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THE QUICK SHUT DOWN AND RESTARTING OF 291 kA PRE-BAKED POTLINE AT JSC "RUSAL SAYANOGORSK» FROM MAY TO AUGUST 2011

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Abstract

Sayanogorsk and Khakas aluminum smelters faced with the serious risk of emergency shut down due to the railway bridge destruction used for the raw materials supplying, after the natural disaster on May 7, 2011. In order to prevent the emergency shutdown UC "RUSAL" decided to reduce temporarily the production volume. As a result, the line amperage was decreased significantly; some amounts of old and sick pots were shunted out in each potline, besides the entire line consisting of 179 pots with a current of 291 kA was disconnected within 2 days. After the resumption of raw materials supply the potline was restarted within 2.5 months. This article describes the sequence of events from the decision to shut down the line to the full production recovery

Introduction

In the morning of May 7, two pillars of a railway bridge located near the Kamyshta train station (Khakass region) collapsed (Figure 1). The bridge had been used both for delivering necessary raw materials to the aluminum smelter and finished products from the smelter. (No one was injured in the accident.)

Figure 1. The collapsed bridge

On May 9, the smelter specialists were able to organize the supply of raw materials to SAZ and KhAZ by road (Figure 2).

For coordination, representatives of the steering committee of UC RUSAL, representatives of the Eastern Aluminum Division, academicians, and designers came to the Khakass region. The management of the Company worked closely with the governor of the region and the region and federal authorities in order to eliminate the consequences of the accident.

On May 9, preparations for the restoration of the bridge – data on the configuration of the terrain were collected and recommendations were given.

Figure 2. Raw material supply by road

Due to the accident, the Khakass region authorities declared a state of emergency. At that time, it was thought that the collapsed bridge would affect the schedule of the recovery of the Sayano-Shushenskaya hydropower station (equipment for the power station was delivered by rail), the East-Beisk coal mine and other enterprises in the region. An ad hoc committee was established. Data were collected 24/7. The sequence of activities aimed at eliminating the consequences of the accident and restoring the bridge was determined by the committee.

At the smelter, the amperage was reduced. Individual cells were shutdown in each potline and one potline was stopped. The main reason for the curtailments was the shortage of alumina. Also, there were problems with other raw materials (coke, pitch, etc.)

Potline Shutdown

Two ways can be used for shutting down cells (followed by curtailing the amperage in full.) The choice depends on the amount of time available.

If there is time, some preparations can be made in order to shut down cells in a more systematic way.

Due to the fact that there was no time for such preparations (the bridge collapse), the sequence of operations for shutting down cells was as follows:

On the day when the cell shut-down took place, no anode change and no bath composition adjustment were made. The alumina distribution & handling system was disabled (the time for disabling the system in each particular cell was defined individually; the amount of alumina left in the bin was taken into account.)

Metal was tapped from those cells which were planned to be shut down. The cells were shutdown with no power reduction by short-circuiting the anode to metal following the established electrical safety procedures. The amount of cells shut down by such a method was limited to the number of wedegs at the smelter (80 sets).

Metal was tapped down from 28 - 30 cm 10 - 15 cm from those cells that were not planned to be shut down.

Figure 3. The shut-down cell

Then, the bath was tapped (as maximum as possible) from those cells which were not planned to be shut down (followed by short-circuiting anodes to metal.) The bath tapped was used for the cells in operation. The bath surplus was poured into special containers. The bath remained was poured into the cathode cavity of the cells shut down for relining (Figure 3).

After tapping the bath and short-circuiting the anode to metal, the alumina distribution & handling system was disabled.

Then, the potline was curtailed. After curtailing the potline, anodes were separated from metal. (The metal remained was tapped.)

Restart preparations began right after the potline curtailment (in order to be able to restart the shut-down cells when the bridge is restored.)

