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CAST SHOP for ALUMINUM PRODUCTION

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Casthouse Productivity and Safety

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NEW CASTHOUSE SMELTER LAYOUT FOR THE PRODUCTION OF SMALL NON-ALLOYED INGOTS: THREE FURNACES/TWO LINES

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Abstract

This paper deals with a layout for a smelter casthouse producing small non-alloyed ingots.

The layout of aluminium casthouses has important consequences with respect to safety, investment and operating cost. Traditional solution for casthouse producing non-alloyed ingots is two furnaces per one ingot line. In order to improve the economics and logistics of the casthouse a detailed study was done, which required:

- Detailed performance analysis, in particular relating to furnace/ingot line connections, impact on maintenance, operations, etc.
- Hazard study
- Modelling of metal flow from tapping in the potline through to the end-product, including breakdowns and downgraded operation
- Thermal and flow modelling in the launder, in steady state and temporary operation
- Detailed determination of the launder.

It was demonstrated that a layout based on such a configuration is superior in terms of full economic cost. This design is now part of our casthouse basic engineering package.

Introduction

The study to reduce the number of furnaces in a casthouse producing non-alloyed aluminium ingots was conducted in the framework of a larger project aimed at reducing overall smelter costs (CAPEX and OPEX). The new arrangement consists in installing a group comprising three furnaces/two ingot lines (referred to as a "trio" in this document).instead of two groups of one ingot line connected to two furnaces (referred to as a "pair" in this document) as it is conventionally done. This new arrangement remains to be implemented but is adopted in new Rio Tinto projects.

Presentation of layout

Figure 1 shows a conventional installation with a pair of furnaces.

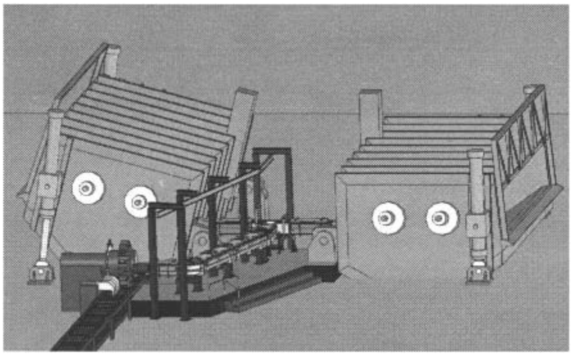


Figure 1: 3D view furnace pair: 2 furnaces-1 ingot line

The casthouse is composed of groups of pairs operating independently of each other (other than in certain exceptional downgraded operating conditions such as: prolonged failure of an item of equipment, major potline backlog, etc.).

The capacity of the furnaces is geared to that of the ingot line and the arrival of metal from the potline (size and number of metal ladles). This ensures that casting is practically continuous: the second furnace is ready to cast when the first one is empty.

Figure 2 shows the new installation with Trio arrangement.

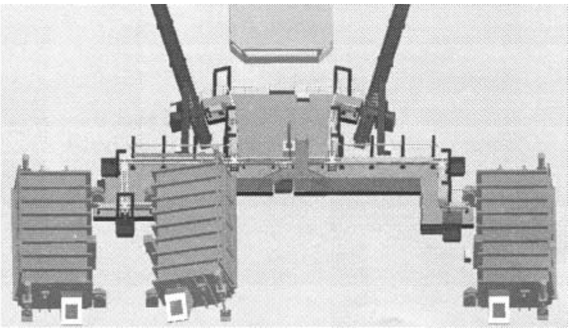


Figure 2: 3D view of a trio: 3 furnaces-2 ingot lines

Features of the trio arrangement are:

- A launder connects the three furnaces and the two ingot lines.
- While a single furnace is casting, the two others are being filled and in preparation. Alternatively, each furnace casts either on one or two ingot lines.
- Safety: a risk analysis at the design stage was carried out with the participation of operational experts from Rio Tinto Alcan smelters. This led in particular to:
  - giving preference to a symmetrical layout of the ingot lines with the operators' working side being separated from the machine circulation side,
  - physically separating the operators' working zone on the launder from the working zone on the furnaces,
  - defining pedestrian routes and mobile equipment routes,
  - analysing detail drawings of the launder.
- The position of the furnaces and ingot lines is such that the differences in distance between furnaces and ingot lines are kept to a minimum. Molten metal temperature loss therefore varies only slightly, regardless of the furnace/ingot line configuration during casting.
- The building floor area is optimised, in particular thanks to inclination of the ingot lines with respect to the casthouse centreline, and thanks to the location of the ingot lines and superpack (assembly of 24 stacks) formation equipment in the shadow of the furnaces.
- The symmetrical layout of the ingot lines makes it possible to keep the operators' working area completely separate from the area in which vehicles circulate. The casting stations are also close to each other, enabling a single operator to supervise both lines (refer Figure 3).

