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# 60 TPH SINGLE LINE GREEN ANODE PLANT COMMISSIONED AT QATALUM

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**Abstract**

The first single line 60 tph green anode plant ever was successfully commissioned at the Qatalum smelter. This green anode plant was designed to fulfil the anode requirements of the 585,000 tpy metal capacity smelter.

The single process line is based on the Rhodax® technology for dry mix preparation and the IMC® technology for the paste mixing/cooling already demonstrated at Sohar Aluminium at 36 tph capacity. For Qatalum, new equipment, including crusher, coke preheating screw, continuous paste mixer/cooler and vibrocompactor, had to be designed, optimized and fine tuned to suit the 60 tph production level without compromising the anode quality and the plant reliability.

High capacity green anode plants contribute to lower the CAPEX of greenfield or brownfield smelter projects.

This paper describes the technical challenges that were met to realize such high production capacity and summarizes the operation performance achieved during one year of industrial production.

## Introduction

In spring 2010, the green anode plant of Qatalum went into operation. This new plant was a technical challenge not only because of its high capacity but also because it combines all the key innovations developed in the past decade and validated in standard capacity paste plants:

- The Rhodax® crusher for the preparation of the dry aggregates of the paste recipe. Already referenced at Alba (Bahrain) [1][2] and Sohar (Oman) [3].
- The IMC® process (Intensive Mixing Cascade) which relates to the preparation of the paste, before anode forming. Already referenced in China (Aostar, Hunan & Qinghai) [4] and Sohar [3].
- The Xelios™ vibrocompactor [5] which relates to anode forming, already referenced at RTA's Saint Jean de Maurienne plant (France).
- The Eolios™ pitch fume treatment system already referenced at Alcoa Mosjøen (Norway) [6]
- A cooling tunnel designed with a shorter residence time

The performance of this high capacity green anode plant then required a specific attention during design phase and a close collaboration with Qatalum operation team during commissioning in order to check and validate the relevance of the extrapolation design rules.

## Qatalum Green Anode Plant

The green anode plant was supplied by Solios Carbone as part of an EPC contract awarded by Qatalum, a joint venture between Hydro Aluminium SA and Qatar Petroleum, in 2007. It includes the main green anode plant tower (Figures 1 & 2), the cooling tunnel, the raw material storage, the carbon recycling unit and the carbon operation center with the maintenance workshop and the laboratory.

The green anode plant is designed to fulfil the requirement of a 585,000 tpy metal capacity smelter (phase 1) with one single line of 60 tph capacity producing more than 1400 green anode blocks per day. Producing anodes with one single line GAP is usual for greenfield smelters (e.g. Sohar Aluminium). For high capacity GAP, the green anode storage capacity just has to be bigger to cope with bigger shortage of anodes during unscheduled stoppages. Qatalum selected the 1 x 60 TPH GAP innovative option versus 2 x 30 TPH GAP's to minimize the CAPEX

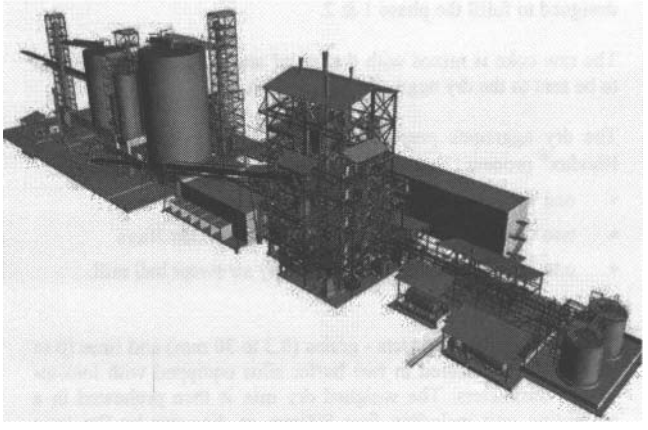

Figure 1 – Qatalum Paste Plant 3D Bird View

Here are some key figures of the GAP construction:

- Civil works = 11 000 $m^3$ concrete, 1700 t rebars & 185 piles
- Structural steel = 2850 tons
- Plateworks = 400 tons
- Mechanical equipment = 1300 tons & 8840 m of piping

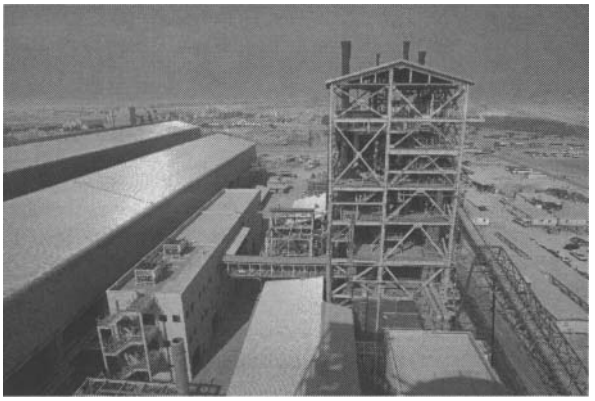

Figure 2 – Qatalum Paste Plant Main Tower

The site work required a bit more than 4 000 000 man-hours with only 2 loss time injuries, with a peak of presence of 50 Solios Carbone supervision staff and 1300 sub-contractor labor.

The raw material storage consists of one 2500 tons raw coke, one 5000 tons baked scrap, one 600 tons green scrap silos and two 400 tons capacity pitch daily storage tanks. They were all designed (capacity and extraction) to fulfil the needs of existing phase 1 and future phase 2 of the smelter.

The 50 tph carbon recycled unit consists of one primary crushing unit with a MR15 jaw crusher fed by green & baked scraps followed by a secondary crushing with a RC1200 roll crusher producing a final product with a 80mm top size. It is also designed to fulfil the phase 1 & 2.

The raw coke is mixed with the baked and the green scraps prior to be sent to the dry aggregate preparation line.

The dry aggregate preparation line (Figure 3) is based on the Rhodax® process [2] including:

- one variable gap & speed Rhodax® crusher RX1100
- two variable speed TSV™ 1800 dynamic classifiers
- one 3m x 7m variable speed & fully air swept ball mill

The dry aggregate products - grains (0.3 to 30 mm) and fines (0 to 0.08 mm) - are stored in two buffer silos equipped with loss-in-weight dosimeters. The weighed dry mix is then preheated in a preheating unit including four 800mm in diameter by 9m long hollow shaft screws.

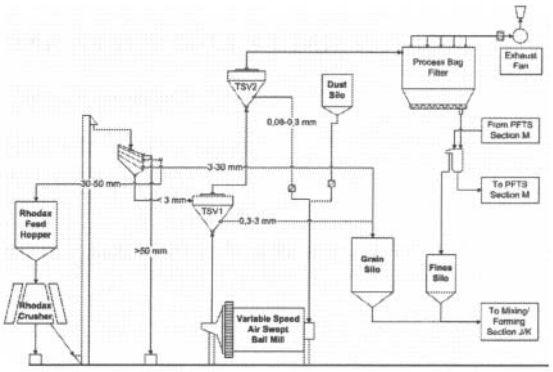


Figure 3 – Dry Aggregate Preparation Line

The preheated dry mix is then fed along with liquid pitch into the IMC® (Intensive Mixing Cascade shown in Figure 4) unit which consists of two bi-rotor and continuous RV32 mixers. Each machine has 410 kW installed power distributed over two variable speed high torque motors.

The mixed and cooled paste is then fed into a weighing hopper and dumped into a transfer hopper to feed two XELIOS™ vibrocompactor moulds alternatively. The vibrocompactor is equipped with counter pressure and a vacuum unit and is able to produce more than 60 anodes per hour with two tables only.