Restart Preparations

Preparations for the cell restart and cell baking were made according to the approved *Program for the Potline Restart.*

Based on the program, the following was developed:

- schedule for disassembling, maintaining and assembling beams;
- scheduled for manual / automated cathode cavity cleaning;
- schedule for removing (cutting) metal pads;
- schedule for patching cells;
- schedule for cleaning the bus bar and insulation / checking the insulation (anode superstructure, cathode shell, ducts);
- schedule for cleaning / checking shunts;
- schedule for manufacturing, assembling and dissembling shunts;
- temporary power supply diagram for the first group of cells to be restarted;
- schedule for restarting the silicon controlled rectifier equipment;
- schedule for raising the amperage;
- calculation of the voltage required for the potline (during restarts);
- schedule for preparing baking equipment;
- schedule for checking and starting auxiliary equipment: GTC, compressed air, cell control cabinets;
- standards for the raw materials / materials used for baking / restart;
- metal / bath balance during restart; and
- schedule for the supply of raw materials, materials, start-up tools, tools.

Based on the schedule for preparations for the cell restart, the readiness of cells for the cell restart, the number of units for flash baking, the number of shunts, the voltage generated by the rectifier , and the crane availability, a schedule for baking and restarting cells was made up. The cells to be restarted were broken up into 4 groups.

Preparations

Bottom Cleaning

After curtailing the potroom, a schedule for cleaning the bottom from the bath and frozen aluminum was made up. First, butts were removed (Figure 4) and bath lumps were collected.

Figure 4. Butts removing

Then, the bottom was cleaned both manually and automatically. Manual cleaning included the use of hammers and concrete breakers. After cleaning, the removed bath / Al was put into containers (by shovels) and sent for weighing and then crushing.

During cleaning, attention was paid to fillet (peripheral) seams, block-to-block seams, side and bottom blocks (in order not to break them during cleaning.)

For some cells, it was decided not to remove frozen Al. Such a decision was made in order to be able to do metal preheating. RUSAL's specialists had done metal preheating before that (but of less powerful cells.) Therefore, there were high risks that the restart of such cells would not be successful – the bottom covered with Al could have been damaged; it is also difficult to preheat such a big cell with a thick layer of frozen Al up to the required temperature; such cells are not that MHD stable.

Cathode Inspection

After cleaning, the cathode was inspected. A team of experts assessed the possibility of restarting the cell without relining. In those cases when patching was required, the team had to determine the scope of work to be done.

After inspecting each cell, a record on the condition of the cell was made up. Such a record contained (if required) information on cathode damages and a list of things to be done.

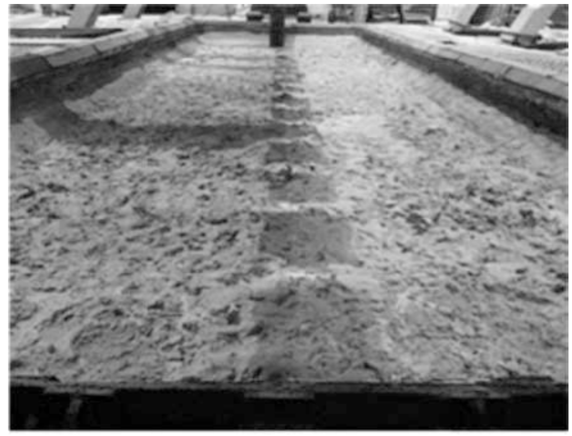

Figure 5. The cathode before the cell restart

Table 1. The criteria for the evaluation of the condition of the bottom

No.	Criteria	Unit	Value	Actions to be taken if the criteria are not met
Before cleaning				
1.	Service life, more than	month	83	to be relined
2.	Fe content at the moment of curtailment and/or the presence of any periods of operation with a high Fe content (not related to stub / deck plate melting), more than	%	0,30	to be relined
After cleaning				
3.	One or more local corrosion zones on the bottom with a depth of not more than	cm	13	to be relined
4.	Damaged bottom blocks to be replaced	each	1	to be relined
5.	Al in seams and cracks within bottom blocks	-	-	to be patched (in order to remove Al and restore the integrity of the bottom. If it is not possible to remove Al, it shall be relined)
6.	Wear-out of the hole cap of the fillet seam	-	-	to be patched (in order to restore the fillet seam)

Autopsy & Cathode Cleaning

Based on the record received, people from the relining shop cut damaged parts of the bottom up to a depth of 200mm. In those parts where damages or cracks were above the collector bar, the cutting depth was not more than 200mm.

