Light Metals 2012 *Edited by: Carlos E. Suarez*
TMS (The Minerals, Metals & Materials Society), 2012

COMMISSIONING OF EMIRATES ALUMINIUM SMELTER POTLINES

B.K. Kakkar, David S. Spencer, Walid Al-Sayed, Salman Abdulla
Emirates Aluminium Smelter, P.O. Box 111023, Abu Dhabi, United Arab Emirates.
b.kakkar@emal.ae; d.spencer@emal.ae; w.alsayed@emal.ae; salmansd@emal.ae

Keywords: Greenfield, commissioning, start-up, reduction, Phase I, Emal

Abstract

On the 2nd of December 2009, Emirates Aluminium (Emal) commenced its journey of starting 756 Dubal DX technology reduction cells. This undertaking was successfully completed on the 2nd of January 2011, thirteen months later, resulting in an average start-up rate of 13.3 pots per week. This sets a new benchmark for Greenfield Smelters. This remarkable achievement was possible due to an efficient work organization, with committed and experienced employees. The pot start-up rate and pot technical results give measures of the success by which the task was accomplished.

This article provides insights into the experiences gained and systems used by the Reduction Operations Team, in managing the organizational complexities of commissioning the largest Greenfield Smelter start-up to date.

Introduction

Emal Reduction Operations Team achieved what it considers to be a remarkable feat by starting 756 pots in less than 396 days; maintaining an excellent safety record, only 1 LTI; 0 pot failures to date; and sustained pot technical performance. Questions arise as to how this has been achieved: good fortune or good management? Some may say both, but management practice is the only area where insightful comment can be made. So what practical management practices did the Team adopt and what worked and what did not? Before answering these questions some background information as to the relevance of this article is given.

Background

Before commencing on its commissioning and start-up campaign the Team reviewed the technical literature in the hope of learning from the experience of others. A number of useful documents were found, e.g., by Reny et al. [1], but often the focus was on the management of the interfaces between Projects and Operations teams and not on the day-to-day challenges of starting a large modern smelter. The Team also recognized that projects of a Greenfield nature are becoming more and more common, particularly in the MENA[1] region, so there was a good opportunity to document the operational challenges and opportunities it had faced and link them to the technical outcomes achieved.

Reduction Operations Team Organization Design

In order to understand the operational challenges and opportunities faced, it is necessary to describe the Reduction Operations work structure and functional organization.

One of the unique features of Emal's start-up was that it encompassed two potlines, each consisting of 378 pots. This arrangement, coupled with the vast number of pots, resulted in an extended start-up period and subsequent overlap of (a) the start-up and commissioning activities and (b) the steady state operation see Figure 1. Each activity was independently staffed and managed. Following the completion of activity (a) on Potline 2 this partial overlap was removed, as both activities (a) and (b) for Potline 1 fell under the direction of one Manager. Following the completion of activity (a) on Potline 1, the management of the two Potlines was further rationalized under one Manager. Challenges associated with this overlap will be discussed throughout the article.

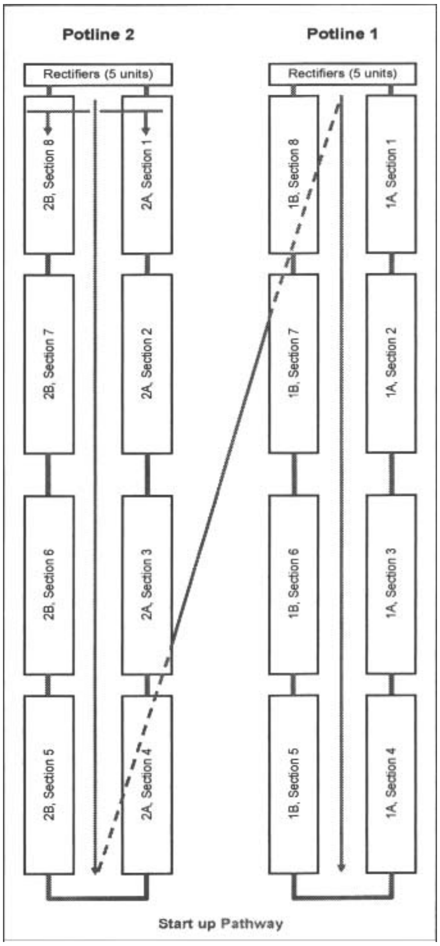


Figure 1. Start-up and Commissioning Work Flow

Focusing on the activities associated with (a) the start-up and commissioning of the Potlines the process was split into five areas, see Figure 2.