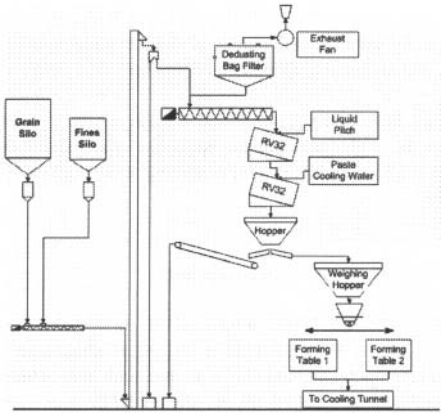


Figure 4 – Paste Mixing and Anode Forming Line

The formed green anode blocks are then cooled down to less than 70°C (skin temperature high limit at any time after cooling) through a water spraying cooling tunnel of less than 75 minute residence time.

Aligned with world class standards, Qatalum stack emission limits are stringent. Several dust collection systems have been designed to maintain an optimum working environment and to limit dust stack emission to less than 5 mg/$Nm^3$. An EOLIOS™ pitch fumes treatment system based on the combination of a dry scrubber and a RTO [6] has been designed to limit the PAH emission levels to less than 1 mg/$Nm^3$ and to minimize the energy consumption.

**From 36 to 60 tph, New Equipment Range**

Until recently, paste plant capacity was limited to 36 tph. With the increasing performance of electrolysis cells, both greenfield and brownfield smelters today require higher capacity green anode plants minimizing CAPEX.

This trend was anticipated several years ago at R&D level by designing equipment ranges and processes able to produce up to 80 tph paste equivalent.

At 60 tph production rate, the capacity of Qatalum paste plant is almost twice more than the last reference in Sohar [3]. It was then clearly necessary to push the range of some of the major pieces of equipment up to levels which were beyond the experience.

As an indication, Table 1 below compares the size of key pieces of equipment required for a 36 tph and a 60 tph capacity modern green anode plant.

Table 1: Equipment Size vs GAP Capacity

| Key Pieces of Equipment | GAP Capacity 36 tph | GAP Capacity 60 tph |
|---|---|---|
| Rhodax® crusher | RX600<br>25 – 40 tph (1) | RX1100<br>40 – 80 tph (1) |
| TSV™ | TBF & HF1400 | TBF & HF1800 |
| Ball Mill | Diam. x Length<br>2.6 m x 5.75 m | Diam. x Length<br>3.0 m x 7.0 m |
| Preheating screw | Quatro 6.75<br>Four 600 mm<br>x 7.5 m screws | Quatro 8.90<br>Four 800 mm<br>x 9.0 m screws |
| IMC® | 2 RV24 boosted<br>2 x 200 kW | 2 RV32 boosted<br>2 x [160 + 250] kW |
| XELIOS™ Vibrocompactor | 2 tables | 2 tables |
| Cooling tunnel | 90 min | 75 min |
| Pitch fume treatment system | Dry Scrubber only | Dry scrubber + RTO |

*(1) Paste equivalent throughput*

Selected Rhodax® crusher, TSV™ dynamic classifiers, Ball Mill and IMC® models, were existing in the designed range but with applications in other mineral industries. The design of the selected preheating screw model (Figure 5) was available but it was the first and biggest one ever built.

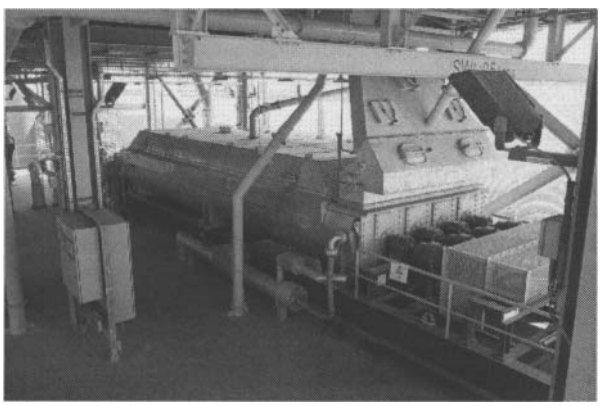

Figure 5 – Preheating Screw

Except for IMC®, the principles and mechanical design of all the key pieces of equipment listed here above in Table 1 remain unchanged at this higher size range. Therefore their expected process performance was extrapolated with a high degree of confidence.

