

# Economic Simulation-based Decision Support for Cathode Re-lining Facility

J. Caissy<sup>1</sup>, Shawqi Al-Hashimi<sup>2</sup>, L. Tikasz<sup>3</sup>, R.I. McCulloch<sup>4</sup>

1. Reduction Specialist

3. Modeler

4. Center of Excellence Manager

Bechtel Canada Co, Montreal, Quebec, Canada

2. Project Director

Aluminium Bahrain B.S.C., Kingdom of Bahrain

Corresponding author: jcaissy@bechtel.com

## Abstract

Within Bechtel Mining & Metals, the Technology Center tests and validates design alternatives and operational variants including economic analysis. During the Front-end Engineering and Design (FEED) for the new Alba Potline 6 Project a study was done for a new cathode re-lining facility with limited available space for the new re-lining facility. The first generation of pots would fail following a Weibull distribution curve. Waiting for the pots natural end of life would involve a very high peak re-lining rate and therefore a high capital cost re-lining facility. Most new smelters prefer to have the pot out of service before the end of their predicted life to reduce the peak re-lining rate and therefore reducing the necessary capital cost. Using a dynamic model combined with a lifecycle cost analysis, it is now possible to generate a curve to determine the optimum lifecycle cost considering operating and capital cost for a series of different peak pot re-lining rates. The now available “economic-process” model would be well parameterized, adaptable to other plants and would provide the benefit of a more controlled program for various pot failure scenarios.

**Keywords:** Alba Potline 6 cathode relining facility; pot failure statistical distribution; Weibull distribution; lifecycle cost analysis.

## 1. Introduction

The Alba Potline 6 Project would be located in the existing Alba Smelter boundary in the Kingdom of Bahrain. The project scope includes the construction of a 6<sup>th</sup> Potline utilizing Dubai Aluminium (DUBAL) DX+ULTRA reduction technology consisting of two (2) potrooms with a total of 424 pots and associated Carbon Plant, Cast House and Infrastructure facilities.

Bechtel has been engaged by Alba to prepare a FEED study for the the Alba Potline 6. A new lining and de-lining facility is part of the FEED. The new Potline 6 Project would have limited available space requiring, the new re-lining and de-lining facility design to be located in the available space between the two potrooms. The design of the re-lining process has been based upon operating 52 weeks per year, seven days per week and 24 hours per day.

In determining the design and configuration of the new facilities for a series of different re-lining rates per year, several key questions arose including:

- How many potshell cooling stations would be required?
- How many de-lining pits and lining stations would be required?
- Should potshell repair be done in-house or by an outside contractor?
- What would be the risk associated with different scenarios?

The typical method used to answer these questions would be to create a static, sequential schedule with estimated time to accomplish different operations within an assumed operating and maintenance schedule.

For the first cathode re-lining cycle in a new smelter all the pots require re-lining within a short time period. Therefore, the cathode re-lining facility needs to be capable of sustaining the initial peak of pot failure.

The static model was run several times to determine the number of the following stations required for each scenario:

- Cooling stations
- Transfer pits
- De-lining pits
- Lining stations

The static model was run with an in-line lining de-lining arrangement. Due to the limited space available between the potrooms adjacent to the central passageway it was determined that a second lining de-lining building would be required, located between the potrooms at the non-rectifier end of the potrooms.

To validate the Alba Potline 6 scenarios a discrete event model (DEM) was developed by Bechtel. The DEM is an ideal platform to simulate dynamically the cathode re-lining process. The DEM provided flexibility for the user to explore and rapidly test different numbers of lining stations, de-lining pits, operating schedule variants, cathode cooling time, maintenance shift requirements, breakdown frequency and other multiple iterations. Once configured the DEM provides an ideal tool to rapidly test multiple scenarios.

While developing the model, Dubal provided the tentative cycle time for each of the operations, The model created an opportunity to review the re-lining operation in terms of cooling stations, lining stations, de-lining pits, shell repair stations, transfer pit, equipment and tools. This is an optimized approach to the design the cathode re-lining facility.

The purpose of the DEM was to provide an optimum facility configuration for each of the different pot re-lining rate scenarios.

After completion of the DEM model runs, an economic study has been performed considering the Capital Expenditure (CAPEX) and Operating Expenditure (OPEX) for each configuration. The new lining facility would re-use the equipment required for construction of Alba Potline 6, therefore the equipment cost was considered to be zero. However, as the de-lining shop would be new, all associated cost for the new de-lining equipment have been included.

