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THE APPLICATION OF CONTINUOUS IMPROVEMENT TO ALUMINIUM POTLINE DESIGN AND EQUIPMENT

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Abstract

The design and supply of technologies to a large number of aluminium smelter projects, over the last two decades, has provided a unique opportunity to benefit from continuous improvement. This improvement process starts with feedback from customers and suppliers, combined with input from R&D and internal reviews, to identify, validate and then incorporate experiences and innovation from many areas.

The process can be described as systematic continuous improvement and the results are superior technology packages that incorporate the latest enhancements and better meet clients' needs. This paper describes the methodology used to manage the continuous improvement of technology packages.

It includes examples of improvements such as ancillary equipment redesign to improve safety and reduce forklift truck use. Also discussed are the challenges and opportunities of working with potline equipment suppliers. Effective cooperation enables the development of fit for purpose solutions that minimize potline commissioning issues and maximize pot performance.

Introduction

Constructing an aluminium smelter requires generating a technology package containing large amounts of documentation including drawings, specifications and procedures. In many cases the documentation is based on previous projects. However with a constant focus on investment cost and cost reduction, new ideas lead to changes and improvements. Expectations, especially health, safety and environmental (HSE), are also increasing from one project to another. Not only is it a challenge to generate the amount of documentation required, but to ensure it contains the latest improvements.

Improving a technology package is not an easy task as many factors impact on its development. A big issue is that a smelter project is not the best place to develop new ideas. What a smelter project expects from its technology provider is a demonstrated technology to minimize risk. To meet these expectations the timeframe of a project does not allow for investigation and demonstration of new processes, layout, plant or equipment. In most cases this is because proposed changes need to be validated by trials. Therefore Rio Tinto Alcan, as the supplier of AP Technology™[(1)], has implemented, alongside project work, a parallel stream of activity to develop new ideas, processes, plant and equipment for inclusion in its packages.

The R&D developments of the AP Technology™ are well known and documented [1,2]. For many decades these have been the visible part of AP Technology™ package improvements. The R&D work focuses on the process side of the technology; such as pot technology as in the case of Reduction. However, there is also a requirement for improving other aspects of the technology. Although these are often referred to as engineering improvements, Rio Tinto Alcan uses the label "industrialisation" to distinguish it from traditional R&D activities. This paper will explore the development and control of industrialisation work. Because of the range of the subject, discussion will be limited to describing the overall process and providing examples drawn from the Reduction.

Technology Package

A smelter technology package is made up of a number of elements. In Rio Tinto Alcan terminology these are referred to as technology bricks. A technology package for an aluminium smelter involves the selection of many technology bricks. (Figure 1) Some bricks come from previous projects while others arise out of the needs of a new project. In most cases existing bricks in AP engineering database must be adapted to the specific characteristics of the project. A technology brick is an element of the engineering package detailing one part of a smelter, be it a complete shop or only a single piece of equipment.

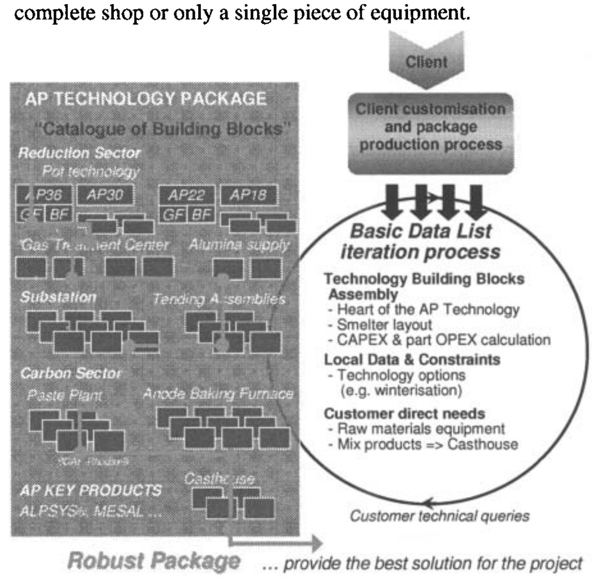

Figure 1. Technology Package Building Block Catalogue

The degree of interaction between the bricks is quite high. This adds to the complexity of modern technology packages and makes changes or additions time consuming to implement.

