# Considerations for Selecting an Open Top Anode Baking Furnace Relining Strategy

**Daniel Reichelson[1] and Ana-Maria Becerra[2]**
1. Process & Refractory Engineer, Light Metals
2. Carbon Lead, Light Metals
Hatch, Montréal, Québec, Canada
Corresponding author: daniel.reichelson@hatch.com

**Abstract**

Anode baking furnaces are designed to operate for many years. Whether due to end of life wear or anode dimension changes, furnace relining causes a major disruption to the production of carbon anodes in an aluminum smelter. There are several options available when it comes to determining when and how to approach this critical event. Anode production can be stopped over a prolonged period of time to allow for a complete open top furnace reline, a furnace can be relined one tub at a time to allow for production to be partially maintained, or one fire can be extinguished in order to reline a few furnace sections while maintaining anode production.
This paper covers the different elements that should be taken into consideration before selecting a specific rebuild method. Project drivers, planning, logistics, refractory design and capital costs are just a few of the issues that must be evaluated. Although the decision may not be obvious at first, a comprehensive engineering and construction analysis can ensure that the best business strategy is retained

**Keywords:** Open top anode baking furnace; furnace reline; anode production; refractory design and installation; firing cycle.

## 1. Introduction

Anode Baking Furnaces (ABF) are one of the most critical equipments operated in an aluminium smelter and can generate high operational expenses. In order to reduce smelter costs, anode production has to aim for quality and process consistency [1]. A well operated and maintained furnace can produce consistent quality anodes for the potlines, while minimizing carbon sector costs such as anode reject rates, refractory maintenance and energy consumption. Consistency is the key in maintaining high current efficiency in the pots where every anode effect impacts production costs.

However, the furnace condition deteriorates over time, due in part to the baking process itself (thermal cycling, chemical attack of the refractory, etc.) and plant operations (baking cycle time, firing system, sodium content, maintenance, etc.). The equipment's end of life may occur when anode quality begins to deteriorate, when energy consumption increases or when refractory maintenance costs are too high.

When a smelter decides that it is time to renovate the baking furnace, many factors should be taken into consideration. A furnace can be relined in the same manner it was built, keeping the same design and material specifications. A furnace can be raised to allow the production of longer anodes. A new furnace design may be considered to allow a change in anode dimensions or to compensate for previous changes. In this case, the entire refractory design may be modified, upgrading to thinner tub insulation with superior insulating materials, changing the fluewall arrangement to improve thermal distribution and improving the overall energy efficiency of the furnace. Ultimately the decision to reline, raise or redesign will have an impact on the shutdown strategy selected.

## 2. Planning

The key to success for any ABF reline project is proper planning. These types of projects are generally cost or schedule driven, which are they themselves affected by many other variables as shown in Figure 1 below.

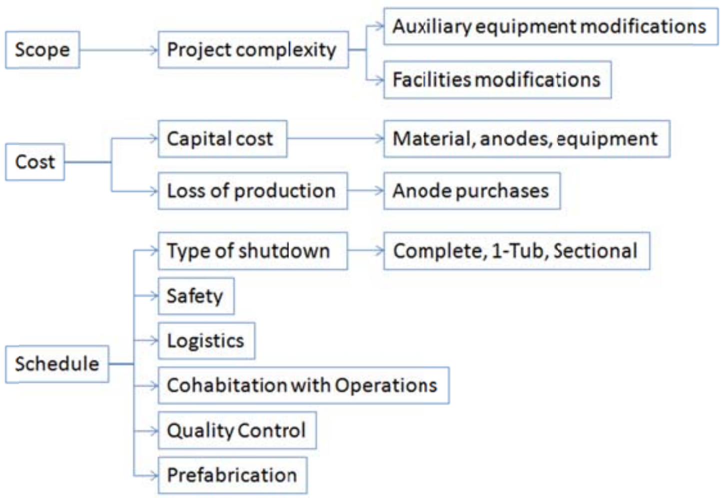


**Figure 1. Variables affecting project drivers**

During the engineering phase, coordination with operations, maintenance, and even the contractor will allow project management to properly define the roles and responsibilities of all participants. With ongoing production, there can be significant health and safety risks that must be identified with mitigation plans put in place. Lines of communication, priorities, rules and expectations to name a few, must be established early on in the project. All of these activities can only be achieved with the collaboration of all vested parties.