For IMC®, the mixing principle remains unchanged but the mechanical design is significantly different as RV32 machine (Figure 6) includes two rotors (co & counter-current) whereas RV24 has only one co-current rotor. Therefore, process performance extrapolation was anticipated not to be as straightforward and provisions were made to give operation teams some flexibility to fine tune rotor speed and paste hold-up during commissioning.

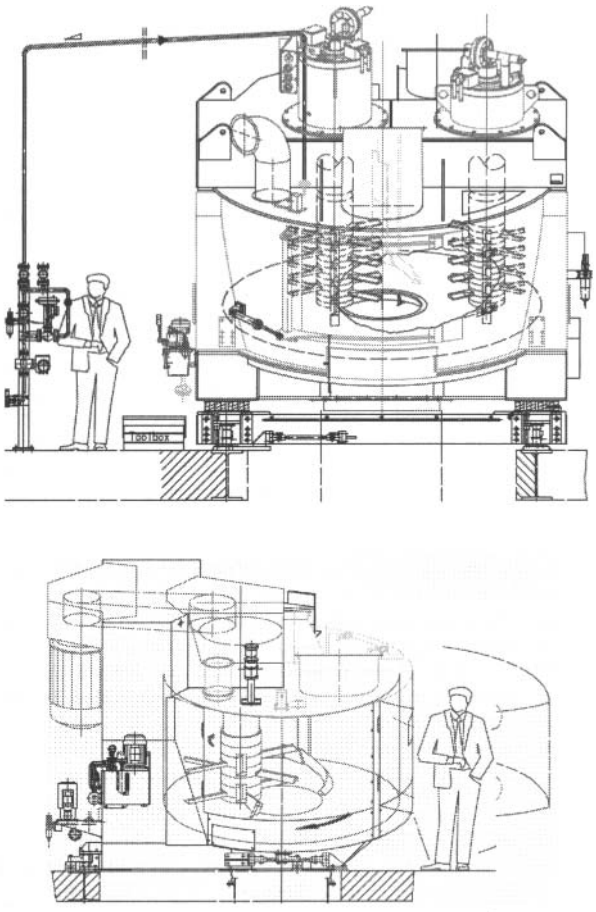

Figure 6 – EIRICH RV32 vs RV24
*(by courtesy of EIRICH)*

XELIOS™ Vibrocompactor model shown in Figure 7 remained unchanged but the related anode forming automatic sequences had to be optimized to eliminate unnecessary waiting time so as to suit the 60 anodes per hour production rate. This optimisation consisted mainly in adding an intermediate weighing hopper and designing the hydraulic circuit to speed-up the mould and pushers movements.

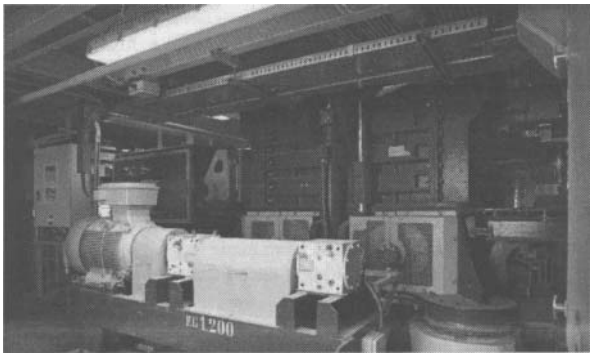

Figure 7 – Xelios™ Vibrocompactor

**From 45 to 60 tph, A Step by Step Ramp-up**

Once equipment selection was done, erection and cold commissioning completed, the next technical challenge was then to start the plant and carefully ramp-up the production.

