid metal	4.8
3 days	100 mV/day	4.8 - 4.5
2 days	50 mV/day	4.5 - 4.4
10 days	20mV/day	4.4 - 4.2
15 days	10 mV/day	4.2 - 4.05

(2) Metal level and bath level

The metal and bath height targets are given in Table 3.

Table 3. Metal and bath height targets.

Parameter\Time	1 st week after start-up	2 nd week	3 rd week	4 th - 5 th week	2 nd month
Bath height (cm)	30 - 35	26 - 30	24 - 26	18 - 22	17 - 19
Metal level (cm)	17 - 19	18 - 20	~ 20 - 21	21 - 22	22 - 23

(3) Cryolite ratio (CR)

The CR targets are given in Table 4.

Table 4. Control plan for CR.

Parameter\Time	1 st week after start-up	2 nd - 4 th week	5 th - 6 th week	2 nd month	3 rd month
CR	~2.9 - 3.0	~2.85 - 2.9	~2.7 - 2.85	~2.55 - 2.7	~2.3 - 2.5

(4) Anode effect (AE) targets

The AE targets are given in Table 5.

Table 5. AE targets.

Parameter\Time	24 h	48 h	3 rd - 7 th day	8 th - 30 th day	2 nd month	From 3 rd month
AE frequency (#/pot-day)	1.0	1.0	0.5	0.3	0.15 - 0.2	≤ 0.1
AE duration (min)	≤ 10	≤ 5	≤ 3	≤ 2	≤ 2	≤ 2

(5) Alumina feeding interval

The alumina feeding interval is defined as the interval between two successive feedings of groups of feeders. There are six feeders, divided into two groups: 1-3-5 are the first group and 2-4-6 are the second group. All three feeders in a group feed at the same time, 1.20 kg/feeder, 3.60 kg per shot altogether. The alumina feeding interval targets between these two groups are given in Table 6.

Table 6. Alumina feeding interval.*

Parameter\Time	The first three days	From the 4th to 10 th day	From 11 th to 15 th day	From 16 days on
Set feeding interval (s)	85 - 90	80 - 85	75 - 80	75

*Note: After the cover material melts and AE is quenched the set feeding interval should be controlled to 90 s. Set feeding interval adjusts according to voltage curve of the pot.

4.2. Pot Operation

From the second day after start up, metal tapping should be done (when metal level is higher than 18 cm). Anode changing should begin from the eighth day and regulate anode change cycle.

5. Characteristics for Preheating and Start-up of ETI Aluminum Plant**5.1. Change Preheating from High to Medium Voltage**

Use high quality coke and graphite and mix them together to be the heat generating layer. With this mixture, the initial pot voltage could be decreased below 4 V. At the same time make sure the temperature of the lining increases evenly and make sure that the cathode block preheat temperature meets the conditions for startup.

5.2. Charging the Pot with Different Layers of Granular Material in the Pot Side Channels while Keeping the Centre Channel Empty

In the central channel only 5 cm thickness of cryolite is laid on the surface of the cathode to prevent cathode oxidation. At the same time, this is in favor of using heat to increase the lining temperature instead of melting materials; this efficiently improves the energy consumption; Replace coarse bath with powder bath between anode and side blocks cavity; this helps increase the temperature between anode and side blocks channel and can avoid the damage of the lining efficiently because of smaller temperature gradients. This way, safe start-up of the pot is assured.

5.3. Preheating Changed from Shunted Current to Full Current

Do not use any kind of shunt device and use full current to preheat. The advantages of this are:

- Decrease any meaningless loss of heat, thus improve energy consumption,
- Shortened preheating time,

- It is easy to operate and it reduces the labor.

5.4. Use Greater Mass of Bath to Start up

Use greater mass of bath to start up, that is, add extra mass of liquid bath during startup. Normally, the addition is approximately twice the liquid bath mass in normal operation. Startup process needs labor and time for melting pot cover materials that can melt easily with more liquid bath. Therefore, improve the safety of startup process, shorten the time of startup, and reduce the labor.