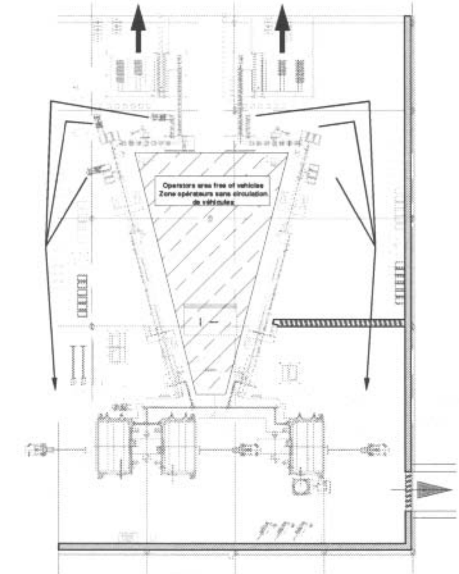


Figure 3: vehicle/pedestrian traffic plan

- As in the case of a pair, the capacity of the furnaces is determined so as to keep the lines in almost continuous operation.
- In a complete casthouse, the number of lines naturally depends on production. If the number required is odd, a pair will be added to complement the trio modules. For example, a casthouse at a smelter with a production of 378 000 kt/year comprises a pair and a trio (refer figure 4).

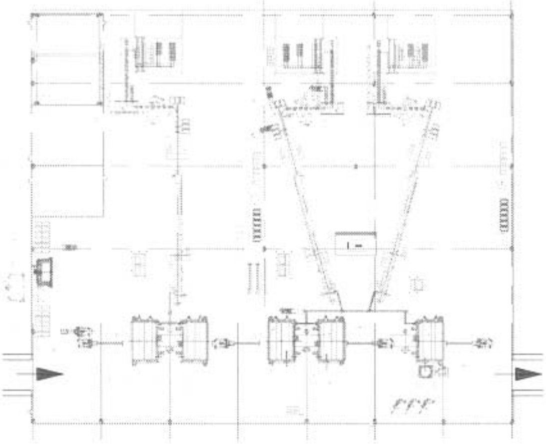


Figure 4: Casthouse layout for 360 AP37 pots

Production performance

1. Presentation of modelling principles

The design of the system presented is based on complete modelling of the metal flow, from pot tapping to formation of the superpack.

The model takes numerous parameters into account:

- MTBF and MTTR of all the equipment: pot tending machines, metal ladle transport vehicles, ladle skimming stations, installation of metal siphoning system in the furnaces, ingot lines, installation of superpack formation units, etc.
- Distance in and between shops
- Duration of each operation
- Sequencing of operations
- Process values: e.g.: targeted casting temperature range, metal cooling rate in the ladles and in the furnaces, reject rate.

This data comes from measurements, information collected in the various Rio Tinto Alcan smelters and from suppliers. They are introduced into the model in the form of an algebraic function depending on the type of equipment. The sequencing of operations was determined with the participation of operation experts from Rio Tinto Alcan smelters.

The simulations performed on the model are used to check the consistency and respect of operating criteria of a casthouse.

2. Methodology and acceptance criteria

The casthouse is modelled:

- In normal mode: all equipment is available (breakdowns and short maintenance periods are taken into account)
  Two criteria are analysed:
    - The percentage of shifts and maximum number of backlogged ladles,
    - The over-capacity of the furnace which is estimated by the times required to accept a one shift potline tapping backlog.
- In downgraded mode (long-term maintenance on an ingot line or a furnace):
  The criteria analysed are:
    - for the furnace maintenance, the percentage of shifts with backlog,
    - for the ingot line maintenance, the number of shifts with backlog built up during the stoppage.

