Innovative Applications and Technological Breakthroughs of 60-tonne Double-Chamber Furnace in Aluminium Recycling Industry

Gaston Riverin[1], David Gagnon[2], Denis Bouchard[3], Xianzhong Zhu[4], Guangsong Yu[5] and Zhengying Han[6]
1. Casting Consultant
2. Casting Director, Technical Services
3. Project Representative
Rio Tinto, Saguenay, Canada
4. Chief Design Engineer
5. Project Manager
Suzhou Longray Thermal Technology, Suzhou, China
6. General Manager International Business
China Nonferrous Metals Processing Technology (CNPT), Luoyang, China
Corresponding author: gaston.riverin@riotinto.com
https://doi.org/10.71659/icsoba2025-ch005

Abstract

This paper details the innovative technological breakthroughs in the 60-tonne double-chamber furnace aluminium recycling project implemented at Rio Tinto's aluminium electrolysis plant in Canada. Guided by CSA safety standards, the project introduces systematic innovations in safety design, material handling, aluminium tapping systems, molten aluminium circulation, and flue gas treatment, fundamentally rethinking and optimizing traditional double-chamber furnace design concepts. Key innovations include rigorous safety system design, intelligent material handling processes, innovative aluminium tapping systems, efficient molten aluminium circulation technology, and advanced flue gas treatment and heat recovery systems. Additionally, the project features comprehensive quality control measures and a safe method to charge a wide variety of aluminium scrap without direct contact with liquid aluminium. These innovative designs not only meet the stringent requirements of CSA standards but also provide new technical references and development directions for the aluminium recycling industry. Through these advancements, the project aims to enhance operational efficiency, reduce environmental impact, and set new benchmarks for safety and productivity in aluminium recycling.

Keywords: Aluminium recycling with double-chamber furnace, Safety design and CSA standard, Electromagnetic stirring, Flue gas treatment, Quality control.

1. Introduction

Aluminium recycling was identified as a key input for the Rio Tinto global strategy. As part of the aluminium circular economy options, a new recycling facility is being installed in the one of its smelter operations in Canada [1]. The source of aluminium scraps identified is from post consummation which implies a certain level of contamination.

The recycling / melting technology selected most meet:

- New scrap source with flexibility in shape / format / thickness / alloys / contamination
- Highest process safety standards more particularly to prevent molten metal explosion
- Aim at zero carbon emission while assuring best melting performance (melt rate + recovery)
- High environmental performance including particulates collection and gas treatment
- Flexibility for molten metal transfer via crucible to be re-introduce in Value Added Product (VAP) primary mix.

A double-chamber furnace technology has been selected. RT has been working with CNPT and Longray, a well-known furnace supplier. Design improvement has been integrated in other to meet the criteria listed above.

1.1 Recycling in Primary Operation

The new recycling facility will enable Rio Tinto to become the first primary aluminium producer in North America to incorporate post-consumer scrap into alloys. This will provide us with a new product offering to meet the growing customer demand for aluminium with a smaller environmental footprint.

It brings its own challenges in terms of incorporating recycling content to already proven value-added products mix in parallel of integrating to existing metal flow and casthouse equipment developed for Primary operation.

1.2 Scrap Type

The scrap used will be post-consumer scrap, mainly from metal recyclers located in Canada. Post-consumer aluminium scrap is aluminium that has been used in a product and is no longer needed, like used aluminium cans or car parts. It is collected after the product has gone through its full lifecycle and is then recycled to create new products.

The material is collected and sorted in different categories mostly based on alloy families. It comes in all formats; loose, shreds, bales and might contain organic contaminants such as plastic, oil, paint and others.

2. Double-Chamber Furnace Technology

Traditional recycled aluminium production involves multiple steps [2]: material handling, unpacking, crushing, sorting, paint removal in rotary kilns, and processing in double-chamber furnaces. For a 5 t/h production line, the pre-treatment equipment requires over 400 kW installed power, consuming 30–50 kWh electricity and 20–40 Nm^3 natural gas per tonne of aluminium. This conventional process is cumbersome, inefficient, and generates significant energy waste and environmental emissions.

To address these challenges and achieve efficient aluminium waste recycling, Rio Tinto's Recycling project collaborated with CNPT and Longray to develop an innovative double-chamber furnace using a new aluminium liquid circulation method.