Re-lining rate scenarios were analyzed from 2 to 10 pots a week, however as it is not possible to add ½ a cooling or ½ a lining station, only scenarios with integer number of stations per week have been further developed.

The life cycle cost was evaluated for each scenario based on an estimated pot life of 6 years. Costs for pots that would be cut out before the end of their useful pot life have been accounted for with the loss of the residual value of the pot.

Finally, a risk curve has been developed to consider the loss of revenue in the event of multiple failures occurring in a short period of time exceeding the re-lining rate capacity.

It is important to note that each project has its own constraints and opportunities. Multiple variables could impact the development of the DEM-economic analysis. Available space on the layout, number of potrooms, possibility of deferring lining de-lining building constructions, local productivity factors and so on are all impacting the configuration of the new facility. It is not the intent of this paper to analyze all these alternatives.

## 2. Model Development

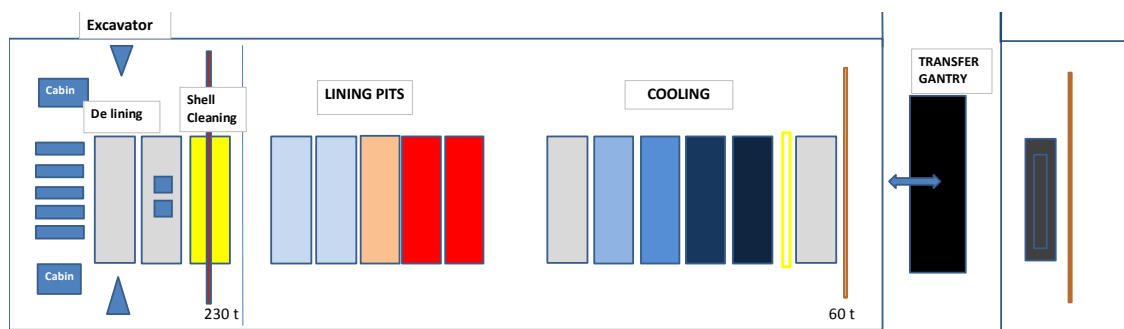
### 2.1. Modeling approach

DEM was chosen as a natural fit for the cathode re-lining facility. The process was modeled in FlexSim, a commercially available modeling and simulation tool (from FlexSim Software Product Inc.). FlexSim is a simulation tool that models, simulates, predicts, and visualizes systems in a wide variety of logistical applications. FlexSim was developed to optimize present and planned processes, identify and decrease waste, reduce CAPEX, and increase revenue. Material flows were composed of FlexSim library modules, e.g. network nodes, routes, queues, transporters. Operational logic was captured by Alba and Bechtel. Particular schedules were set in timetables. Data pre-processing, data input to model, extraction of simulation results and then subsequent post-processing were all performed in MS Excel

### 2.2. Lining de-lining

Due to the restricted space in the courtyard, the Lining and De-lining facility are located in an in-line configuration as represented in Figure 1. The original concept was to have the potshell repair performed by an outside contractor with spaces available in the building to store empty potshells, therefore potshell repair has not been included in the model. The figure below is showing the in-line lining with de-lining in the limited courtyard width.

This concept has been used to develop the different re-lining rate scenarios. A second building on the non-rectifier end of the potline, using similar configuration, would be added to achieve higher re-lining rates.



**Figure 1. Concept for the lining de-lining shop.**

Figure 2 shows the cathode re-lining area as captured in the model; with colored blocks positioned correctly on the layout to mark the main buildings and crane routes assigned to specific tasks.