All these criteria and their acceptance values are based on Rio Tinto Alcan's experience and are shown in Table 1.

Table 1: Criteria and acceptances

Criteria	unit	Acceptable	To Check	Refused
During normal operation, shifts with backlog	%	< 10 %	10 - 15 %	> 15 %
one Electrolysis shift caught up capabality (around 10 % over capacity of the system)	shift	< 6	6 – 9	> 9
shifts with backlog during furnace maintenance (4 weeks)	%	< 40 %	40 - 50 %	> 50 %
Generated backlog during maintenance of an ingot line	shift	< 0.85	0.85 - 1	> 1

		Acceptable	To Check	Refused
Validation criteria of a configuration		5 greens	1 to 2 orange(s)	1 red or 3 oranges

3. Basic data for the modelling

To be representative, the model must be studied in the configuration of a complete smelter.

The following configuration was studied.

Potline:

- AP37 potline with 360 pots
- Output: 378,000t/yr
- Ladle capacity: 13t

Casthouse:

- Furnaces filled by ladle siphoning
- Ingot line flow rate: 30t/h
- Ingot weight: 24kg
- Scrap ratio: 3%
- Constitution of superpacks on leaving the line.

4. Modelling results.

For a pair casthouse:

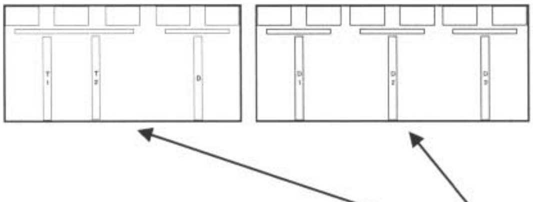
- five pairs each comprising two 80t furnaces and one 30t/h line.

For a trio casthouse:

- one trio comprising three 100t furnaces and two 30t/h ingot lines,
- one pair comprising two 80t furnaces and a 30t/h ingot line.

The table 2 summarizes the results from modelling the two layouts according to the validation criteria used by AP technology

Table 2: Flow model results



Configurations		1 Trio + 1 duo	3 Duos
ANNUAL PRODUCTION PER LINE			
Average T 1 (kt)	Average D1 - D3 (kt)	122	126
D (kt)		133	
NORMAL MODE			
Maximum Backlog		2	3
% of shifts with Backlog		1,0%	1,7%
1 shift catch-up capability (shift)		3,5	3,9
DOWNGRADED MODES			
Furnace maintenance 4 weeks		12%	42%
Ingot line maintenance 1 week		0,2	0,6

This table shows that the output from a trio is equivalent to that of two pairs in both normal and downgraded operation.
In the rest of the study, we will therefore compare one trio with two pairs capable of producing 250,000t/yr.

5. Remarks on operating mode

As indicated in the section on layout, the operating mode proposed is to have only a single furnace casting. Depending on their availability, this furnace casts on one or two ingot lines. A line can be started up or shut down without any problem while the other line is casting.
With this design another operating mode can also be adopted: each end furnace is assigned to one line, with the middle furnace being capable of casting on either one or the other ingot line. This operating mode is not recommended. Modelling shows that the production capacity is lower (5% on average) and that the operating mode lacks flexibility in the event of equipment break down.

Shared launder

This new, key piece of equipment required a detailed study of its design, a thermal modelling study and a study of the metal level disturbance caused by shutting down or starting up a line.

1. Launder design

Figures 5 and 6 show the furnace and ingot line sides of the launder respectively.