The double-chamber furnace comprises a melting chamber, scrap chamber, transfer well, and electromagnetic stirring (EMS) [3]. The chambers are connected by channels to enable molten aluminium circulation, powered by EMS. The melting chamber features two regenerative burner sets for energy supply, while the scrap chamber has two burners set for auxiliary heating with automatic oxygen content adjustment based on raw material conditions.

A partition wall separates the chambers, with flue gas channels in the upper section allowing high-temperature gases to flow from the melting chamber to the scrap chamber. The scrap chamber includes a heat bridge for placing scraps where drying and pyrolysis occur.
The main structure is shown in Figure 1.

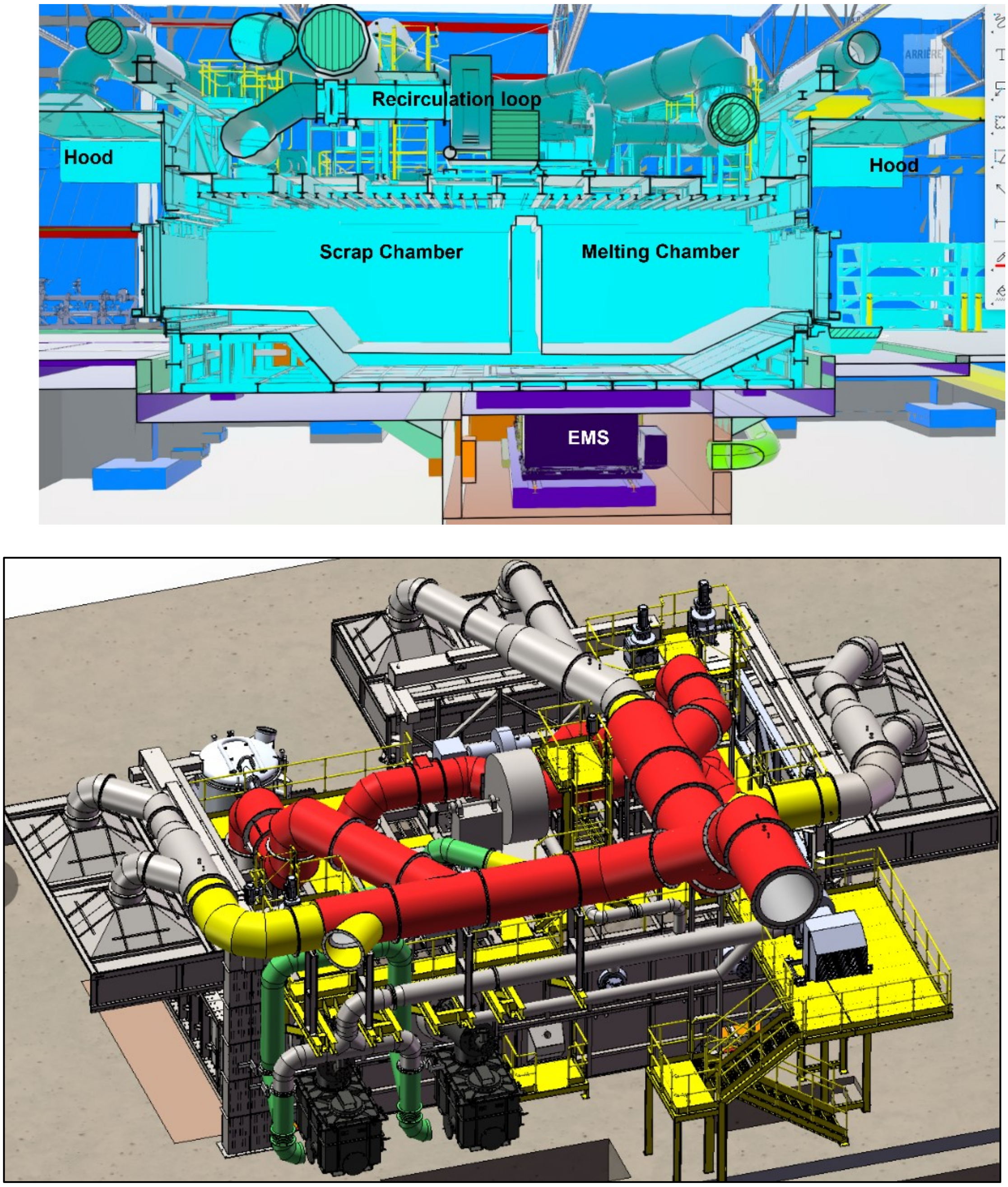


Figure 1. Furnace structure / design.