The plant started-up at a 45 tph production rate which was already far above the 36 tph, the highest throughput achieved by Solios.

With average steps of 3 tph, the production reached the nominal tonnage in about 5 months in August 2010. This conservative ramp-up was justified as after each step up, few weeks of stable operation and tuning were required to monitor new equipment operating parameters, analyse process performances, validate extrapolation rules or conduct detailed root cause analysis when mechanical or process problems were identified.

During the ramp-up, the green anode plant had to go back to half nominal capacity of 30 tph a few times. This half nominal capacity operating mode was tested either with two or only one forming table. The capability to operate the plant at half nominal capacity was part of the project specifications defined by the client. Therefore, optimized operating parameters (Table 2) and transition procedures had to be defined and tested to be able to switch between full and half capacity back and forth with a minimum plant down time and quantity of production reject.

Table 2: Key Process Parameters vs GAP Capacity

| Process Parameters | at Half Capacity (30 tph) | at Full Capacity (60 tph) |
|---|---|---|
| Ball mill speed (%) | 80 | 100 |
| PH screw speed (rpm) | 4.5 | 6.0 |
| Mixer load (kg) | 5500 | 6400 |
| Cooler load (kg) | 5200 | 6200 |

During these transitions, the process showed a very high flexibility. Indeed, variable speed drives were installed on key pieces of equipment and were coupled with an adaptive control philosophy. It was then possible to keep running the plant with the same process performance at these two extreme tonnages.

For instance, changing back and forth the production rate between 30 tph to 60 tph requires a minimum of actions from the control room operator as the control logic adjust automatically the Rhodax® crusher variable gap to limit the crushed production rate and the ball mill speed to limit the power input to what is necessary to produce the lower amount of fines consumed.

Moreover, even at 30 tph, the dry aggregate preparation line designed to produce up to 60 tph, runs continuously without stop and go which eliminates a potential source of disturbances in the dry aggregate size distribution.

Similarly, the mixer and remixer-cooler loads and rotor speeds are adjusted to predefined & fine tuned setpoints which allow to maintain the paste residence time and the power draw to levels required to guarantee an even green anode quality at both paste production rates.

Once the full production capacity was reached, several measurement campaigns or tests were performed in order to optimize and fine tune the process parameters. Among them, it was necessary for Solios to confirm the performance of the short residence time cooling tunnel so as to guarantee a proper cooling of the anodes. Several measurement campaigns had been performed in other Solios cooling tunnels in the past in order to establish and calibrate a finite element model of the anode cooling process. The model predictions were then used to design the Qatalum cooling tunnel with a shorter residence time. The results of the measurement campaigns shown in Figure 8 below confirmed the model predictions and open the door for even significant design improvements in the future.

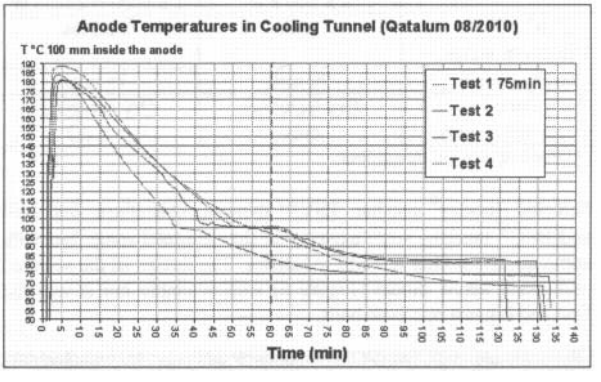


Figure 8 – Anode Temperature Profile in Cooling Tunnel

**Operation Performance Achieved**

As shown in Figure 9, the first good anode was produced end of February 2010. The production rate reached 60 tph in August 2010 and several hundred thousands of good anodes have been produced to date. Reject rates below 2% and plant availability of 90% have been achieved.