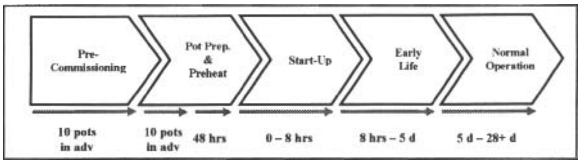


Figure 2. Work Structure

[1] MENA = Middle East and North Africa

Critical Success / Key Learning Factor:
A key learning was the need to have the work structure clearly defined, with respect to the:

- Key tasks steps;
- Expected duration of each task;
- Necessary work-front gap to avoid clashes;
- Handover point;
- Acceptance criteria; and
- Individual accountability for delivering.

The Team achieved this by conducting desktop review sessions prior to the start-up and developing a series of workflow diagrams for each activity, see Figure 3, and sign-off check sheets, see Figure 4.

The workflow diagrams were clearly displayed in the work area and were developed with direct input from the shop floor to foster ownership and understanding. The sign-off check sheets were used for all tasks and have been kept as permanent record of the activities undertaken.

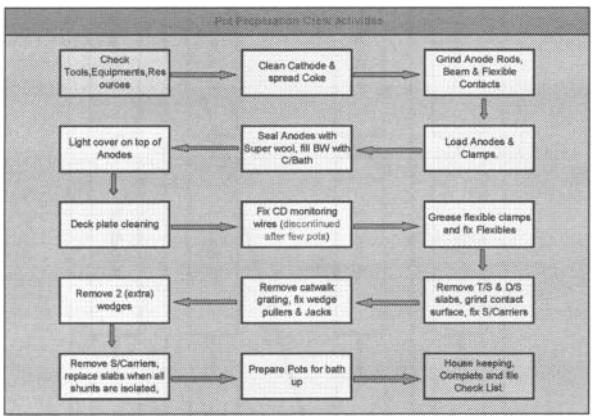
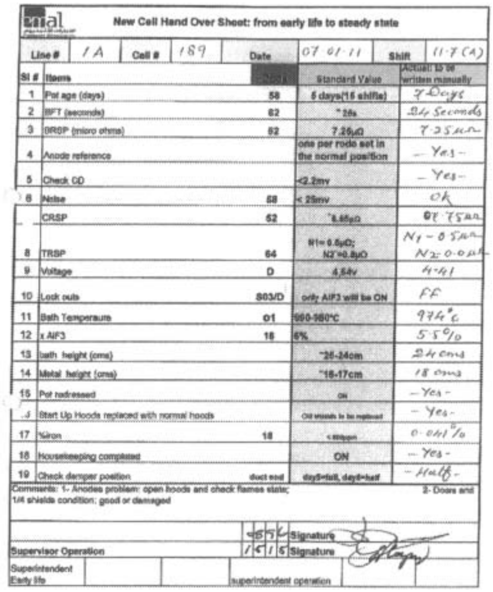


Figure 3. Workflow Diagram Example

Despite the advanced planning, an early challenge faced was the handover process from the Early Life to Normal Operations crews. For Potline 2 Operations this represented a shift in accountability from one "manager" to another, whereas for Potline 1, due to organizational re-design, this was avoided. Re-clarification of the acceptance criteria for the "Pot at target conditions" e.g., @ Day 5 Pot excess AlF_3 should = X% was necessary to overcome this.

While this issue is very minor in nature and did not represent any threat to the start-up process, it merely highlights and reinforces the importance of the need for effective communication and clear scopes of accountability and authority between teams.