The combustion system in the melting chamber achieves high energy efficiency by using regenerative burner technology in the melting chamber. This regenerative burner system alternately heats and recovers thermal energy through paired burners, where one burner fires while the other burner recovers waste heat from exhaust gases, then switches roles cyclically. This technology significantly improves fuel efficiency and reduces emissions compared to conventional burners. A fuel saving of 30 to 40 % is expected from the regenerative burner technology. The combustion system is primarily responsible for providing sufficient heat to the double-chamber furnace. The heat is then transferred to the scrap chamber to melt materials through the circulation of high-temperature aluminium liquid, as shown in Figure 2.

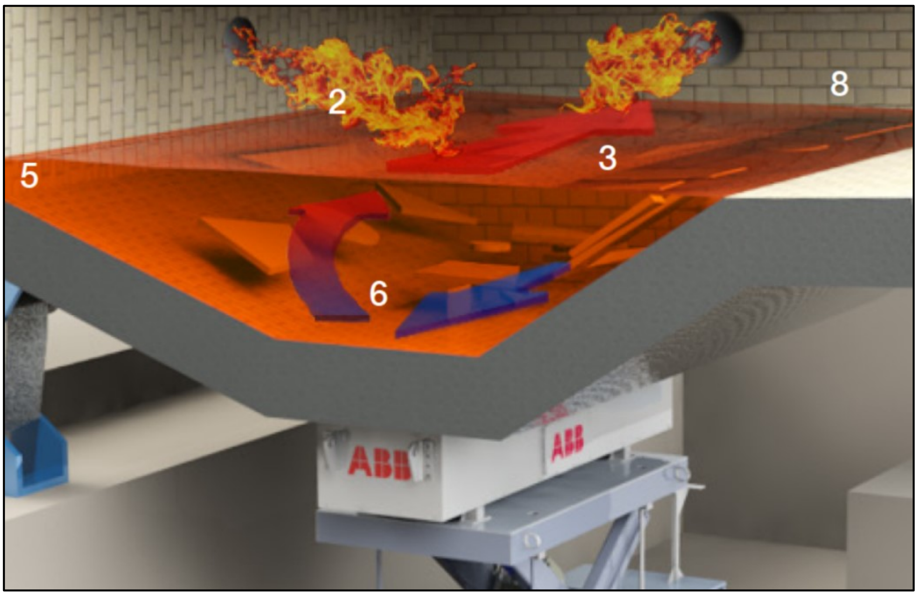


Figure 2. ABB aluminium liquid circulation electromagnetic stirrer.

3. Innovative Design Components

3.1 Double-Chamber Furnace Aluminium Liquid Circulation System

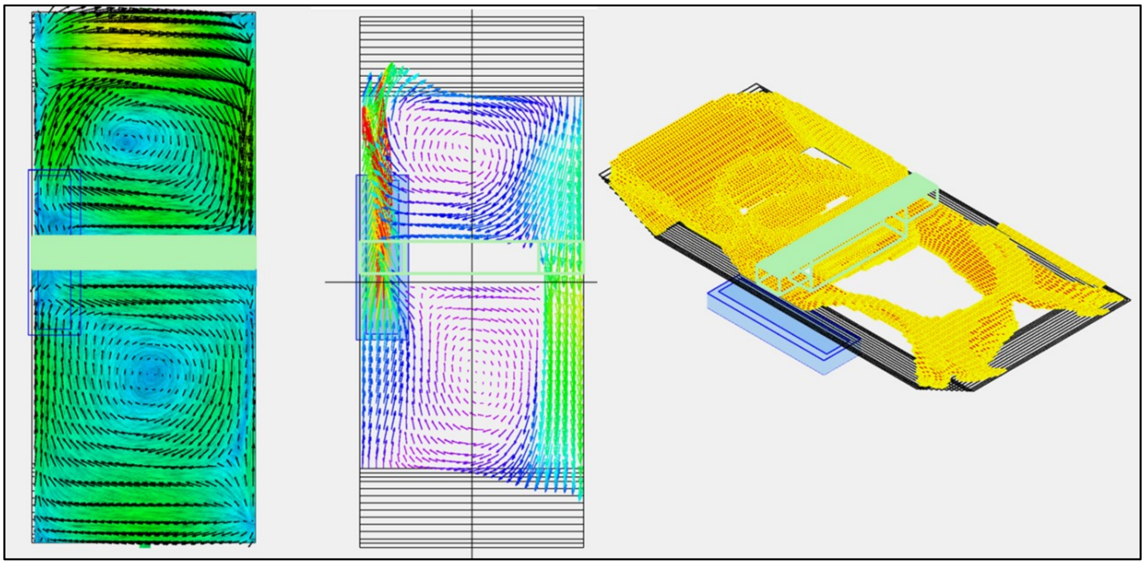
Through in-depth research, the project team discovered numerous issues with traditional external channel aluminium liquid circulation methods:

- External circulation channels cause an additional temperature drop of approximately 20 °C in the aluminium liquid, increasing energy consumption
- High-speed circulation in external channels produces localized or full-range aluminium liquid turbulence, leading to continuous dross formation
- Actual aluminium liquid flow velocity inside the furnace is low (typically less than 0.5 m/s), resulting in large temperature differences between the two chambers
- Limited effective agitation zones, with the actual effective area being less than 1/4 of the aluminium liquid in the furnace
- The maintenance workload of the aluminium liquid circulation propulsion system with external circulation mode is large and the maintenance is difficult.

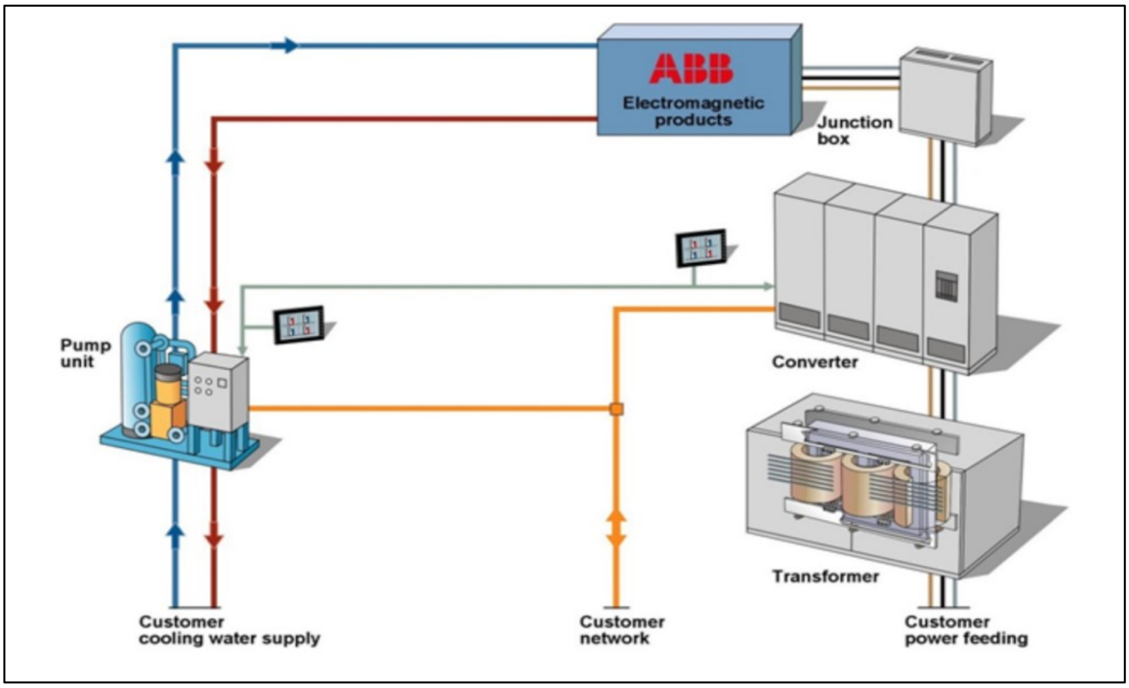
Based on these findings, the project team collaborated with ABB from Sweden to develop an entirely new aluminium liquid circulation system:

- Completely eliminated the external channel design
- Rapid circulation of aluminium liquid occurs directly within the furnace chamber
- Subsurface aluminium liquid flow velocity can be controllably adjusted within 4m/s
- Maximum hourly aluminium liquid circulation volume reaches 3000 t/h
- Non-contact electromagnetic stirring, no longer imposing strict limitations on aluminium liquid height within the furnace
- Longer life of propulsion system and easier maintenance.