6. Early Operation Results

Figures 4 – 7 show the most important pot operation parameters for months from 1 June to 31 December 2018. The parameters until end of August reflect that pots were still being started up, the last one on 22 August.

Pot start up procedure is most important issue for pot stability. If the pot start-up operation was carried out well, pot noise and voltage can be kept under control.

Iron and silicon content are important parameters that demonstrate how successful start-up was. Iron, silicon and temperature must be decreased gradually. In ETI, the start-up and early operation were good and the parameters were stabilizing in a normal way. Some 11 weeks after start-up, the pots were getting too cold; the metal level increased and the bath level decreased. Then we increased the current gradually between 11 and 17 weeks. After that side ledge started to melt and liquid bath level increased; as a result stub washing gave high iron and no ledge on sidewalls gave high silicon. The worst crisis was in November, but after 22nd week of operation, the pots started to be normal again and Fe and Si level decreased.

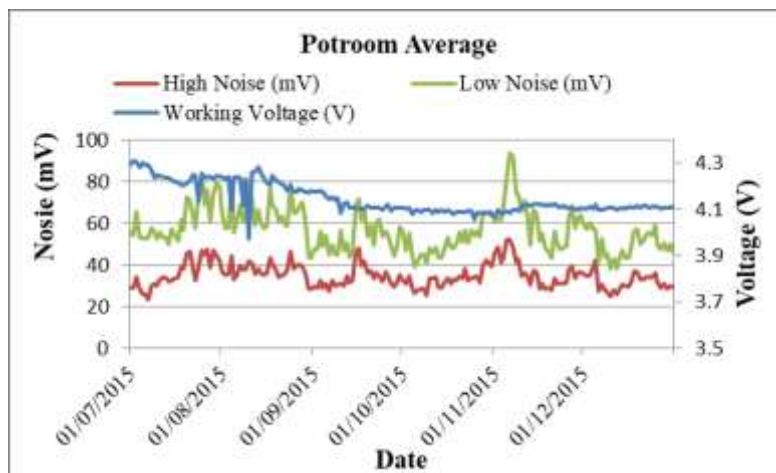


Figure 4. Pot voltage and noise.



Figure 6. Iron and silicon concentration in the metal.

7. Conclusions

1. At the time of charging the channels between anodes and sidewall, they should be filled up but the central channel should be left empty in order to decrease energy consumption and in order to make sure that the liquid bath flows below every anode during start up. This increases the safety of the start-up.
2. The preheat temperature of the cathode is very important for startup and later operation, and must guarantee the temperature in the central channel above 900 °C and the temperature on the sides above 700 °C. Measures could be taken, such as increasing preheat time and dismantling preheat flexibles ahead of schedule. If necessary, the thickness of coke layer could be increased by 1 - 2cm to make sure that the startup will be safe and effective and that the pot will efficiently operate in long term with good lifetime.
3. Preheating with full current is safe, energy saving and simple. High quality of coke and graphite is chosen with reasonable proportions between the two to control the pot voltage below 4 V. This is medium voltage preheating, which provides steady and slow preheat temperature increase.
4. The first pouring of liquid bath into the pot should be more than 5 tonnes. Make sure that the anode is raised 3 – 4 cm in order to bring all the anodes into normal working state rapidly. Ensure even anode current distribution at the beginning of the start-up; use a large amount of liquid bath to start up the pot (twice the amount in normal production); this may shorten the startup time and increase the start-up safety.
5. In industrial practice, manual AE is quite necessary sometime after bath-up. This not only melts all materials in the pot completely, but also increases liquid bath temperature and finally ensures good quality of the startup, lays the foundation for long pot life and improves technical and economical key performance indicators.
6. After the startup of the pot, pouring metal twice is useful for continuous heating of the side wall and for slowly decreasing liquid bath temperature instead of suddenly, which would happen if all the metal would be poured at once.