Logistics is another item that requires proper planning. Understanding the material requirements, especially the types of material used, the location in which they are needed and at what point during the reline, will allow the project team to determine a supply chain methodology that will help optimize the schedule. Additionally, proper shutdown planning will allow the project team to define the equipment required to handle material, if temporary storage is required on-site or offsite with respect to material delivery and schedule.

Demolition and installation strategies have to be properly identified in order to avoid delays during construction and determine the best shutdown approach. Crane utilization is amongst the most critical issues to deal with during a shutdown. Using innovative techniques for material handling to reduce crane dependence can significantly save time. Additionally, modeling individual tasks can help determine activity bottlenecks down to a specific hour, location or task. Figure 2 below shows an example of one of the exercises used to plan the different tasks carried out during a furnace shutdown. The figure is a snapshot of the complete exercise and the images selected represent three specific days where operation, demolition and construction activities had to be carefully coordinated to avoid any accidents and prevent shutdown delays

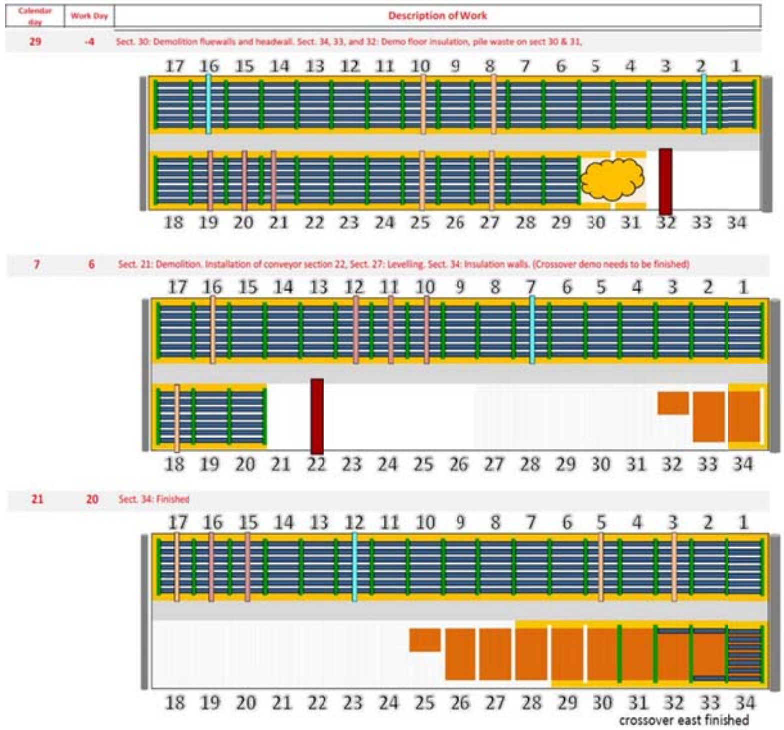


**Figure 2. Different demolition and installation tasks and sequences**

To ensure the success of an ABF reline project, a proper basic and detailed engineering study needs to be carried out before the commencement of any shutdown activities. During this stage, the engineering and management team will be able to determine the best shutdown strategy based on the client's needs and distinct situation.

## 3. Shutdown Strategies

Three (3) typical shutdown strategies can be employed for a baking furnace reline:

1. Complete shutdown;
2. 1-Tub shutdown;
3. Sectional shutdown.

Furnace characteristics such as furnace height, number of sections and pits, fire configuration and the particularities of the plant infrastructure (i.e. central conveyors, number of overhead cranes, garage space, etc.) will help to determine which strategy is best suited for a particular smelter

## 4. Complete Shutdown

A complete furnace shutdown can be considered when all the fires in a furnace are extinguished and production is halted. The entire furnace is emptied of anodes and packing coke allowing for demolition and construction to take place in both tubs (for an open ring furnace) at the same time. The implications of a complete shutdown at the bake furnace are the following:

- A large amount of refractory material will be purchased and stored prior to installation (high capital cost, high storage demand);

- There will be no anode production over the course of the shutdown of this furnace;
- There will be little or no conflicts with operations;
- Logistics are easier to manage as construction activities have priority;
- A long, single furnace shutdown is required but having an overall shorter construction schedule when compared to the other types of shutdowns;
- Production losses will likely require the purchase of baked anodes (high cost to the client);
- A larger construction crew is required on site affecting safety, quality, logistics, and construction efficiency;
- Pre-fabrication of furnace components such as fluewalls, is more challenging due to storage requirements, and not a real net benefit in time savings;
- Safety and quality requirements can be more easily enforced as there is no stress of production "catching up" in case of delays;
- A furnace raise or redesign may be better served by a complete shutdown.