New Cell Hand Over Sheet: from early life to steady state

Line #	1A	Cell #	189	Date	07-01-11	Shift	11-7 (A)

Sl #	Items		Standard Value	Actual: to be written manually
1	Pot age (days)	58	5 days(15 shifts)	7 Days
2	BFT (seconds)	62	~28s	24 Seconds
3	BRSP (micro ohms)	62	7.25μΩ	7.25 μΩ
4	Anode reference		one per rods set in the normal position	- Yes -
5	Check CD		<2.2mv	- Yes -
6	Noise	58	< 25mv	ok
	CRSP	52	~8.85μΩ	07.75 μΩ
8	TRSP	64	N1= 0.5μΩ; N2=0.8μΩ	N1 - 0.5 μΩ N2 - 0.0 μΩ
9	Voltage	D	4.54v	4.41
10	Lock outs	S03/D	only AlF3 will be ON	FF
11	Bath Temperaure	01	960-980°C	974°C
12	x AlF3	18	6%	5.5%
13	bath height (cms)		~25-24cm	24 cms
14	Metal height (cms)		~16-17cm	18 cms
15	Pot redressed		ON	- Yes -
16	Start Up Hoods replaced with normal hoods		Old shields to be replaced	- Yes -
17	%iron	18	[illegible]	0.041%
18	Housekeeping completed		ON	- Yes -
19	Check damper position	duct end	day5=full, day6=half	- Half -

Comments: 1- Anodes problem: open hoods and check flames state; 2- Doors and 1/4 shields condition; good or damaged

Signature
Supervisor Operation 1/5/15 Signature
Superintendent Early life | superintendent operation

Figure 4. Sign-off Check Sheet Example

Operational Challenges and Opportunities: Team Effectiveness

The Critical Success/Learning Factor identified above represents a simple example of the practical systems that were put in place to manage the start-up and commissioning process. Systems of this type were crucial elements in developing an effective and efficient work team. It is to these systems that the article now will focus.

Common Purpose

One of the most critical factors in achieving success was to have a clearly defined objective that was constantly reinforced at both senior management and shop-floor meetings. This objective was simple: "To safely start 756 pots in the shortest time possible". An upper and lower range for the cut-in scenarios was developed and this provided a gauge against which to measure performance, see Figure 5.

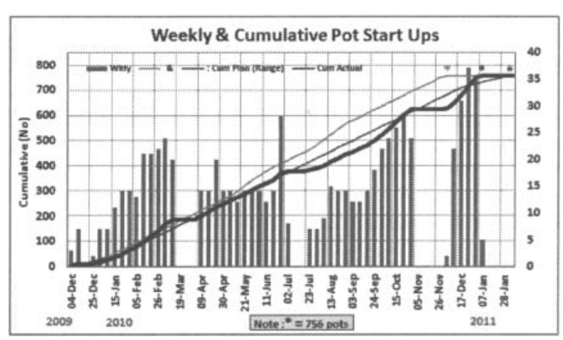


Figure 5. Pot Start up

Critical Success / Key Learning Factor
The "Common Purpose" element was tested at Emal due to the prolonged nature of the start-up and the need to establish two potlines in operation. The Team felt that focus did shift partway through the start-up, as Potline 2 operational issues began to come to the fore. To manage this issue the Team needed to split its resources to cover both areas and redefine

the objective for one part of the team: "Establish operational stability in Potline 2".

The ability to split the Team and refocus its efforts were only possible due to the smooth nature of the start-up. If issues had been occurring in both areas, then it is unlikely that this would have been possible and the rate of start-up would likely have been affected.

Focus was realigned towards the goal of start-up during the latter part of the year, as operational constraints in both Reduction and other areas, e.g., Carbon and Power were resolved.

Critical Success / Key Learning Factor

The smooth start-up and commissioning operation was aided by strictly controlling changes to the method of starting-up and stabilizing the pots. Only minor adjustments were made to the methodology, e.g., soda additions or liquid bath requirements.

The Team managed this by having both a clear understanding of the overall objective and its (the Team's) limitations and boundaries. A Change Management Process was established, through which this could be managed both internally and with the Technology Provider, see Figure 6.


EMAL - REDUCTION

PARAMETER CHANGE REQUEST FORM

Date | PCR No
Employee Name | Employee No
What is the change Requested (specifics required)
Is change associated with a trial or previous PCR? Y / N
Trial / PCR No. | Note: Attach reasoning document –
Where is the change to be implemented?
What is the business case for the change (Quantify Why)?
Safety – First, Last & Always Y / N
Investing in Today for Tomorrow Y/N | Environmental Protection Y / N
We respect individuals & their differences Y/N | Everything can be improved Y / N
Estimated Financial Benefits
When is the change to be implemented and what will be verification mechanism?
Start Date | Finish Date
Verification Mechanism:
EHS Components
Has a risk assessment been completed to assess impact of change? Y / N / NA
Risk assessment Document No: Y / N / NA
Affected Area Acknowledgement
Area: | Employee No | Name | Date
Signature:
Approvals
Area Manager - Requestor
Signature | Employee No | Name | Date
Area Manager - Implementer
Signature | Employee No | Name | Date
Area Owner
Signature | Employee No | Name | Date
Implementation & Verification
Change Implemented By
Signature | Employee No | Name | Date
Change Verified By
Signature | Employee No | Name | Date
PCR Closure By Originator
Remarks:
Signature | Employee No | Name | Date