For this application, a liquid metal transfer of 20–25 t/min is estimated from the melting chamber to the scrap chamber allowing high melting rate of the solid charge while maximizing aluminium recovery from low turbulence. The circulation pattern and the main structure are shown in Figure 3.



(a)



(b)

Figure 3. Electromagnetic internal circulation system:
Simulation analysis (a), Electromagnetic stirring system (b).

3.2 Thermal Contamination Control Mode (Called 'Dirty Mode')

Taking into consideration the impact of volatile substances such as paint on material surfaces in recycled aluminium production, the project team developed an innovative thermal contamination control mode:

- In-furnace organic matter pyrolysis and thermal value reutilization system
- Flue gas circulation system within the furnace
- Coordinated control of the combustion system and air-fuel ratio
- Automatic interlock control of the high-temperature circulation system.

The organic content management process operates as follows [4]: Materials undergo precise preheating and thermal decomposition on the heat bridge in the scrap chamber, causing surface paint and organic coatings to volatilize. The specially designed flue gas circulation system at the furnace top automatically adjusts its operating frequency to capture these volatile organic compounds and direct them to the melting chamber for secondary combustion. This process transforms waste into valuable energy, achieving both energy conservation and reduced pollutant emissions. The main logic diagram is shown in Figure 4.

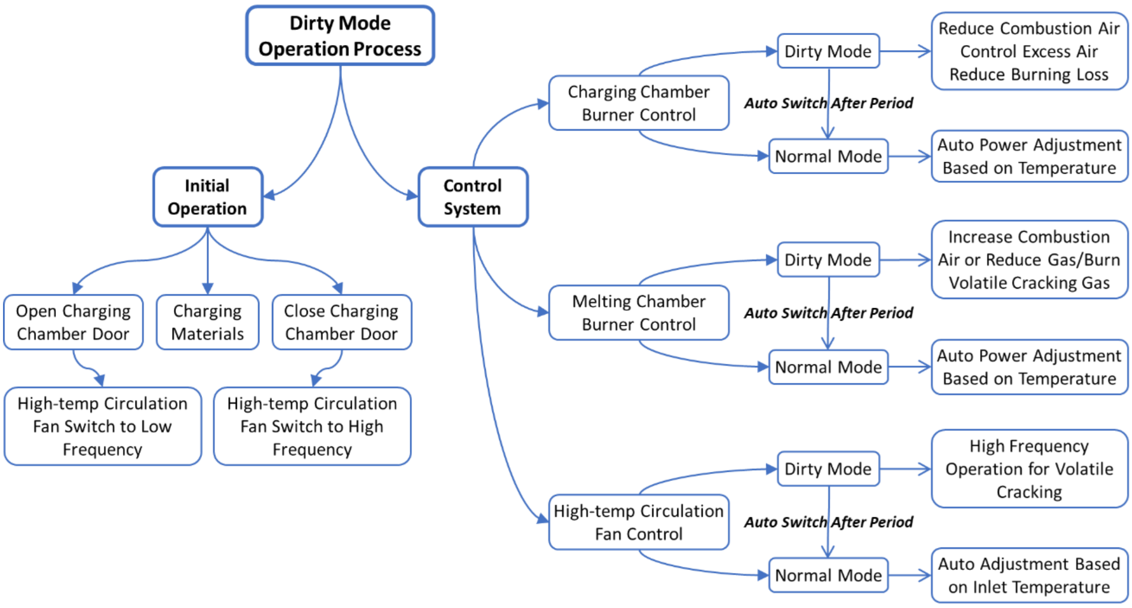


Figure 4. Thermal contamination control mode logic diagram.

3.3 Material Charging – Design & Safety Process

Heat bridge is a platform in scrap chamber which is mainly used to place baled or loose scrap where drying and pyrolysis process take place. The main purpose of the platform is to assure that the material will be always charged with no contact with liquid aluminium.

An automated charging machine is designed based on platform dimensions in width; to use the whole area to spread the scrap for optimized heat transfer and in length to limit displacement away from liquid metal area. Schematic of charging machine is shown in Figure 5a below.