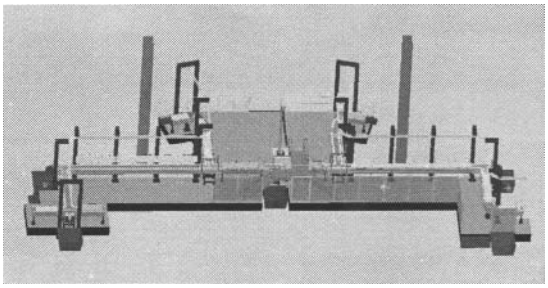


Figure 5: 3D drawing of launder: furnace side

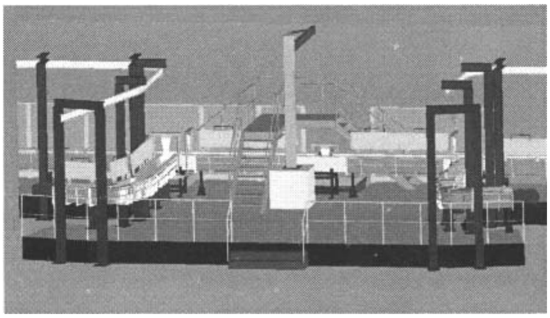


Figure 6: 3D drawing of launder : ingot line side

A screen protects the operators in the vicinity of the furnaces: risks of splattering, etc.
A monorail is used to handle launder sections.
Bins collect the metal in the event that it must be drained quickly during an incident.
Preheating is electrical, by hot air blasting, and covers are fitted to enhance its efficiency.

2. Motorized gates

The motorized gates, shown in Figures 7 and 8, perform two functions:

- Shutting off or connecting the furnaces and the required lines and the drainage bins.
- Limiting level disturbance when starting up or stopping a line. Excessive disturbance would result in scrap being produced on the other line currently casting.

They are controlled automatically by the ingot line PLC.
The gates connected with the lines are opened sufficiently slowly to limit disturbance on the line currently casting and hence avoid producing scrap.

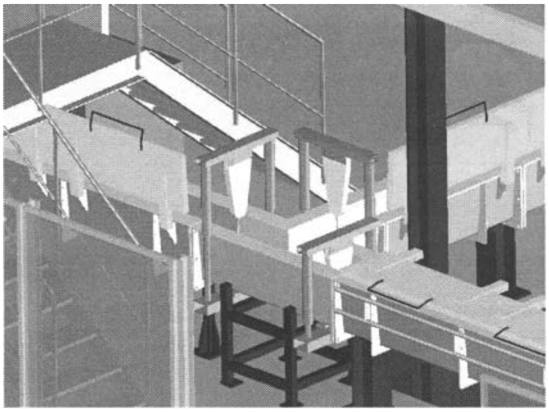


Figure 7: 3D drawing of a gate

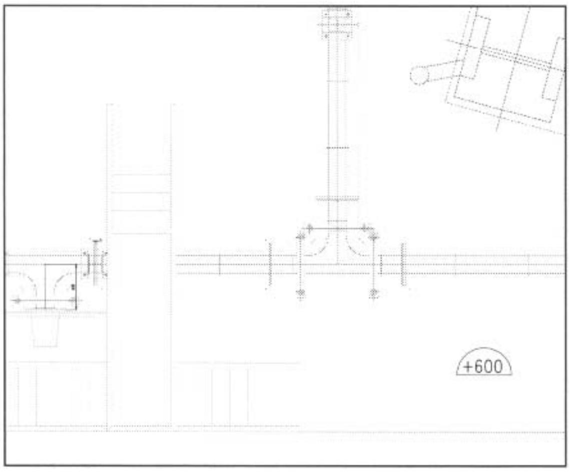


Figure 8: 2D drawing of layout of the gates

Thermal modelling

Aim

Compared to that of a furnace pair layout, the launder has several major differences in characteristics:

- very long (32m maximum compared to a maximum of 10m in a furnace pair layout)
- a difference in length of metal route varying from 32 to 24m depending on the service configuration
- a difference in flow rate from 30 to 60t/h depending on the number of lines in service.

This modelling procedure calculates the thermal losses in the extreme configurations during the unsteady flow period and the steady flow period, in order to check whether they are compatible with the process. The aim is to optimize the thickness and nature of the insulating material and concrete in contact with the aluminium by minimizing heat losses.

Modelling principle

The model used is known as Cosmos and is based on a finite-element calculation. The thickness and characteristics of the components (concrete, insulating material, metal casing) are input data. The calculation is run over the entire length of the launder in order to calculate heat loss. By studying the cross-section at the furnace outlet (the hottest point), it is possible to check that the conditions of use comply with the characteristics of the materials.

The heat equation from the furnace spout to the nozzle is solved, taking into account heat transport, conduction in the launders, the initial state of the launders (cold/preheated), the materials and thickness of the launders.

Transient operation

The model shows, that with the preheating and the use of the covers, the temperature drop on start-up is about 25°C at the maximum and 8°C at the minimum. These values are managed without difficulty. The target temperature at the casting wheel is generally between 700 and 740°C, so the furnace should be indexed at a value between 725 and 748°C.