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[1] *AP and AP Technology are trade-marks of Aluminium Pechiney., used under license by Rio Tinto Alcan Inc.*

In the AP Technology™ delivery process, as the engineering study progresses, batches of documents are delivered to the client in four lots at scheduled points in the project. The document breakdown matches both the need of the client and the EPCM.

- lot A: Substation, paste plant and civil work design, shop descriptions and process flow diagrams, material specifications
- lot B: Pot element design: potshell, superstructure, busbars, lining, etc. Anode baking furnace & casthouse equipment, material handling
- lot C: Annex shop description and operation equipment
- lot D: Workshop organization and operating procedures

With the delivery of lot A, experts are seconded to the client's project team to assist in the use of documentation during the detail engineering and the procurement phases, and to forward client requests for alternative solutions.

Adaptation of the package to the client needs requires competencies drawn from all sectors of the organisation including electrical, process, control, mechanical and civil design.

Industrialisation

Difference Between Industrialisation and R&D

As shown in Figure 2, industrialisation is a process step in the implementation of R&D outcomes. Its role is to take R&D's new development and create the engineering documentation necessary for inclusion of the idea in a technical package.

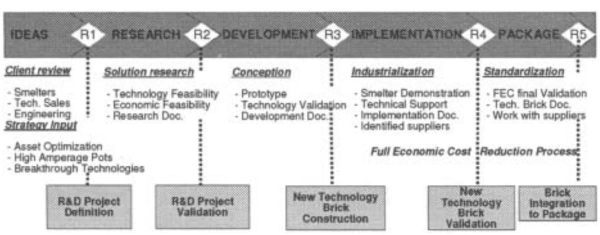


Figure 2. Development of Solutions from Ideas to Implementation

However the difference between R&D and industrialisation can be difficult to define. In Rio Tinto Alcan, R&D work is generally assumed to include an analysis of the fundamentals of the reduction process. An example is the design of pots which require studies of thermal performance and magnetic stability. But sometimes industrialisation does not follow the path shown in Figure 2 and avoids the R&D step with projects involving proven off the shelf technology that is put together in new or different ways. In practice the distinction between R&D and industrialisation can be somewhat blurred.

Industrialisation is defined as the process for improving a technology by integrating new processes, layout, plant and equipment into a unified package suitable for a smelter project. Its role is to develop an engineering package to provide the commercial delivery of the technology.

Previous Approaches to Industrialisation

Industrialisation work has always been carried out, both formally and informally. Traditionally improvement work was included in a project when the scope and timing of the improvements allowed. Some of the improvements were driven by changes brought about by R&D activities while others from specific cost reduction programs aimed at developing new cost effective solutions. Examples include Design to Cost and Full Economic Cost Reduction (FECRI) programs [3]. In these programs, each technical solution was tested and validated in operation in one of the RTA plants prior to being integrated as a brick in a Master Package.

The Master Package concept is a set of reference bricks from which package elements can be drawn for a new project. While a worthwhile concept, in reality it can be difficult to maintain. Also it can be difficult to interface with R&D projects and ideas coming from other sources as these can vary from one project to another and require solutions specific to local conditions.

The reality is that every project is different and has a different set of needs. Often just as much modification is necessary for a Master Package document as there is in using previous project documentation as the starting point. The Master Package concept, while a useful concept, has been replaced by a new industrialisation system that focuses on continuous improvement.

The Present Approach

The new Industrialisation system is built on the theme of continuous improvement. Its aim is to:

- capitalize on information and share it between projects
- ensure changes are integrated into packages
- allow changes to be promoted to the client
- provide an ability to track document changes.

Features of this approach include:

- A timeframe different to that of smelter projects
- The type of effort required including: projects, package improvement and fast track

The demand for industrialisation work comes from many sources as shown diagrammatically in Figure 3. Some of the demand is part of normal work flow such as addressing requests from clients and existing plants. Other ideas and suggestions require effort to collect and analyse information, such as feedback from Greenfield commissioning and smelter best practice. However, no matter what the source, a formal process is required to collect, collate and address these ideas.