### 4.1. Advantages

With a complete shutdown, furnace demolition is simplified as there is little to no impact on operations with issues such as dust generation, cohabitation, and crane availability. Demolition teams can operate 24 h a day allowing the shutdown schedule to be optimized. The removal of waste refractory from the tub and the introduction of new refractory material to the tub can be easily achieved either by the use of a ramp for in-ground furnaces or through a hole in the tub walls for above-ground furnaces. Although, the duration of a shutdown is longer for a complete furnace reline; the overall project duration will be shorter. Consequently, the implication of the shutdown on the other plant areas will be experienced only once.

Furthermore, a complete furnace shutdown provides the flexibility for introducing a new furnace design, such as a furnace raise, or an increase in pit dimensions required for bigger and anodes. Installation quality requirements can be more easily enforced as there is no threat of production catching up (as in the case of a sectional reline). Unforeseen construction issues and delays can also be more easily absorbed into a longer schedule, therefore reducing their impact on the project.

### 4.2. Disadvantages

Capital costs are the main disadvantage for a complete shutdown strategy. A plant with a furnace shutdown lasting several months will probably have little or no supplementary anode baking capacity, and the project will have to plan to either produce an anode buffer or purchase baked anodes to support the potline requirements. Anode purchase is not only costly, but requires additional plant procurement activities, transport coordination, site logistics and storage considerations. Baked anode supply during a furnace shutdown needs to be properly studied, planned and managed.

When considering a complete shutdown, refractory supply, storage and labor requirements are capital intensive. Refractory material is a long-lead item and must be purchased in advance and delivered to site in time for installation, while still respecting the shelf life for certain materials. This then translates into costs for supplementary storage that can either be rented externally or temporarily installed on site. Storage costs and space are also augmented by having to store the packing coke removed from the furnace as well as the spent anodes from the rodshop once paste plant storage quotas are met.

The increased labor cost is often due to the loss of productivity created by having a large workforce within a confined space as shown in Figure 3. The construction schedule can be optimized by separating the different construction activities into separate work zones, Nevertheless working efficiency will always be limited by the availability of the cranes and by refractory logistics.

**Figure 3. Workers during a complete furnace reline**

Additionally, a reduction in the shutdown duration via the use of prefabricated fluewalls is only partially feasible given the limited storage availability. However, this is not considered a limitation since the work organization of a complete reline, as shown in Figure 3, allows for a proper *in situ* construction of fluewalls with the use of scaffolding. It should be noted that the required installation quality is easier to achieve with a fluewall that has been built *in situ* than with one that has been prefabricated and for this reason the *in situ* implementation technique is preferred by the furnace technology supplier.

Finally, one of the biggest concerns with clients looking into a furnace reline is that a complete furnace shutdown requires a big investment and hence does not provide them with the flexibility of spreading out the  cash flow overall a prolonged period of time as it is the case for a 1 tub or sectional shutdown.

## 5. 1-Tub Shutdown

A 1-tub shutdown can be considered when all the fires in one tub are extinguished and production is maintained in the other tub. Only half of the furnace is emptied of anodes and packing coke allowing for demolition and construction to take place in a single tub (for an open ring furnace) at every shutdown. The implications of a 1-tub shutdown at the bake furnace are the following:

- Only a portion of refractory material must be purchased and stored prior to installation (medium capital cost, medium storage demand, reduced implications on transportation);
- Partial anode production will be sustained during the construction shutdowns;
- Cohabitation of construction and operation requires coordination of crane utilization, anode loading and unloading among other activities;
- Additional strain will be exerted on refractory logistics in and out of the furnace tub;
- A shorter procurement time is possible for refractory purchase;
- A medium “continuous” construction period is required – however a longer overall project duration is obtained;