Steady-state operation

The same model used in transient operation shows the temperature distribution on a section (refer on Figure 9 at the outlet of the furnace). The temperatures of the insulating material (about 500°C) and metal casing (20°C) comply with the requirements.

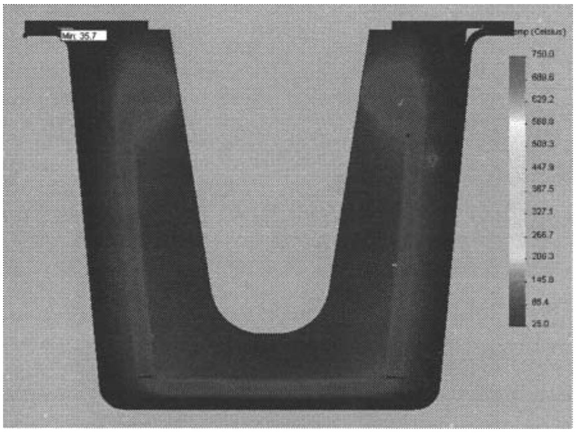


Figure 9: Thermal section from modelling

The model also shows that that:

- The smallest loss (short length: 24m, flow rate 60t/h) is 5°C
- The largest loss (long length: 32m, flow rate 30t/h) is 15°C.

This difference has no impact on casting wheel operation.

Conclusion

By indexing the furnace temperature within a range of values between 725 and 745°C, start-up, casting, the furnace sequence and shutdown can be controlled irrespective of the configuration in service. This 20°C range does not cause problems for operation.

CAPEX and OPEX costs

Assumptions are:

The costs are direct costs.

The costing is in US$, base early 2010.

The smelter is located in the Middle East.

The factors differentiating between the two versions relate to the replacement of four 80t furnaces with three 100t furnaces and the installation of a shared launder.

1. CAPEX

Gain with one trio versus two pairs

	Quantity	kUS$
Casthouse building: m2	900	1120
Furnace civil engineering: m3	30	30
80t furnaces including siphoning	4	14,500
Simple launders	2	50
Total gain		15,700

Losses with one trio versus two pairs

	Quantity	US$
100t furnaces including siphoning	3	12,300
Launder	1	250
Gate automation	1	150
Total loss		12,700

Result

The CAPEX gain in direct costs of the one trio version compared with two trios therefore amounts to US$3 000k for an annual production of 250 000t

2. OPEX

Furnace maintenance

The study is based on an analysis of the costs of maintaining the various Rio Tinto casthouses. It reveals that the difference in maintenance costs between three 100t furnaces and four 80t furnaces amounts to US$200k per year, in favour of the 100t furnaces.

Energy consumed by the furnaces

The reference value in the casthouse with 80t pairs is 450MJ/t.

Impact of the number and capacity of furnaces

Casthouse furnaces are kept permanently hot. In a casthouse where there is little scrap (in the order of 3%) and the process does not require preparation, we adopt the hypothesis that the energy consumed only serves to keep the furnaces at the required temperature and that it is proportional to furnace capacity.
3x100t in the trio casthouse corresponds to 4x80t in the pair casthouse, i.e. a consumption of (3x100/4x80) x450 = 420MJ/t i.e. a gain of 30 MJ/t.
The gain, for an output of 250,000t and a gas cost per MJ of US$0.01 is therefore equal to US$75k per year.

Result

The OPEX gain of one trio compared with two pairs is therefore US$275k per year.

Conclusion

In an ingot casthouse, the trio furnace arrangement (three furnaces supplying two ingot lines) offers substantial gains in comparison with the traditional solution using pairs (two furnaces supplying one ingot line).
In the particular case studied in this document, for a production of 250 000 t/year, a trio of three 100t furnaces supplying two 30t/h ingot lines has an output equivalent to two pairs of two 80t furnaces supplying one 30t/h ingot line.
While at the same time meeting the HSE criteria, the CAPEX gain amounts to US$3 000k and the OPEX gain to US$275k per year. This represents a NPV of US$4 000k
This arrangement forms part of the AP technology package and is retained for Rio Tinto Alcan projects.