Figure 6. Change Request Form

Running improvement trials or testing new materials was not an objective. For example, a basic resistor coke preheat with shunts was utilized. Even though the Team understood there where opportunities to use other materials e.g., graphite powder, it recognized that an adequate cathode temperature was being achieved, see Figure 7, and therefore refinement of the practice was neither necessary, nor focused on.

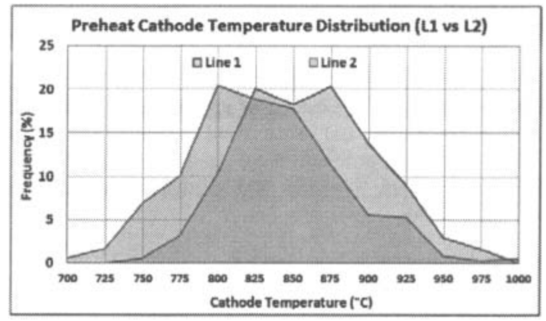


Figure 7. Cathode Temperature TE/DE Surface

Ensuring that all parties recognize and acknowledge that practices or systems will not always be 100% perfect, but if achievement of the overall objective is being met then a compromise is required. Exercising restraint is difficult, but critical in avoiding distractions. Furthermore, the Team felt efforts were rightly focused on resolving people issues and establishing intra-departmental co-ordination and communication channels that actually resulted in solving the majority of operational and technical challenges.

Specific Goals

Setting specific goals, at both a macro and micro level, and then tracking and reporting actual performance of their progress, was also an important element in achieving success. Systems were developed at a management level, but examples of roll-out to the shop-floor included simple reports and graphs, see Figure 8 and Figure 9, which were distributed by the Process Control Team to the Superintendents and Shift Supervisors.

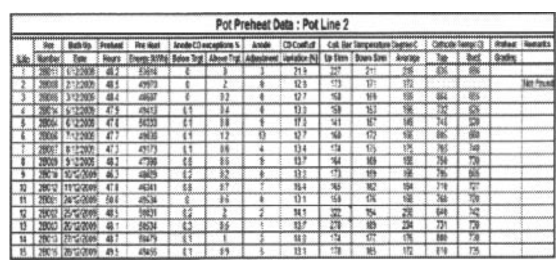


Figure 8. Pot Preheat Data Form

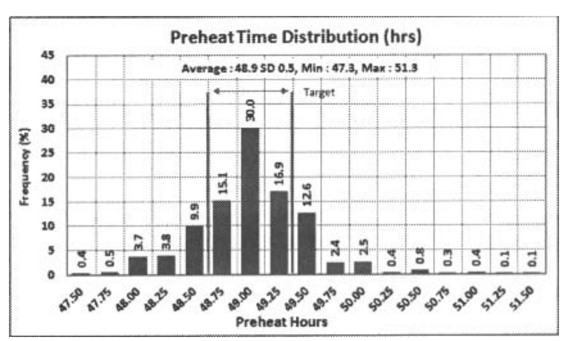


Figure 9. Pot Preheat Time Distribution Graph

Critical Success / Key Learning Factor

The handover of the preheat pots "on-time" was a vital activity in ensuring that the continuity of the bath-up process was maintained. This activity also represented a change in accountability from the Preheat to Operations Team. Close attention to both the "final" cathode surface temperature and the distribution of preheat timings were tracked from the outset, even when only 1 pot per day was being started.

A log was kept for the causes of any deviation so that these potential bottlenecks and issues could be tackled and resolved. Early examples of problems were equipment availability e.g., number of torque wrenches and mechanical problems and sticking wedges.

Critical Success / Key Learning Factor

The use of check-sheets was widely adopted to both guide employees and ensure that tasks were completed as planned.

