Decarbonisation at the Anglo American Barro Alto Smelter Through Implementation of the Ecombustible Technology

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Abstract. As part of the effort to decarbonize the world economy, the advent of the use of hydrogen has awakened interest within the metallurgical industry. Sustainability-driven strategic goals sponsored by the Anglo American Barro Alto industrial complex call for the displacement of fossil fuels with hydrogen to reduce carbon dioxide (CO_2) emissions in existing thermal applications. The environmental and business case strength for the use of hydrogen in thermal processes can vary significantly based on the hydrogen source and the local economic conditions, such as the cost of raw materials and electricity and the price of incumbent fossil fuels. Important safety considerations require close attention as the use of hydrogen as an industrial fuel grows toward becoming ubiquitous in all industries. This paper presents an overview of an on-going project to implement a novel technology that will deliver a hydrogen-based fuel to thermal applications within the Anglo American Barro Alto smelter.

Keywords: Decarbonisation, Hydrogen, Environmental Sustainability

1 Introduction

Ecombustible Energy LLC has developed a patented technology that can generate a customizable hydrogen-based fuel from a novel process which consists primarily of a water electrolyzer and a magnetic reactor. The proprietary hydrogen-based fuel has a higher calorific value than conventional molecular hydrogen fuel on a volume basis. This gaseous product has been named eCombustible.

Ecombustible Energy LLC has signed an agreement with Anglo American Niquel Brasil Ltda to deliver eCombustible fuel with the goal of decarbonising some thermal applications at the Barro Alto Industrial Complex which currently consume Liquified Petroleum Gas (LPG). Gas Cleaning Technologies LLC and Ecombustible Energy LLC are engineering the implementation of an eCombustible fuel generation plant to be installed within the Barro Alto Industrial Complex as part of Anglo American's strategic objective of producing green ferronickel. This paper presents an initial overview of this project. Process details around the eCombustible technology implementation will be presented at a later date.

2 eCombustible Technology

The eCombustible technology consists of a unique industrial electrolyzer that requires less power to decompose water into hydrogen and oxygen. The thyristor or SCR controller is tuned in such a way that it dissipates a minimum amount of energy in the microcell units without affecting the quantity of hydrogen generation. Another unique feature of this technology involves the conversion of ortho-hydrogen into para-hydrogen with the use of a magnetic reactor to generate eCombustible fuel. Both the produced oxygen and eCombustible fuel are collected, compressed and stored prior to transfer to an end-user. The system's key process equipment includes:

- Water Treatment System
- Electrolyzer
- Water Recirculation Cooling System
- Gas Collection and Handling
- Magnetic Reactor
- Buffer Tanks, Compressors, and Storage Tanks for Hydrogen and Oxygen
- Drain Collection and Wastewater Handling System

3 Barro Alto Industrial Complex

The Anglo American Barro Alto Industrial Complex is a nickel production facility located in the municipality of Barro Alto, Goias, in Brazil's mid-west region. Figure 1 shows location details.

Fig. 1. Location of the Barro Alto Industrial Complex within Brazil

The nickel (contained in ferronickel) production process adopted in the Barro Alto Industrial Complex consists of ore crushing, homogenization, drying, calcining, reduction and refining. The Rotary Kiln – Electric Furnace (RKEF) technology is employed for calcination and reduction of the ore. Figure 2 shows the Barro Alto Industrial Complex general process flowsheet.