This collection becomes a portfolio of ideas for potential industrialisation projects. The effort required to develop an idea varies greatly as does the timeframe involved. Because of this the ideas are separated into three categories:

1. Fast track issues
2. Package improvement ideas
3. Industrialisation projects

Fast Track Issues These are issues that are identified as being required for the technology packages currently under development for a client where timing is critical. The issue is given a high priority with the industrialisation team and is investigated, resolved and implemented to meet the client schedule.

Because of the time constraints, it is sometimes difficult to develop optimum solutions. Similarly innovation can be difficult because of the risk or lack of time for validation. For these reasons Fast Track can lead to subsequent industrialisation projects.

Package Improvement Ideas Many ideas involve improvements to the description of the technology in the existing documentation. This can include:

- More detailed description of plant and equipment in the drawings
- Revision of wording in a specification
- More details in a specification
- The need for new specifications and/or drawings

While package improvement can require significant work, the solution is usually already known or defined. The effort is limited to producing the documentation. An example given later is the development of "residual risk" documentation.

Industrialisation Projects

Industrialisation projects cover the issues not dealt with by the fast track and package improvement streams. Generally, these are longer duration projects requiring significant engineering input to integrate the solution into a technology package. This can include customising R&D solutions, customising or qualifying suppliers' solutions, or perhaps developing completely new solutions to meet changing requirements.

The HUB A database called the HUB has been developed to control the flow of industrialisation work. This differs from normal project management software because it must keep track of solutions until such time as they can be integrated into the AP Technology™ package of a project. It also provides a formalised mechanism for this implementation.

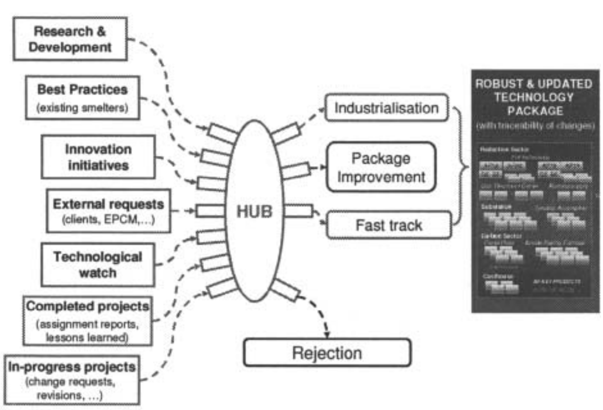


Figure 3. Information flow in the HUB

In the HUB system, an idea is listed and assigned to a person for clarification and evaluation. An on-line ideas form is filled in. Technical Directors monitor the new ideas on a regular basis and, in conjunction with project mangers, assign the Fast Track option on an as needs basis. Fast Track ideas are managed by the project manager.

A review committee meets on a regular basis to review ideas, assign resources and establish priorities. Where possible the industrialisation work is linked to the schedule of an existing smelter project.

The HUB database is a multi-project view, tracking changes across all projects and thus providing a traceability function. It provides a record of the evolution of ideas as well as the reasons for adopting the solution. It also documents when a solution is integrated into a particular package and by whom.

Project team members refer to the HUB to determine which ideas and solutions are ready for including in package documentation currently under development.

Status of Progress An industrialisation project system is differentiated from the usual project management systems by inclusion of some specific steps. In an industrialisation system the steps include:

1. proposed
2. approved
3. in progress
4. to be validated
5. ready for integration
6. integrated

The methodology for industrialisation projects is similar to other projects including the use of six-sigma methodology. However validation is a key step in industrialisation work. This can take the form of plant or workshop trials, prototype testing or review by subject matter experts. Validation needs to be fully documented to insure the thoroughness of the work and to provide tractability of technology changes. Once validated, it becomes ready for integration into a technology package. Upon integration its status moves to that of fully integrated and it is only here that the project can be considered complete.

Challenges with the Industrialisation Approach

Challenges with implementing an industrialisation process can include:

- Resource priorities
- Integrating with Greenfield project schedules
- Finding an appropriate method for integration in the technology package
- Solutions delivered in advance of their requirement.

The issue of resource priorities is traditionally a decision between having the technology package delivery team do the industrialisation work or setting up a separate team which focuses only on industrialisation work. Presently AP industrialisation work is carried out by the technology package delivery team. The challenge is to balance the industrialisation work with the team's primary purpose of delivering a technology package to schedule. This requires strong leadership to balance competing priorities.