After cutting, an additional inspection was carried out. No frozen Al, carbide formations and cracks were allowed.

If there were defects (such as frozen Al, cracks, carbide formations), cutting continued. Shrinkage cracks in bottom blocks (not filled with Al) formed due to cooling of the bottom after the process of curtailment were not taken into account.

Bottom patching

After removing the damaged parts of the bottom, seams (up 300mm in length) were rammed by using a manual pneumatic perforator.

If damages were more than 200mm in depth and 300mm in length, fillets (inserts) cut from the bottom block were used. The length and width of the carbon fillet (insert) were 80 to 100mm less than the length and width of the defected part (Figure 6).

Figure 6. Bottom patching

Autopsy & Side Block Cleaning

In order to repair the side lining, fillet (peripheral) seams and corroded side blocks were demolished (up to the refectory brick wall.)

After removing the damaged side lining, periphery bricks were inspected. The presence of frozen Al was not allowed. If there was frozen Al in fillet seams near the block that was in a good condition, the seam was continued to be demolished.

Side Lining Patching

Before installing side blocks, the cathode shell was inspected. If it was required, burnouts were patched by welding metal plates over the burnout from the internal side of the shell. After welding, the deformation of the shell was assessed. If local deformations were not more than 2mm, the walls of the shell were leveled by using a mortar based on concrete. Then, a leveling layer was dried for at least 2 hours.

After drying, SiC side blocks were glued to the cathode shell.

Cell Baking & Preheating

Relined cells were baked according to the current documentation used for the cell (Figure 7).

Gas preheating was deemed to be over when the temperature (according to the thermocouples used) was in a range of 580 to 900°C.

Figure 7. Cell baking

Bath Preparation & Potline Restart

A day before the restart, cells in other potrooms were being prepared to be used as donor cells.

Soup cells were chosen as follows:

- the service life should be not less than 12 months;
- cells which are 12 to 36 months old (not more than 1 time a month);
- cell with a high temperature (or if there was a trend for a temperature raise.); and
- cells with critical cathode and side lining deformations were not allowed.

The following was done with the soup cells chosen:

- no corrective Al fluoride additions;
- the voltage was raised;

- a hole in the crust was made from which it was planned to take the bath;
- the bath was taken once a shift during 3 shifts in an amount of 300 to 600 kg (depending on the cell);
- after each bath take, a covering material or alumina was added; and
- in order to control the process of raw material melting, the level of the bath was measured.

The criteria for the readiness of the bath were the temperature (not less than 970℃) and the CR (not less than 2.40.)

136 tonnes of the bath had to be prepared, including:

- 88 tonnes for the first 4 cells; and
- 48 tonnes – additional bath for two backup cells.

The delivery time (from the soup cell to the cell to be restarted) had to be not more than 15 minutes.

The total time for pouring the bath into 4 cells had to be not more than 45 minutes.

Cell Restart

By June 6, 2011, the bridge was temporally restored (Figure 8). Raw materials started to come to the smelter in full.

Figure 8. Temporary bridge

On June 8, 2011, when the rectifier equipment and the bus bar were ready, the first 4 cells (807, 821, 707, and 720) were started to be baked. The preheating (baking) duration was 48 hours.

The mentioned cells were chosen based on the following: no cathode deformation; 3 to 36 months old; the cells were prepared (patched), their location (it had to be easy to transfer and pour the bath.)

In 12 hours, another 4 cells were started to be baked (801, 803, 701, and 703.) These 4 cells were going to be used as backup cells. (They can be used if there are problems with the first 4 cells (cell tap-out, insulation problems) or problems with the rectifier (it is to provide the required amperage.)

The amperage crept step by step. When an amperage of 100 kA was reached, the team checked the shunts. In 2 to 3 minutes, an amperage of 150 kA was reached; then 200 kA was reached. In the next 2-3 minutes, the required amperage was reached.