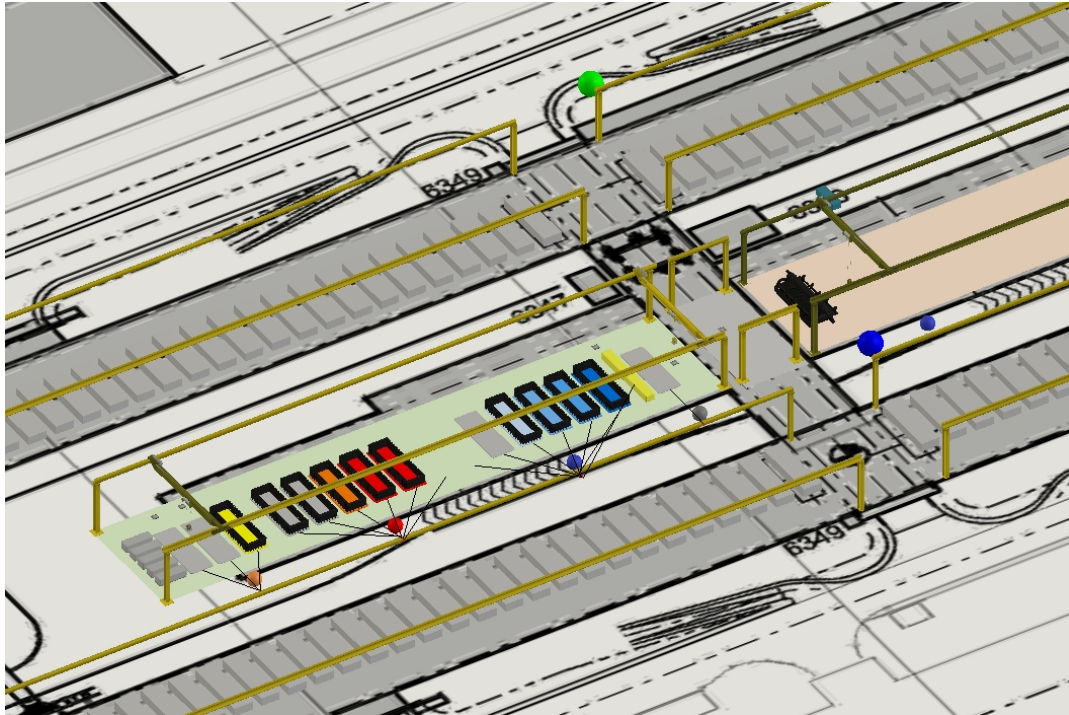


Figure 2. Re-lining area.

### 3. Weibull Distribution

The economic analysis was based on historical pot life data from Alba. The results have been scaled to the potline 6 with 424 pots. Figure 3 below represents the Weibull distribution of the pot failures. An option with a much narrower distribution was also analyzed.

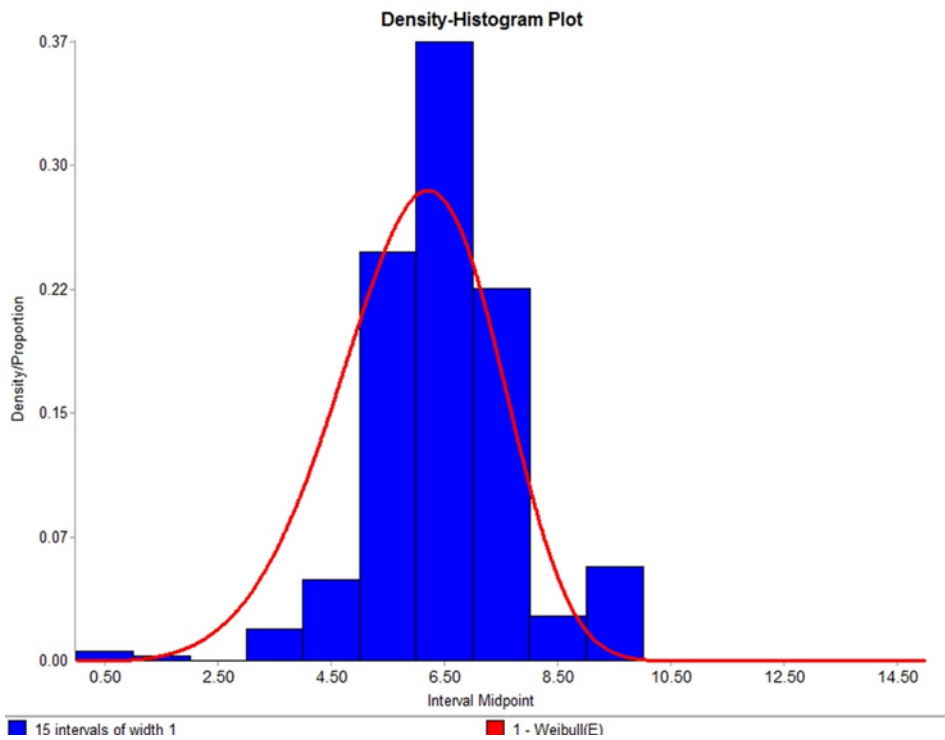
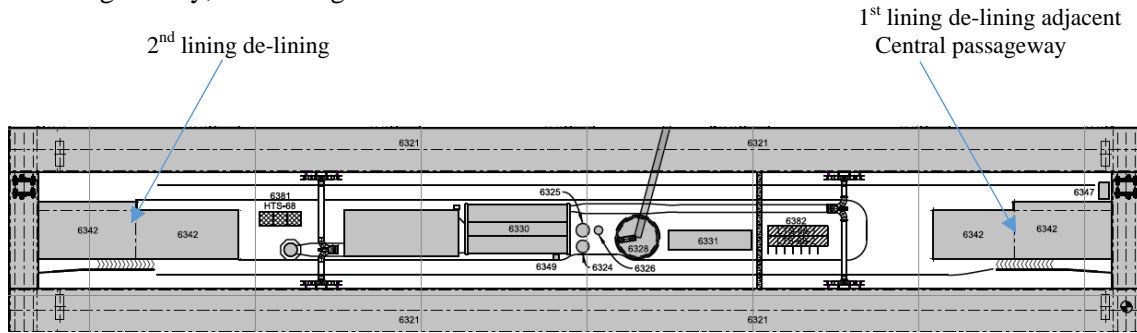