Integrating industrialisation work into a project provides further challenges. Deciding whether a solution is sufficiently advanced and validated for inclusion in a particular package needs to be part of the formal process of running an industrialisation portfolio.

A further challenge arises if there is no immediate technical package for a solution to be incorporated into. The solution needs to be well documented and stored in such a way that it can be readily integrated into a package at a later stage. This leads to issues such as remembering that the work has been done and also determining if the solution is still valid. Again this is where the HUB database is invaluable because it ensures completed work becomes tagged as "ready for integration".

Examples

Examples are the best way of explaining the nature of industrialisation work. While the pot is often the focus of attention from a technology perspective, a lot of effort goes into the support plant and equipment and it is from here that the examples are drawn.

Residual Risk

AP is typically involved in the basic engineering phase of a project. Traditionally it reviews the risks and implements appropriate controls based on its understanding of the technology. However at the basic engineering stage and at subsequent stages not all risks can be controlled. Upon completion of each stage, the remaining risks, called "residual risks", must be handed on to be addressed in the next stage. (Figure 4) "Residual risks" are those risks to health, safety and environment (HSE) that are not eliminated or sufficiently reduced by the protective measures adopted in the previous stage of the project. Consequently residual risks need to be addressed by the client together with the client's project team. It was recognized that the communication of "residual risks" could be better managed and so specific residual risk documentation was developed.

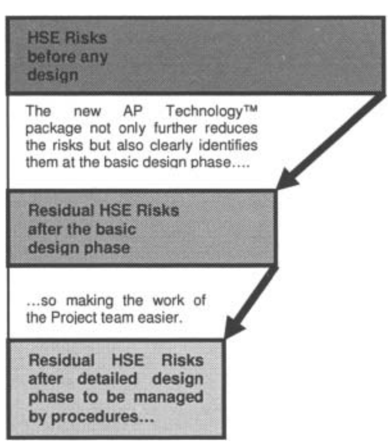


Figure 4. Residual Risk

As well as considering the residual risks identified during the previous stage, risk analysis reviews are required at each stage involving equipment suppliers and future operators as appropriate. These reviews identify hazardous phenomena taking into account HSE related aspects, such as installation and commissioning, normal use of equipment, its reasonably expected misuse, servicing by the user and maintenance by the maintenance personnel, smelter stoppage, demolition and equipment and material recycling. The probability and severity of these risks must then be evaluated. Risk reduction and management measures are then identified.

To better help the client understand and deal with the residual risks flowing from the basic engineering stage, new AP Technology™ package documents have been developed to identify residual risks associated with various sections of the smelter such as a substation or potline. An abbreviated example from a recent substation document is shown in Table I.

Table I. Example of Residual Risk Documentation

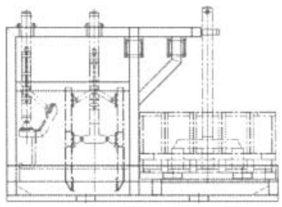
Risk	Hazard explanation	Risk Reduction by Engineering & Manufacturer	Residual Risk for client to address
Direct electrical contact	- Risk of electrocution, contact with live parts: - High current bus, - HV bus & cable ends - LV conductors in auxiliary boxes - People falling (or objects dropped by people) due to surprise of electric shock	- Fencing off the substation - HV equip. signage and identification - Fencing off the high current busbar - Signage of electrical rooms and boxes - As Built electrical drawings.	Substation access rules: - Lock-out procedures - Earthing trolley procedure - LV power supply lock-out - PPE for work on electrical installations
Indirect electrical contact	- Danger of electrocution with metal frames that get accidentally energized - People falling due to the effect of surprise caused by an electric shock	- Equipotential bonding of metal frames + earthing. - Labelling indicating the risk of equipment connected to potline potential.	- Regular monitoring of earthing and equipotential bonding. - Banning use of copper-corroding herbicide.

Start-up Tools and Equipment

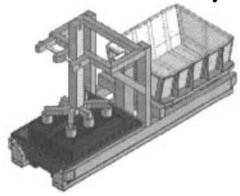
One area that is continually undergoing change is the design of tools and equipment. Smelters are always looking for better ways to carry out tasks. The RTA group in total provides a very rich source of inspiration with a variety of solutions to any given problem to draw from.