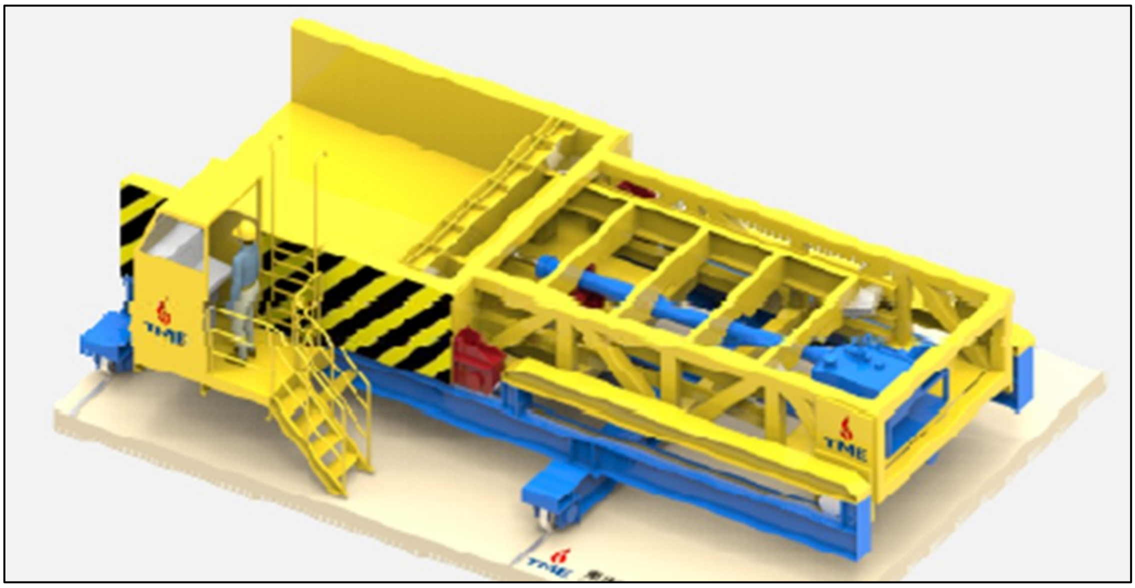
The length of heat bridge is flexible and designed to meet scrap size and scrap quantity. Typical load would be 2 rows of baled scrap (2 × 3) is proposed to charge per load considering operation efficiency and stability of charging vehicle.

To address issues with recycled aluminium raw materials that may contain rainwater, snow, ice, and liquids in sealed areas of compressed packages, the project team designed a comprehensive material safety pretreatment system:

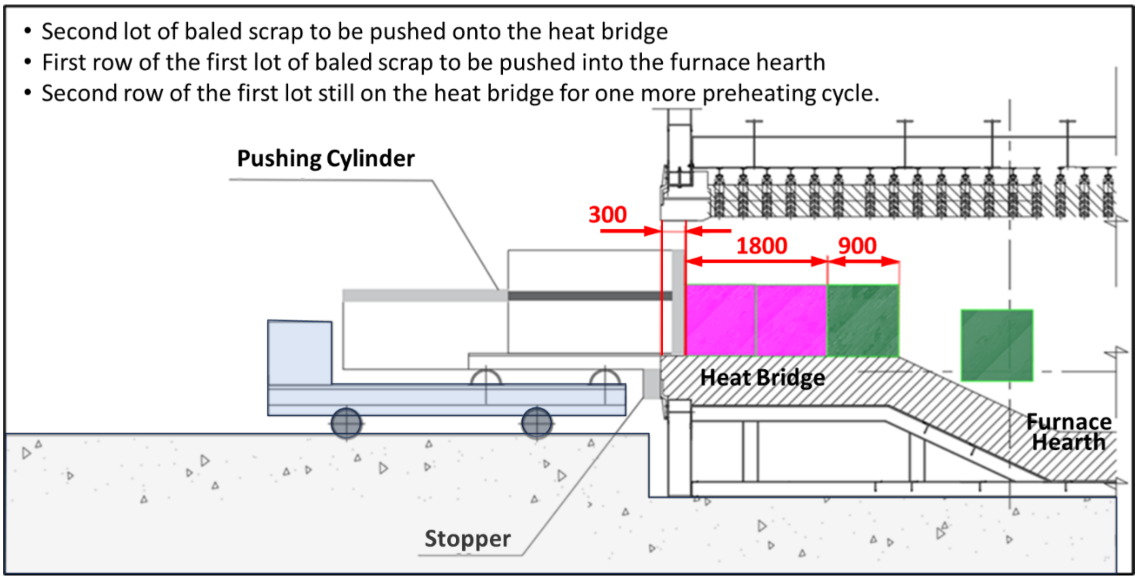
- Automated material charging system to reduce risks from manual operations
- Anti-abrasion furnace charging process to extend furnace lining life
- Controlled technology for stable material entry into the furnace, preventing safety risks from turbulence
- Separation of material charging and in-furnace skimming processes
- Theoretical calculation and empirical verification of minimum drying and preheating time for materials

- Camera system to always visualize charge status in the furnace to be used by the operators before pushing next charge in the furnace

The main logic diagram is shown in Figure 5b.