- Production of an anode inventory or purchase of baked anodes may still be required; but mitigation activities can lessen this cost impact since production losses are minimized.
- Construction may take place with a smaller construction crew improving labor productivity, safety and quality control;
- Prefabrication of fluewalls requires much less storage space than for a complete shutdown and it also provides a more efficient work site with easier local logistics;
- Safety and quality requirements must be rigorously followed as there will be ongoing production during construction activities.
- A furnace raise or design change is still possible

### 5.1. Advantages

A 1-tub shutdown has some benefits and some drawbacks when compared to a complete shutdown. The biggest advantage can be attributed to the longer overall project duration. Performing a furnace reline in various shutdowns allows the plant to spread out the capital costs and also the material and anode inventory. Refractory materials and storage requirements will be lessened and along with it transport requirements. Partial anode production will be maintained, thus reducing anode purchases to offset the production loss obtained over the course of the shutdown. If well planned, it is even possible to increase production ahead of the shutdown in order to build a partial anode inventory.

Labor requirements are less than for a complete furnace shutdown with the added benefit of continuous improvement by applying the lessons learned from the previous phase.

Prefabrication of fluewalls can greatly alleviate the strain on crane utilization while saving valuable time in construction. Moreover, it will be easier to carry out when compared to a complete furnace shutdown, due to the reduced number of fluewalls and storage requirements.

The same can be said for a furnace raise or revamp – that is, optimization of the installation can still be made to incorporate a new furnace design. However an additional element of complexity is introduced when a furnace reline occurs simultaneously with anode production. Quality control and assurance can still be enforced given that production, the major stressor for schedule, is kept separate from construction activities.

### 5.2. Disadvantages

The most notable disadvantage to a 1-tub shutdown is the overlap between the production and construction teams. Crane utilization, firing equipment moves, anode loading and unloading and operator activities are key components that need to be studied and coordinated during the planning stages. The success of a 1-tub shutdown hinges upon the co-existence of the operation and construction teams.

To manage this cohabitation, operational activities in the adjoining tub are usually consigned to specific windows when construction activities are halted. Typically they are planned to occur overnight (i.e. 4 h) and on weekends. This generally has the effect of slowing down the firing equipment which will impact the plant’s overall anode production, but it allows the project to clearly separate construction and operational activities and reduces safety risks and interferences.

For a 1-tub shutdown, demolition activities are challenging given that an opening in the tub wall for the removal and entry of material is generally not feasible due to the construction schedule. Hence, material handling becomes more complicated both for removing spent material during demolition and for introducing new refractory during construction. The removal of spent refractory can still be optimized by using conveying equipment inside the tub and reducing crane dependence. Close attention to the method of demolition is required in order to minimize dust generation, and interactions with operations need to be planned and coordinated.

Although each 1-tub shutdown can be completed in a shorter duration, the cumulative time that the furnace is not producing will be longer. Ultimately the duration of the project will be longer, and consequently, a smelter will be operating an inefficient part of the furnace for a longer period of time. To add to this inefficiency, production in the adjoining tub is partially reduced when the sections adjacent to each crossover are filled with baked anodes. This is done as part of the strategy for operating on a tub with no crossover.

Each 1-tub shutdown also brings with it subtle effects on the paste plant, whose production will oscillate with the various shutdowns periods.

Finally, relining 1-tub at a time can be problematic when raising the furnace tub or operation floor. Once a tub is complete, it will sit higher than the adjoining tub until the latter is relined. Part of the operation floor may also be raised to be flush with the new furnace tub and there will be a step down to the furnace tub which has not been relined.  This difference in operation floor levels poses and additional health and safety risks in between the shutdown periods.

## 6. Sectional Shutdown

A sectional shutdown can be considered when the fire configuration of a furnace allows one fire to be extinguished converting the available space into a rebuild zone, as shown in Figure 4. Two different types of sectional shutdowns are possible: continuous (“on-the-run”) shutdown or campaign (“batch”) shutdown. The decision to use either type will be dependent on existing facilities, furnace design changes, work on the furnace auxiliary equipment and preference for overall project duration