The need to pay close attention to detail is demonstrated by the fact that even when the Team was achieving a start-up rate of 6 pots per day, with a gap of approximately 30-40 minutes between pots within pot rooms, it became an established practice (and requirement) that all equipment checks were repeated, e.g., crucible tilter operation and battery status were reconfirmed every time, see Figure 10.

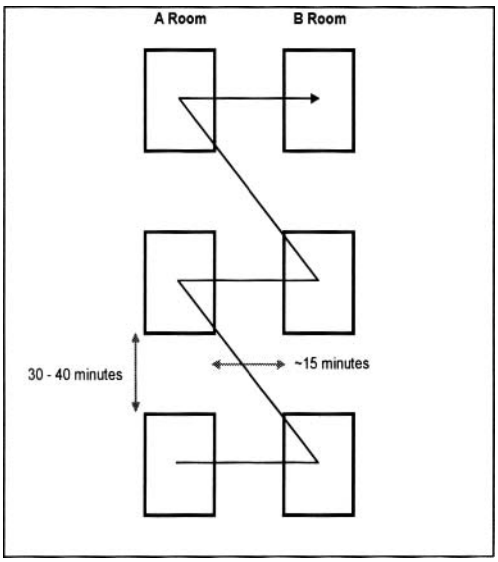


Figure10. 6 Pot Bath-up Sequence

Critical Success / Key Learning Factor

An interesting observation from the Team was that approximately every three months the general goals appeared to shift.

Goals for the first 3 months were observed as being:

- Establish employee familiarity with equipment
- Establish work practices
- Gauge areas of Strength and Weakness
- Limited focus on adherence to pot ramp-up rate rather establish behaviours, systems and methodologies

Goals for months 4 to 6 were:

- Focus on establishing the pot ramp-up "drum-beat"
- Begin process of establishing formal systems
- Prepare employees and potlines for Summer period

Goals for months 7 to 9 were:

- Maintain the ramp-up rate through Summer and Ramadan period
- Focus on tackling operational challenges associated with Potline 2
- Continue the process of establishing formal systems

Goals for months 10 to 12 were:

- Accelerating the ramp-up rate to complete start-up as quickly as possible
- Prepare and undertake Guarantee Testing
- Finalize the embedding of formal systems

Critical Success / Key Learning Factor

Two key challenges associated with "Accelerating the ramp-up rate to complete start-up as quickly as possible" were:

Towards the end of the start-up activities the Team realized that the rate limiting step shifted from the ability to cut-in and start pots, to the ability of the Early Life and Normalization Team to maintain and sustain performance.

This issue was managed by shifting employees from Potline 2 to Potline 1 to assist with the work. Essentially this was similar to what occurred during the Potline 2 start-up, however, it is important to mention that the stability of Potline 2 Operations allowed this to occur.

The ability to quickly normalize pots was also important in managing the technical issue of not exceeding the Potline Over-voltage. Daily tracking of the Potline Voltage trend and number and severity of Anode Effects was used to ensure feedback could be given to the Operations Team on their performance, see Figure 11 and Figure 12.

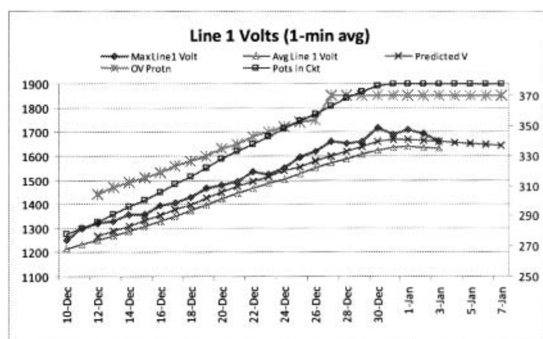


Figure 11. Potline Daily Voltage Trend

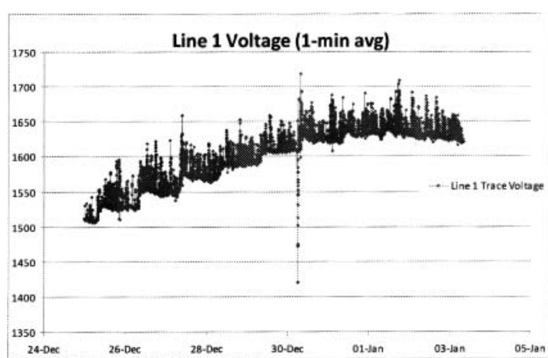


Figure 12. Potline Daily Voltage Trend

Composition - Abilities of Members

The Reduction Operations Department is made up of ~565 employees covering Potlines, Services, Maintenance, Process Control and Production Management Systems (IT & Automation). Potlines represent 300 of these employees and the task of ensuring that the team composition of new and experienced employees was optimal was a key challenge for the business.