Figure 3. Weibull distribution.

#### 4. Capital Cost

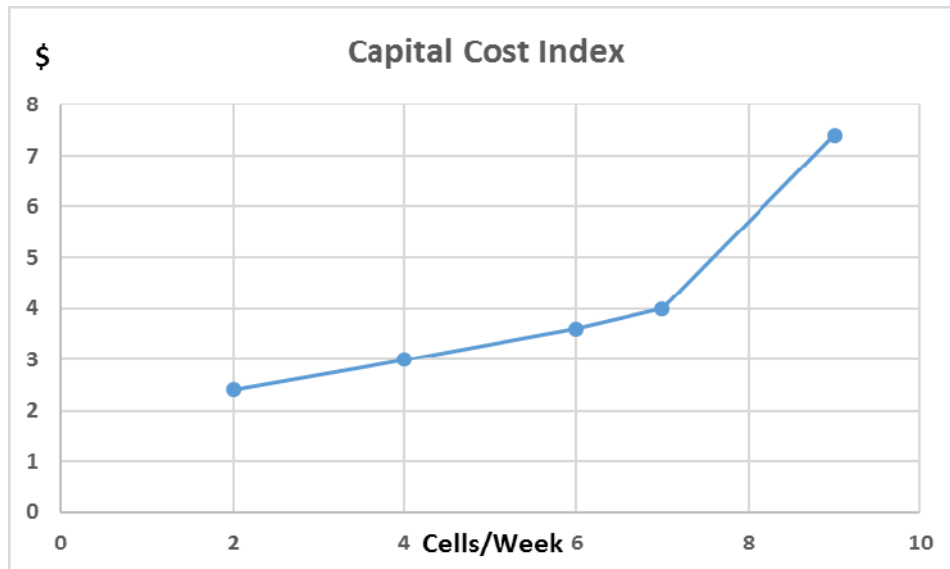
The capital cost of each scenario has been evaluated. For the pot lining area, it has been assumed that the equipment would come from the construction activities of building potline 6. Therefore, no money was allowed for lining equipment.

Due to restricted available space, lining more than seven (7) pots a week required another lining de-lining facility, refer to figure 4 below.



**Figure 4. Addition of a second lining de-lining building.**

A second lining de-lining facility is required above a relining rate of 7 pots per week. Figure 5 below shows the capital cost for the different alternatives and the step change above 7 pots per week. Please note that the dollar value indicated in the figure is based on an index to protect proprietary financial numbers.



**Figure 5. Capital cost for different relining rates**

## 5. Operating Cost

The forecast pot life of Alba line 6 is considered to be six (6) years. With a smaller facility for lining de-lining, operating cost increased as the pots are stopped before the end of their normal life. Table 1 below shows the different lining scenarios using the Weibull curve distribution and the selected lining rate capacity.