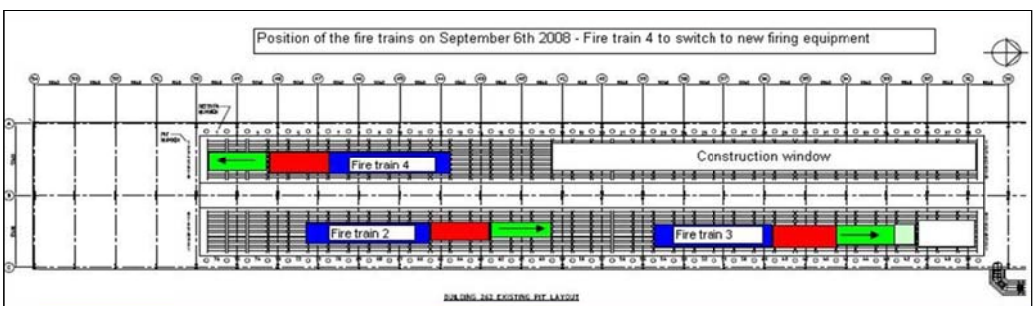


**Figure 4. Sectional “on the run” shutdown [2]**

A continuous on-the-run shutdown is characterized by having the construction zone follow the remaining fires in the furnace as they continue to produce baked anodes. To facilitate the construction schedule the firing cycle may be slowed down. A campaign or batch shutdown considers a static construction zone, with the reline of just a few sections in the time it takes for the remaining fire trains to reach the zone. The construction team will therefore get in and out and then wait for the next available operating window in order to reline the subsequent furnace sections. In either instance, only a small portion of anodes and packing coke are emptied as demolition and construction activities are continually completed and moved forward one section at a time in conjunction with production.

### 6.1. Continuous "On-the-run" Section Shutdown

The implications of a continuous, on-the-run sectional shutdown at the bake furnace are the following:

- A large amount of refractory material will be purchased and stored prior to installation (high capital cost, high storage demand, large transportation and logistics implications);
- The majority of anode production will continue over the course of the shutdown;
- Daily interactions with operations are frequent;
- The reline can be done in a relatively short period;
- The purchase of baked anodes is minimized;
- A reduced quantity of personnel is required for demolition and installation due to the limited construction area (easier to manage safety, quality, logistics, and productivity);
- There is an incentive to prefabricate fluewalls and other furnace components as it can allow construction activities to be spread out and liberate the work zone while also optimizing the schedule. Prefabrication of other furnace components although physically possible is usually not recommended by the technology suppliers since it directly affects the installation tolerances and as a result the implementation Prefabrication will then be dependent on available storage and crane availability
- Safety and quality requirements will constantly be pressured as there is the additional stress of production "catching up" in case of delays;
- A furnace design change is still possible but raising the furnace is more challenging.

#### 6.1.1. Advantages

The biggest benefit a continuous sectional reline offers is the ability to maintain most of a furnace's production while rebuilding. This significantly reduces, and can even eliminate, the need to purchase anodes which can equate 10% to 20% of the project budget [2]. The reduction in anode purchase reduces the effect a shutdown would otherwise have on other sectors of the plant that are interlinked with the bake furnace (i.e. paste plant, anode handling, storage and rodshop).

A smaller labor crew is required since only a portion of the furnace can be worked on at any given time. Since work is synchronized with production, the entire furnace can be relined in the time it takes a fire to make a single rotation, although the fire train may need to be slowed to accommodate construction activities.

#### 6.1.2. Disadvantages

As in the case of a 1-tub shutdown, the most difficult challenge faced by a sectional reline is the cohabitation between operation and construction activities. Since the furnace is continually producing and fires are advancing, construction activities have to maintain the same cadence. Furthermore, relining activities cannot exceed the established construction schedule since they are constantly stuck between the cooling end and the beginning of the next fire train. Every construction activity has to be properly evaluated to determine time to completion and then meticulously followed to ensure there are no delays in the schedule. Any unknowns or delays can have a seismic effect on the outcome of the project.

Safety will be the highest priority and will be very difficult to manage given the numerous ongoing activities, the frequent use of overhead cranes and furnace tending assemblies (FTA), the fluid construction zone, the advancing fire train, and the complexities of working at different ends of the furnace (i.e. maintenance bays vs. anode handling zones). All parties need to be involved in developing a rigorous health, safety and environment (HSE) management plan and in fostering a safety culture throughout the life of the project. A proper risk review needs to be carried out during planning stages in order to identify the proper mitigation plan and avoid construction delays as much as possible.