Critical Success / Key Learning Factor

The Team had ~70 employees directly sourced from Dubal, many in key leadership positions. This ensured that a core group was both familiar with the Pot Technology and the Control Systems for operation. Familiarity within the group of individuals' working styles and personalities meant that the time typically associated with group establishment, via dynamic processes - forming, storming, etc..., was reduced.

Critical Success / Key Learning Factor

Emal Management's decision to start the smelter approximately four months ahead of schedule had the effect of initially reducing pressure on ramp-up pace. This provided an opportunity for employees to become familiar with the various equipment under their control (PTMs, Bath Tapping Vehicles etc..) without the fear of hindering the goal attainment.

There were also three periods through the year where start-up was halted due to resource constraints. While these delays did have some impact on bath generation capability, they were also beneficial as they allowed the Team to take stock of developments, evaluate performance and provide breaks for employees before launching into renewed activities. Given the prolonged duration of the start-up, it is probable that at least one break would have been required regardless.

Critical Success / Key Learning Factor

A key learning was that during Potline 2 start-up limited employees from the Potline 1 Team gained exposure to the normal day-to-day operations of the pot technology and associated equipment. This represented an issue when the team moved to Potline 1, as time was required to familiarize and train these employees. This issue could have been avoided by allowing individuals to transfer between teams.

Team Efficacy

The Team recognized very early on that developing a sense of ownership and more importantly self-belief was necessary to achieve success. Emal was the first major Greenfield expansion for the DX Pot Technology and likewise many other systems utilized represented their first major industrial application, e.g., Alstom's Pot Feed System. This translated to both an opportunity and a risk for the Operations team.

Critical Success / Key Learning Factor

Given that there is a greater probability that unforeseen issues may arise with the technologies, there is a strong need to continually evaluate and evolve the relationship between the Team and the Technology Provider. Appreciation that shop-floor employees may be observing real differences between the full scale operation and trial sections is required. The experiences and knowledge of these employees should be utilized. An expectation or reliance on the Technology Provider to fix all problems is unrealistic.

To gradually build a sense of independence within the Team, as problems surfaced they were required to formally communicate them to the Technology Providers, but also to include a request to implement any potential solution(s) they may have discovered. This freedom to problem solving was integral in developing their sense of self-confidence. Examples of some of the problems tackled by the Team were:

- Methodology of soda ash additions;
- Wedges stuck at cut-in; and
- Suction failure during bath tapping.

Leadership

The concept that strong leadership helps foster the development of an effective team is not necessarily that surprising. Rather than focusing on the characteristics of an individual, which make for a successful leader, the practical example set by the Superintendents is described.

Critical Success / Key Learning Factor

The Superintendents were typically present on-site one hour before the day shift team arrived and departed at a minimum one hour after. Coverage of weekends was required and communication channels were open on a 24 hour basis. The superintendents would check in, via telephone, with the afternoon and night staff regularly every 24 hours. Leave was minimized to ensure continuity of points of accountability.

Key points stated by the superintendents were:

- Ensure communication is kept simple, with clear direction given as to the expectation of deliverables or outcomes.
- Ensure the superintendents have a common expectation.
- Establish a fear free environment, e.g. no written warnings were issued during the start-up period, and it was considered to be learning period.
- The shop floor staff were empowered to suggest changes in the work practices and where feasible, these were evaluated and implemented, e.g., using the same tapping yoke for tapping bath multiple times on days with more than one pot bath-up, by just blow-cleaning the aspirator, thus saving time and equipment.
- Ensure that any change needed to the process or equipment was simulated, tested and approved before implementation, e.g., feed logic changes in early operation pots to reduce anode effect frequency and intensity, so that additional power is available for faster ramp up towards the completion of Line 1 start up (max. power demand).
- Develop and maintain standards for housekeeping for each and every task.

It is important to recognize that significant sacrifice is required from team members to achieve the goal. Methods of rewarding and compensating these individuals often require the HR Team to understand the fundamental differences between a start-up environment and normal steady state operations.