**Table 1 Scenarios at different relining rates per year.**

Weibull Curve Based Re-lining Rate per Year - Base Case					
Year	2 Pots/Week	4 Pots/Week	6 Pots/Week	7 Pots/Week	9 Pots/Week
2018	0	0	0	0	0
2019	0	0	0	0	0
2020	0	0	0	0	0
2021	0	0	0	0	0
2022	19	9	9	9	9
2023	104	23	23	23	23
2024	104	102	102	102	102
2025	104	197	197	197	197
2026	93	93	93	93	93
Total # of cells	424	424	424	424	424

A pot failure scenario was done assuming that all pots have an exact six (6) year life (reducing the distribution) to evaluate the economical sensitivity on lifecycle cost of different pot failure distributions. At a re-lining rate of nine (9) pots per week the lining capacity exceeds the number of pots (424) installed in the potline six with a rate of 468 pots per year. Table 2 below indicates the alternative re-lining rate per year. The sensitivity scenario is shown to demonstrate the influence of lining the majority of the pots in the same year on the life cycle cost. However, in practice it is not recommended to line all the pots in the same year as it would increase the exposure to have multiple pots out of service at the same time. Moreover, it would become a challenge for the operating team to stop and start multiple pots in a short period of time.

**Table 2 Sensitivity Option 1.**

Alternative Re-lining Rate per Year - Option 1					
Year	2 Pots/Week	4 Pots/Week	6 Pots/Week	7 Pots/Week	9 Pots/Week
2018	0	0	0	0	0
2019	0	0	0	0	0
2020	0	0	0	0	0
2021	8	0	0	0	0
2022	104	9	9	9	0
2023	104	23	23	18	0
2024	104	195	80	33	0
2025	104	197	312	364	424
2026	0	0	0	0	0
Total # of pots	424	424	424	424	424

## 6. Life Cycle Cost

Figure 6 below shows the combination of OPEX and CAPEX of the new facility. Please note that the dollar value indicated in the figure is based on an index to protect proprietary financial numbers.

The base case scenario was calculated using Weibull distribution data for pot life, with this distribution the best re-lining rate would be four (4) pots per week. However, the Weibull distribution was based on a limited number of data, a sensitivity scenario was calculated based on a scenario with a narrower pot life distribution where all pots terminate their normal life after six (6) years. This sensitivity scenario is designated Option 1. Option 1 indicates that the most economical re-lining rate would be to have a re-lining rate of seven (7) pots per week.