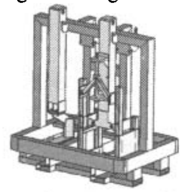
As a result of feedback from a recent project, opportunities were identified for improving the design documentation of some of the start-up tools and equipment. This also provided an opportunity to review equipment safety in light of current standards. Two areas in particular will be discussed, the design of stands and their transportation.

Process Improvement Analysis of the faulty anode pallet showed that concept of having a single pallet for tools, the removed anode assembly and a bin for the broken butt pieces was not the way operation people worked. The single pallet was originally designed to minimize the transport of equipment to the pot. However at a smelter the butt pieces and anode assembly go to the carbon plant while the tools belong to reduction. A more logical approach was to split the pallet accordingly (Figure 5).



Pallet for Faulty Anodes – Original Design



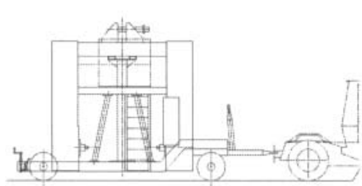


New Carbon Pallet

New Reduction Tool Stand

Figure 5. Spitting Up of Pallet for Faulty Anodes

Equipment Transportation Many smelters use forklifts for transportation of equipment in the potline. However it is recognized that forklift transportation of large items in the potline is less than ideal. The large size of the object makes visibility difficult for the driver or results in the practice of driving backwards, neither of which are considered best practice. Review of industry best practice has led to expanded use of anode transport vehicles for these tasks. Several equipment stands such as for ladle lifting beams and tapping pipes have been accordingly redesigned. An example is shown in Figure 6.

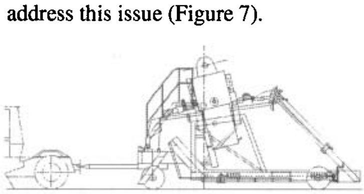


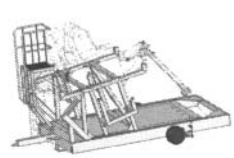
Original Trailer Design

New Stand

Figure 6. Ladle Lifting Beam Transportation

However, not all equipment stands are amenable to this solution. Some are still large enough to require a tow motor and trailer solution. Recent incidences have shown that hitching a trailer can be a hazard because an operator, or more particularly their hands, can be caught between a moving vehicle and a stationary trailer. AP (RTA?)now recommends using self hitching tow motors to address this issue (Figure 7).





Original Design

New Design

Figure 7. Self Hitching Trailer Solution

Supplier Integration Excellence of smelter operations not only relies on the performance of the pots, but also of the auxiliary equipment. In this context it is of high importance that suppliers' equipment becomes tested and integrated into the technology package. The example given here is that of entry into the cabin of the pot tending assemblies (PTA).

In the traditional AP potline design, entry into the PTA cabin is via a set of wooden stairs located in the potroom duct end aisle. Because the PTA travel cannot be impeded by the stairs, the handrails cannot protrude above the top landing. This has meant that as the operator is about to enter the cabin, there is no or little handrail, Figure 8.

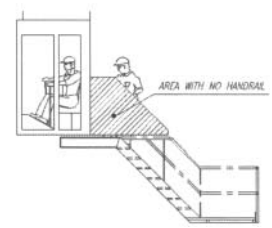


Figure 8. Traditional PTA Cabin Entry

This small, but significant issue has recently been addressed by a joint effort with ECL, the supplier of the PTAs. A review showed that not only the handrail but also control of access to the stairway was important.

As a result there is a new approach to cabin entry that addresses both issues. A small, pivoting handrail section has been added adjacent to the entry point for the cabin. (Figure 9) Because of clearance restrictions during PTA operations, the handrail section needs to fold flush with the cabin when not in use and yet deploy automatically when the cabin is in position with the stair landing.

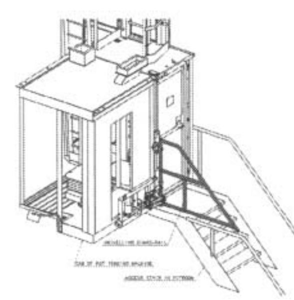


Figure 9. Pivoting Cabin Handrail

The development of the cabin handrail went from concept design, through mock up testing to full scale workshop tests. In parallel the design of the stairway system was altered to include an interlocked door at the foot of the stairs. The interlock works such that the door will not open to gain stair access unless the PTA cabin is in position and the handrail has been deployed.