Crane allocation must be scrupulously monitored in order to ensure that both operations and construction activities are carried out in the proper time and place. Crane-dependent activities should be minimized as much as possible to reduce stress on this bottleneck. Managing logistics efficiently and safely for both construction (removing waste material, introducing new refractory material, installation of equipment, scaffolding and tools) and operations activities (anode loading and unloading, packing coke distribution, firing ramp movements and maintenance) is paramount to the execution of the project.

Due to the high interaction between operations and construction, and the fact that demolition is ongoing throughout the entire reline, special attention has to be paid to reduce noise and dust levels inside the bake furnace building. The possibility of organizing certain daily activities at the same time will help mitigate these issues. For instance, demolition activities can take place at night when there is no installation activities scheduled. If the plant is unionized, co-existence of all parties involved must be well managed so that the requirements and limitations of the work contracts of each group is respected [2]. If a furnace raise is being done, demolition and corbel installation activities should be executed before relining work.

Quality control will be very difficult to manage. It will be critical that all parties clearly understand the minimum quality requirements for refractory installation, and develop a quick and efficient methodology for dealing with non-conformities. Including key members of the construction teams such as foremen, supervisors and group leaders, in the planning stages of the work will help accord sufficient time for specific tasks and develop methods to control and monitor installation activities (jigs, personal tools, puzzle pallets, etc.).

### 6.2. Campaign “Batch” Sectional Shutdown

The implications of a campaign sectional shutdown at the bake furnace are the following:

- Only a small portion of refractory material must be purchased and stored prior to installation (lower capital cost, lower storage demand and reduced transport requirements);
- The majority of anode production will continue over the course of the shutdown;
- Daily interactions with operations are frequent;
- The reline of a few sections can be relatively short, but the overall duration of the project will be long;
- The purchase of baked anodes is minimized;
- A reduced quantity of personnel is required for demolition and installation due to the limited construction area (easier to manage safety, quality, logistics, and productivity);
- The incentive to prefabricate the fluewalls and other furnace components is essential due to the very short timeframe to execute demolition and installation activities as well as the lack of space. Prefabrication will be dependent on available storage space and crane availability;
- Safety and quality requirements will be hard to control given the pressure to maintain the construction schedule and additional stress from production “catching up”;
- A furnace design change or raise is not really possible with this relining method.

#### 6.2.1. Advantages

As with the continuous sectional reline, a batch reline might be preferred given that it allows the continuity of production during the construction activities, utilization of a smaller construction crew and minimization of the shutdown effect on the operations for the other areas in the carbon plant.

A batch sectional reline may be favored over a continuous reline since it allows the client to spread material supply, transport and cash flow over a longer period of time.

#### 6.2.2. Disadvantages

A batch sectional shutdown has similar disadvantages to a continuous sectional shutdown. However, the most notable difference between the two is that in a batch sectional shutdown, a change in the furnace design or raising the tub is simply not feasible. Raising the operation floor or replacing the ring main collector is not possible either. A batch reline is then only suited for a simple refractory refurbishment.

Furthermore, of all the shutdown methodologies, a batch reline has the longest project duration and it may be that by the time that the furnace has been completely relined, the first area relined might be ready for fluewall replacement.

## 7. Case Studies

So which relining strategy is the most appropriate for any given smelter? Below are three case studies where Hatch, along with the client determined the most suitable shutdown methodology.

### 7.1. Case Study #1 – Complete Furnace Reline

Hatch was involved in relining a 72-section, 9-pit (10 anodes per pit), open ring anode baking furnace that had been decommissioned several months earlier due to end of life. Owing to reduced production requirements, only one of the two available furnaces needed to be operated to support potline requirements. However, the second furnace too was quickly approaching its end of life and the plant was forced with opting between purchasing anodes or relining the furnace.

In this scenario, the obvious strategy was a complete rebuild of the decommissioned furnace. There were minimum conflicts with operations and ample crane availability. There was no impact on current production or the need to purchase anodes while the other furnace continued to operate. Up-front capital costs were high, but this was justified in that the furnace needed to be operable within a relatively short time frame. The client decided to redesign refractory, repair the concrete tub walls and maintain the existing fluewall and pit configurations, while attempting to increase fluewall life and increase energy efficiency with a new firing system. The tub repair and refractory installation was completed in 5 months. The project was completed under budget despite having issues with refractory supply, and without any lost time to injury.