(a)



(b)

Figure 5. Material charging safety: Charging machine (a), heat bridge (b).

3.4 Material Charging – Safety Process (Water / Humidity / Organics)

Furnace will be charged by 2 to 6 tonnes every hour. The principle is to put the solid charge (scrap) on the platform and allow enough time to eliminate all traces of humidity and water and evaporate all organic compounds to maximize metal recovery.

A temperature of 200 °C is desired to eliminate all water and a temperature of 400 °C for the organics. This is in conformity with Aluminium Association Safety Guidelines [5]. The heat is supplied from 2 sources: (1) the recirculation loop between the scrap chamber and the melting chamber and (2) from the combustion system installed in the scrap chamber.

An oxygen monitoring system is installed in the circulation loop to ensure complete removal of organic compounds.

Once the scrap temperature target is met. The charge can be pushed in the liquid area to complete the melting process. Water and moisture removal will ensure minimum dross generation and maximum recovery.

4. Performances

The equipment performance parameters are:

1- Capacity:
   a. Furnace capacity: 60 t
   b. Furnace type: Stationary
2- Productivity
   a. Melt rate up to 7 t/h
   b. Utilization rate at 80 %
   c. Aluminium liquid circulation method: Bottom-mounted electromagnetic stirring device
3- New scrap source with flexibility in shape / format / thickness / alloys / contamination
   a. Material form and specifications: Baled or compressed packages, maximum dimensions 900 × 900 × 1200 mm
   b. Organic contamination
      i. Average at 1 %wt
      ii. Could be at 5 %wt
4- Highest process safety standards more particularly to prevent molten metal explosion
   a. All charging of a refractory platform
      i. Zero contact with liquid aluminium
5- Aim at zero carbon emission while assuring best melting performance (melt rate + recovery)
   a. Regenerative burner system
   b. Energy consumption estimated at ~65 Nm^3/t
      i. Maximum at < 72 Nm^3/t
   c. Electricity consumption per tonne of aluminium: ~40 kWh/t (including electromagnetic stirrer)
6- Metal Recovery
   a. Net metal recovery estimated at 98 %
      i. For scrap at organic content < 1 %wt
   b. Melt loss at < 1 %
      i. That includes recovered metal from dross generation
7- High environmental performance including particulates collection and gas treatment.

5. Conclusions

The new furnace design has very significant effects on improving product quality, increasing furnace productivity, enhancing production safety and reliability, and reducing energy consumption. These innovations not only meet the specific requirements of the Rio Tinto Recycling project but also provide new technical references and development directions for the recycled aluminium industry. In the future, we will further optimize the system design, explore the application of intelligent control technologies, and promote the development of the recycled aluminium industry towards greater efficiency, environmental protection, and safety.

Using this equipment, Rio Tinto will be the first primary aluminium producer in North America to incorporate recycled post-consumer aluminium into aluminium alloys.

Clean aluminium scrap sourced locally from used vehicles and construction materials will be remelted to produce recycled content that will be used in aluminium billets at the Arvida smelter as well as other products from Rio Tinto's Quebec facilities.

6. References

1. Rio Tinto Media Release – Rio Tinto invests in a new recycling centre in Arvida, 26 August 2022, https://www.riotinto.com/en/can/news/releases/2022/rio-tinto-invests-in-a-new-aluminium-recycling-centre-in-arvida-
2. Rui Gong, Process Research on Grade-Maintaining Regeneration of UBC Materials, *Non-ferrous Metals Processing*, 2023, 52(05), 6-10 (in Chinese).
3. Wen Tao Li, "Application of electromagnetic stirring in aluminium melting furnaces," Aluminium Fabrication, 2010(06), 30-34 (in Chinese).
4. Feng Bo, "Research on Double-Chamber Furnace Production Technology," China Plant Engineering, 2023(20), 251-253 (in Chinese).
5. Guidelines for Handling Molten Aluminium, - The Aluminium Association – 2023 . Guidelines for Handling Molten Aluminium | The Aluminium Association