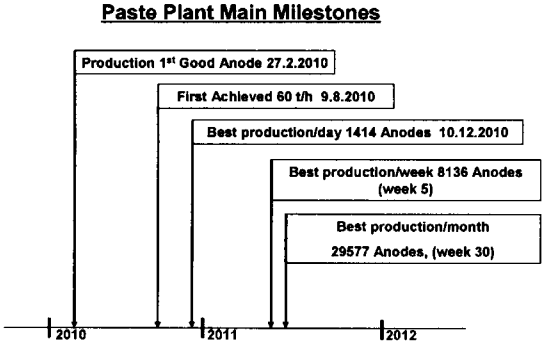


Figure 9 – Good Anode Production since Start-up

The raw material quality parameters are within a normal range as shown in Table 3 here after. The pitch content is on a low range and the several pitch optimizations done confirmed that value to be the optimum.

Table 3: Key Green Anode Plant Process Parameters

| | **Process Parameters** |
|---|---|
| Rated paste capacity (tph) | 60 |
| Coke Apparent Density (g/cm3) | 1.73 |
| Coke TBD ISO 1-2mm (g/cm3) | 0.79-0.81 |
| Coke HGI | 39 – 42 |
| Pitch Softening point (°C) | 115 |
| % of Baked scraps | 20 – 25 |
| % of Green scraps | 0 – 6 |
| G/S ratio | > 7 |
| Ultrafines (%) | > 14 |
| % Pitch content | 13.1 – 13.5 |
| Paste Specific Energy (kWh/t) | 9 – 11 (depending on tools conditions) |
| Green anode density (g/cm3) | 1.610 – 1.635 |

Despite a rather fine coke (95% < 13.2mm), the dry aggregate size distribution remains as expected for this type of process with a G/S ratio above 7 in average and more than 14% of ultra fines.

As shown in Figure 10, the dry aggregate preparation line remained very stable and quite insensitive to production capacity (half and full) which is the result of the flexibility of the Rhodax® process.

The green anode density levels reached so far are within the expected range with values up to 1.64 depending mostly on raw coke density, baked scraps percentage and mixing tool wear conditions.

Since plant operation has been stabilized, Solios and Qatalum teams have been carrying out extensive optimization tests. These tests allowed Qatalum operation team to establish a relationship between the green anode density and the key process parameters which are useful for day to day process optimisation. The green anode plant has been supplying the anodes required by the smelter in quantity and quality.

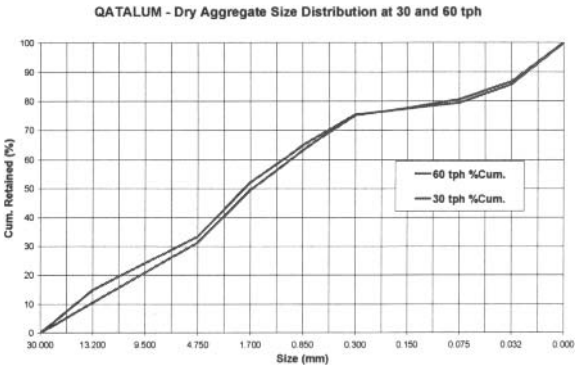


Figure 10 – Typical dry aggregate size distribution at full and half plant capacity

It also allowed Solios team to gain experience by validating equipment and process design rules and updating start-up procedure for high capacity paste plants. Thus, the commissioning of the green anode plants coming in the near future: Maaden 2 x 40 tph, Mahan 35 tph and Aditya 52 tph, will beneficiate from that experience.

## Conclusion

Starting the first single line 60 tph green anode plant was a challenge. A step by step ramp-up, continuous equipment and process performance monitoring as well as combined efforts of Qatalum operation and Solios commissioning teams were required to achieve that goal. This new referenced high capacity plant is a major milestone for the industry. By lowering the CAPEX, it contributes to the success of the Qatalum smelter project.

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