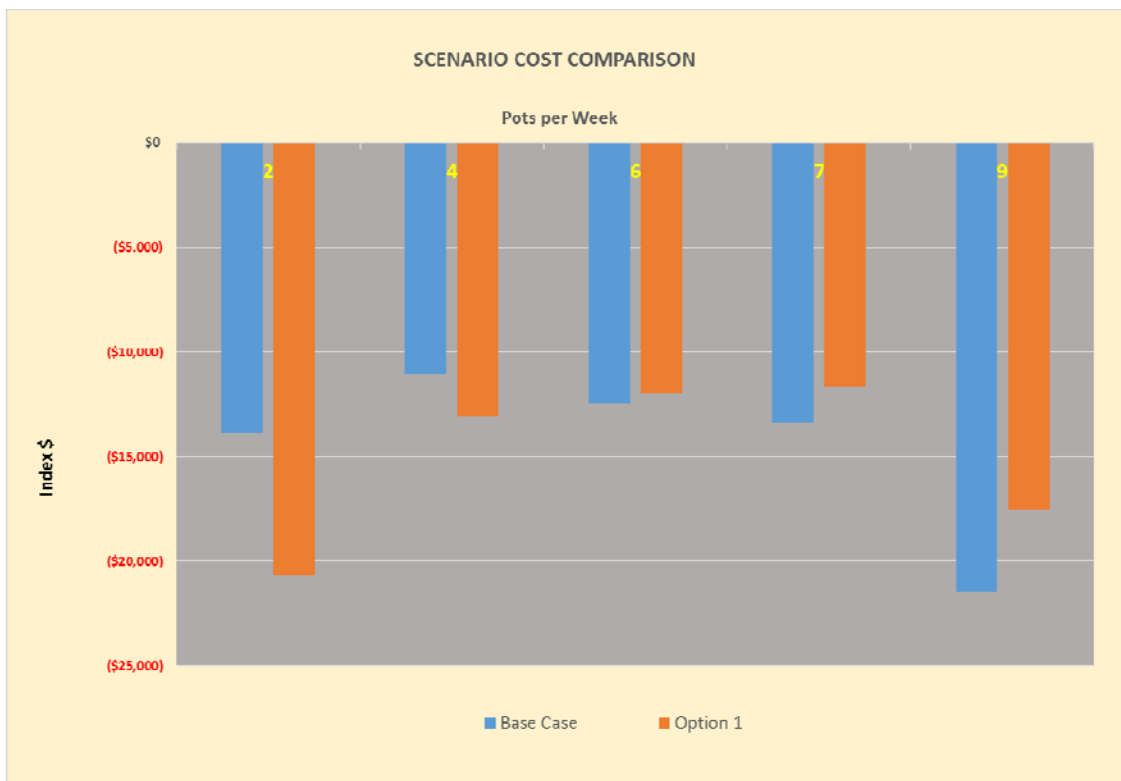


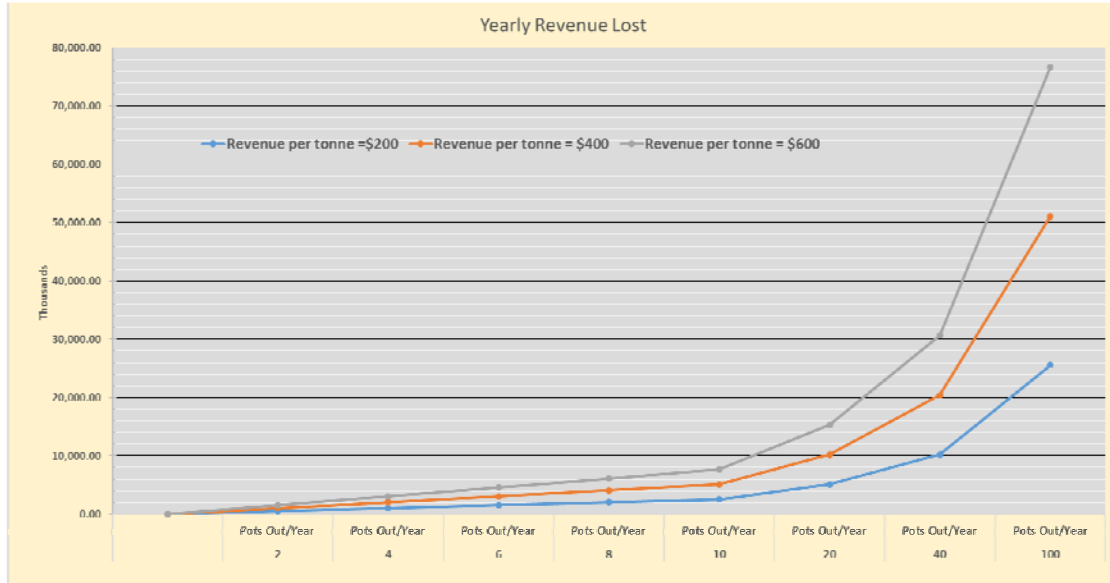
Figure 6. Scenario cost comparison.

## 7. Risk

The optimum life cycle cost has been determined however increasing the lining de-lining rate would increase CAPEX and would “de-risk” the operation in case of multiple failures occurring in the same week. This would have a negative impact on metal production.

To help evaluating the risk and the sensitivity of losing multiple pots above the re-lining rate capacity. Figure 7 below shows the curves at different metal loss revenue with different number of pots out of circuit for a full year.

As the optimum lining delining rate is between four (4) and seven (7) pots a week (depending on the selected distribution) excluding metal loss. The smelter could use these curve according to their own revenues to help in the decision making.



**Figure 7. Risk per number of pots remaining out of service for a year.**

## 8. Conclusions

It is not always obvious the select the best scenario for the lining de-lining facility. Indeed, using past data is not always the only basis, as often past data of pot life has been distorted with amperage increase, pot design changes and operational upsets. Therefore, a basic toolset, containing all the major equipment of a generalized de-lining and re-lining facility has been developed to help analyzing multiple scenarios. By using the combination of DEM and economic analysis, it has been demonstrated that with these tools it facilitates the decision making for the design and configuration of future lining de-lining facilities.

It is now possible to support both the economical and modeling work at the Bechtel Center of Excellence. During recent years, modeling toolsets have been systematically developed in many smelter areas. Now, boundary condition modules and control logic modules are available in commercial software for easy model development to suit most smelter customer needs.

Benefits through flexible models, pre-developed with the parameters used in most plants today and combined with the ability to quickly adjust to a user who is willing to explore innovations, offers potential cost savings and an increased level of confidence.

## 9. Trademarks

Flexsim is a registered trademark of Flexsim group.

## 10. Acknowledgements

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