This work highlights several of the previously mentioned issues of industrialisation work. These include the time frame to develop new ideas being different to the project timeframe, the need to integrate a solution into the technology package and the validation of the solution before it is supplied to a client.

Supplier Qualification In this competitive world, suppliers are always improving their products and looking for ways of reducing costs. This can be both an opportunity and a challenge for a technology package. While the aim is always to drive down the costs of smelter construction and operation, any changes must be assessed to make sure technical requirements are still met.

An example of supplier qualification is the development of a new generation of ECL anode beam raising frames (ABRF) for AP pots. While the existing generation of ABRFs for AP pots have a well earned reputation, ECL decided to develop a new machine that was not only less costly but also had better functionality. It is not intended to discuss the details of the new design, rather to describe the collaboration with ECL needed to qualify the design for use in a Greenfield project.

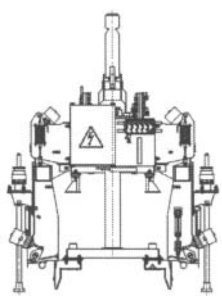


Figure 10. New Generation of Anode Beam Raising Frame

The main technology issues were the positioning of the frame on the superstructure and adequacy of the new clamping system. In ABRFs for AP pots, the frame is lowered onto the superstructure and then clamping arms are lowered against the anode stems. This is a two step operation that requires mechanism to control the raising and lowering of the arms. To simplify the frame, ECL returned to an earlier design which is still in use in many smelters. In earlier designs, the frame is lowered onto the superstructure and at the same time operators must check that the stem clamping system aligns with each stem. In the new ABRF, ECL reverted to the previous design concept but addressed alignment issues by redesign of the guidance system onto the superstructure. In order to be assured that the new design would perform adequately with AP pots, joint ECL and AP reviews were held to consider the new design, visits made and advice sought from smelters operating close variations of the new design.

A prototype of the clamping system for a single stem was manufactured and a series of tests conducted at the St Jean de Maurienne smelter to ensure the fitting and clamping of the mechanism on an operating pot in the magnetic field. As well workshop endurance testing was carried out. Issues arising from these tests were resolved with further modifications to the design.

This example demonstrates the effort required to qualify changes to critical equipment before its implementation in a technology package can be considered.

Potroom Electrical Insulation

In a potroom operators are in contact with equipment or building elements at a high electrical potential. However, the design of the potroom allows the operator to work safely. This design is a story of continuous improvement and optimization from one project to the next. Recent improvements were driven by the increasing number of pots in modern potlines. This results in increased potline voltage, which, when over 1500V, requires that insulation complies with IEC standards. This along with increased line current which impacts operating temperatures, affects the thickness, the creepage distance and the quality of the material.

The insulation design has also evolved to improve constructability and ongoing maintenance. For example, special neoprene slab bearings are used to avoid cracks in the concrete and in the insulation material. Naturally the material and the construction methods are designed to minimize capital costs.

The transitional areas between earthed and insulated slabs have been improved to avoid short-circuits caused by pedestrians or vehicles moving between different potentials.

A new busbar and pot support design takes into account their upgraded requirements. In addition, improved levels of engineering detail help ensure correct detail design

Finally, the slab design has been changed to reduce cost while at the same time its electrical design is improved to increase operator safety.

Conclusion

Perhaps industrialisation is not as glamorous sounding as R&D, however, it provides a vital role in improving the content and robustness of the AP Technology™ package. A technology package is an ever changing product. There will always be the desire to improve it and to drive down costs for the benefit of the client.

Industrialisation ensures the proper integration of equipment and processes into the AP Technology™ package through controlled testing and qualification of all improvements. However, tight integration also means that simple answers are not necessarily easy to give. It can take time to establish all the impacts of a proposed change.

Industrialisation is an ongoing process used to validate equipment and processes before delivery to the client. Thus, clients can be better assured that proposed equipment and processes are fit for purpose.

Acknowledgement

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