### 7.2. Case Study #2 – 1-Tub Reline

Hatch was involved in relining two 34-section, 6-pit (18 anodes per pit) open ring anode baking furnaces one tub at a time over the course of 4 years. Both furnaces had been operated for almost 25 years, with over 400 fire cycles on the original headwalls and insulation. Although insulation and tub walls were in excellent condition, the decision for a complete reline was predicated on increasing anode length. An entirely new refractory design was developed which included raising the furnace by 250 mm and gaining another 80 mm in streamlined floor insulation in order to further augment pit depth and regain proper packing coke height. FTAs were raised along with the operating floor, though the ring main and crossover structures were left in-place.

The decision to proceed with a 1-tub reline was driven by minimizing production losses and anode purchases as well as by spreading out capital costs. As such, anode storage and refractory storage were significantly reduced per shutdown. A plan was developed to increase anode production in the months preceding each shutdown in order to build a baked anode inventory and further limit anode purchases.

Over the course of the project, anode purchases were significantly reduced and material supply and capital costs were spread out over a 4-year period. Fluewalls were prefabricated in the garage zone not only to optimize the installation schedule, but to avoid interactions with operation and construction activities. A new furnace design was incorporated within the same tub walls after a 13-week shutdown, starting from first available section for demolition until 2 sections were made available to operations. Following the first phase, the installation schedule was further reduced to 12 weeks having developed streamlined activities. Quality control of refractory material and installation activities was maintained to a very high degree due in part to the collaboration of the contractor, the furnace technology provider, the client and project management. The schedule was extremely well detailed and incorporated sufficient time for strict safety and quality reviews.

### 7.3. Case Study #3 – Sectional Furnace Reline

Hatch was involved in relining a 76-section, 8-pit (10 anodes per pit), open ring anode baking furnace on the run. The client opted to reline this furnace by extinguishing one of four fires while maintaining a 29-hour fire cycle. A second furnace (end to end) continued operating at an accelerated rate of 27 hours bringing the total anode production to 85% during the shutdown. A new furnace design was implemented within the existing tub walls in order to allow for future anode size increases, the waste gas main was replaced and a new Fume Treatment Center was built to increase draft capacity, permitting a faster firing cycle.

In this scenario, reduced anode purchase was the main driver. This then put a tremendous amount of pressure on logistics, given that demolition, installation and operational activities were taking place in both of the furnace’s tubs at the same time. Equipment handling was found to be the bottleneck due to crane availability. The building housed two bake furnace and both the north furnace (under repair) and the south furnace shared common crane rails spanning the length of the building, with each of the furnace tubs separated by center columns. In total there were 4 FTAs two additional construction cranes were added for the project.

During certain periods of the reline, the construction team had to deal with specific constraints. When rebuilding close to the maintenance bays, operations had continual access to the anode handling equipment in the middle of the building resulting in maximum crane rail availability. However when rebuilding close to the center of the building, production had to pass overhead with anodes thus forcing workers out of the rebuild zone and relegating the construction crane to the maintenance bay. This co-activity has a significant effect on progress.

Fortunately, it was recognized early in the planning phase that the logistics of material movements and crane allocation time were the keys to the success of the project [1]. A model containing operational activities and cycle times combined with the position of the work area allowed the project team to determine crane availability at any given moment. From this model, detailed daily activities could be planned and time-saving options, specialized equipment and contingency steps were devised to improve crane availability.

Refractory demolition and installation was achieved in 3 ½ months, on schedule and under budget.

## 8. Conclusion

When a smelter decides that it is time to renovate the baking furnace, many factors should be taken into consideration. These types of projects are generally cost or schedule driven, and are affected by many variables such as project complexity, anode purchase, logistics, safety, quality control, labor requirements and cohabitation with operations.

Regardless of the shutdown strategy chosen, the key to success for any baking furnace reline project is proper planning. A well-defined engineering study needs to be carried out before the commencement of any shutdown activities. During this phase, coordination with operations, maintenance, and even the contractor will allow project management to properly define the roles and responsibilities of all participants. Modeling demolition and installation tasks can help determine activity bottlenecks down to a specific hour, location or task.

## 9. References

1. Frank Goede, Refurbishment and modernization of existing anode baking furnaces, *Light Metals* 2007, 973-976
2. Richard Coulombe et al., On the logistics of rebuilding and anode baking furnace while maintaining operation, *Light Metals* 2010, 999—1004