Overall Performance Results

In order to quantify the impact that an effective team provided, it is necessary to look at the Smelter's performance results through the ramp-up period and their continuation into 2011. Tables 1 and 2 and Figure 13 show the Safety Performance and Pot Technical Performance achieved so far.

Table 1. Safety Record Reduction Operations

Performance Indicator	Periods	
	2009-2010	2011 YTD Oct
LTI	0.15 (1 incident)	Nil

Table 2. Pot Technical Performance

Performance Indicator	Periods	
	2009-2010	2011 YTD Oct
Total production, t	340,885	622,467
Ave. Potline Current, kA	350.1	351.4
CE, %	92.0	96.0
DC Spec. Energy, kWh/t	13,809	13,072
Fe content in metal, %	0.065	0.046

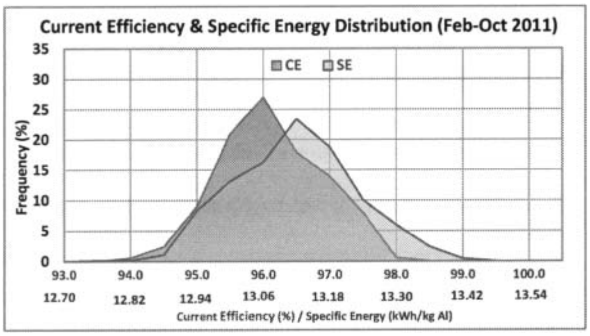


Figure 13. YTD Current Efficiency and Specific Energy Performance

In Emal's opinion these results represent a very impressive set of performance data. The Team recognizes that the technical performance is not solely the result of its effectiveness, but represents "one part of the pie", with other important elements being design, materials and construction, see Hale [2].

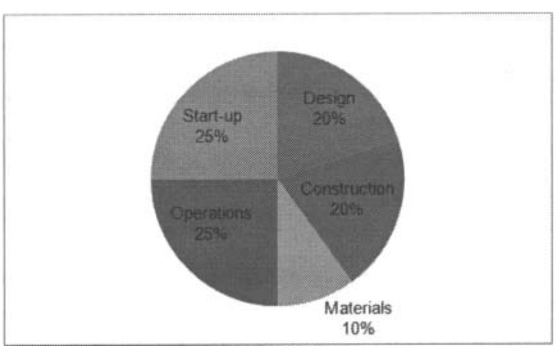


Figure 14. Performance Elements

The Last 100 Pots in 21 days

To further illustrate the impact of developing such an effective team, one needs only to look at the achievement of completing the start-up of Potline 1. While many would consider that the rate of start-up should decrease, as both manpower and equipment resources were stretched to their limits, Emal was able to achieve the last 100 pots start-up in 21 days. This compares to 74 days for the first 100, see Figure 15.

This feat was possible due to a commitment given from both the shop-floor and management team to work additional hours above their contractual obligations. This support was given willingly from all teams: Operations, Service, Maintenance and Process Control.

Many individuals had already provided extended on-site presence without compensation, but the team spirit and desire to achieve a milestone drove them on. This type of behaviour and the achievement a feat greater than the sum of each individual's contribution fundamentally represents a well-functioning team.

Figure 15. First vs. Last 100 Pots: Start-Up Rate

Conclusion

The success of the Emal Phase 1 project was in no small part due to the ability to establish effective work teams within the Reduction Operations area. Critical factors, which assisted in this process were common purpose, specific goals, and abilities of members, team efficacy and leadership.

The consequences of the cohesive and collaborative team environment were a start-up rate of 13.3 pots per week and impressive and sustained Potline production performance.

References

[1] P. Reny, J. H. Lombard & R. J. Green, Alouette Phase II: Starting-up the Right Way, *Light Metals 2006*, 2006, 225-230.

[2] W.R. Hale, Improving the useful life of aluminum industry cathodes, *JOM*, 11, 1989, 20-25.

Acknowledgement

The authors wish to thank the many organizations and individuals that supported the project throughout its various phases: Mubadala, Dubai Aluminium, SNC Lavalin and Worley Parsons. Within the Reduction Operations team special recognition goes to the shop-floor superintendents: Nasser Mohammed Yousuf; Zacharias Francis; Bijan Kumar Malladeb; and their staff.