In order to provide the second group of cells with the amperage, the following operations were performed:

- amperage curtailment up to 0 kA;
- shunts were removed from the first group and used for the second group;
- the restart team and the potline personnel were informed of the readiness of cells for the cell restart; and
- the amperage begun to creep step by step (as previously.)

The restart of the cells with frozen Al (metal pad) on the bottom was performed according to separate procedures. Nine cells were restarted according to such procedures. One restart was not successful. Due to the fact that the cell were MHD unstable (Al splashes out of the cavity), it had to be shut down.

Other cells were started up according to the existing procedures. By August 25, 2011 (2.5 months), all the cells were restarted.

Amperage creep up to the pre-emergency amperage

After the start-up of the first group of cells, the amperage was set at 255kA. Before the start-up of the following groups of cells (2 to 4), the amperage crept up to 239kA (the pre-emergency amperage) (Diagram 1.)

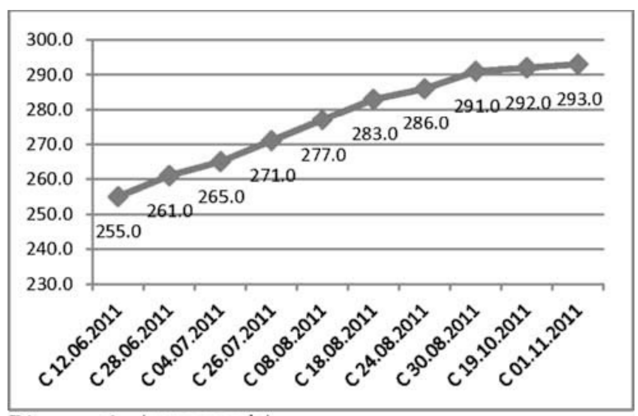

Diagram 1. Amperage, kA

The possibility to raise the amperage was determined based on the exiting criteria.

As a result, the pre-emergency amperage was restored in 4.5 month after the restart.

Discussion

Based on the results of the inspection performed, 40 cells were relined. 139 cells were restarted.

On August 31, 2012, 43 restarted cells (from 139) were shut down for relining. 96 cells are still in operation (Figure 9). The cells have operated for at least 14.17 months since the restart. They continue to operate (their average service life as of August 31, 2012 is 40.67 months.)

Figure 9. Potroom

The distribution of the number of shut-downs depending on the service life of the cell after the restart (as of August 31, 2012) can be seen on Diagram 2.

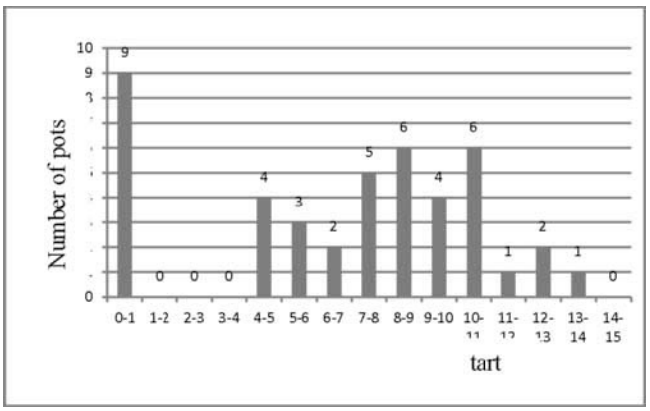

Diagram 2. The distribution of the number of shut-downs depending on the service life of the cell after the restart (as of August 31, 2012)

Nine cells (6.5 percent) were shut down right away. Their service life (after the restart) was less than 1 month. Other cells operated for at least 4 months, i.e. the restart without relining was economically successful. The average service life of the Potline 4 cells before the accident was 61.5 months. After one year of operation, it is safe to say that that the average service life of the restarted cells will be not less than 50 months.

Conclusions

The potline was shutdown in 2 days. It took one month to make the potline ready for the restart. It took 2.4 months to restart it and 2 months to reach the targeted indicators.

Taking into account the dynamics of shutting down the restarted cells, the service life expected is not less than 50 months. Therefore, the restart (after emergency shut-downs) can be deemed to be technologically and economically successful.

Acknowledgment

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