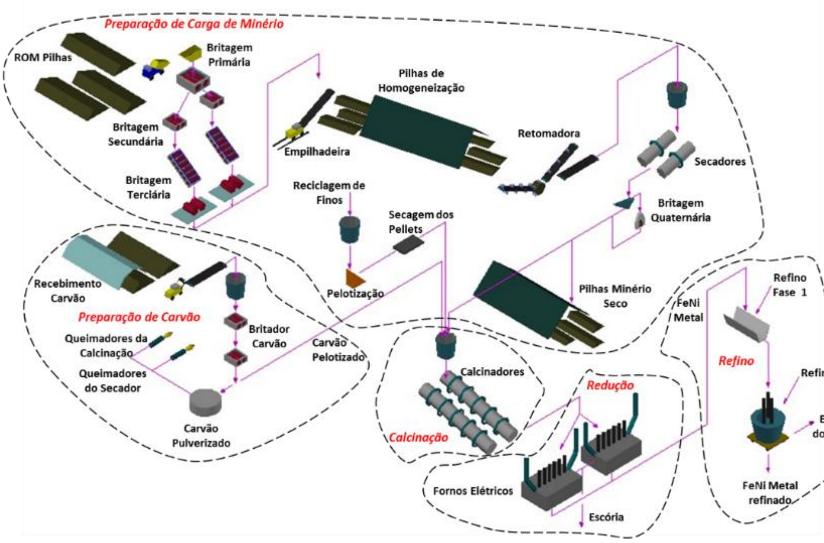

Fig. 2. Barro Alto Industrial Complex Process Flow Diagram

The ore extracted from the Barro Alto mine is initially processed in the ore preparation process, where the stages of crushing, homogenization and ore drying take place. The prepared ore is fed to two rotary kilns (calcination stage), where the load is completely dried and calcined. The energy required for the operation comes from the use of pulverized coal together with heavy fuel oil. With the rotary kiln feed, a charge of reducing carbon is also added, which participates in nickel reduction reactions during the reduction stage. In addition, dry pellets are fed into the calciners, which are produced using ore fines that are recovered from the calcination and reduction processes. Out of the rotary kilns, the calcined ore is fed into two rectangular Electric Furnaces, where the charge is smelted to produce the pay metal (ferronickel or FeNi) and slag. The ferronickel is transferred in ladles to the refining stage, where part of the impurities existing in the alloy are removed before metal shotting and packaging for sale.

Within the Barro Alto Industrial Complex, there is an LPG fuel supply facility. The LPG is used in the pelletizing area (pellet drying), in the coal pulverization plant (coal drying), and also in the refinery for pre-heating of ladles and tundishes, and FeNi drying (after shotting with water).

At the pellet drying plant, LPG is supplied to each of the two hot gas generators (HGGs) to produce hot gas, which is used as a heat source to dry the pellets. The coal plant processes coarse wet coal, simultaneously grinding and drying it inside a coal mill. Dry pulverized coal is used in the drying and calcination stages as a fuel source. The coal plant HGG produces hot gases which are used to directly dry the wet coal. The refinery operates five LPG-fueled burners including one vertical ladle pre-heater, one horizontal ladle pre-heater, two tundish pre-heaters, and one rotary dryer used to dry FeNi.

4 Thermal Application

The eCombustible fuel will be produced on-demand to displace the use of LPG currently consumed in the pelletizing, pulverizing and refining stages, generating environmental benefits for the Barro Alto Industrial Complex in addition to eliminating the operation's exclusive dependence on LPG. Similar to LPG, eCombustible will be burned in the existing burners resulting in zero CO_2 emissions. Unlike conventional hydrogen, the unique eCombustible fuel provides similar flame characteristics and calorific values as fossil fuels such as LPG which allow it to replace such fuels with minimal modifications to existing equipment. The eCombustible fuel production plant’s installed capacity is expected to be approximately 22 MW of thermal energy in delivered fuel. After installation of the eCombustible production plant, reserves of LPG will be maintained only as a back-up fuel. The existing combustion systems will be adapted to operate dually with either of the two fuels.

The pellet dryers HGGs will be prioritized as the first stage to demonstrate the technical performance of the eCombustible fuel operation. A ramp-up program will be implemented to ensure that the combustion performance of the new fuel satisfies safe control standards and that the hot gas generated complies with the target process conditions required to enable effective and efficient drying of the pellets. Figure 3 shows a pellet dryer HGG.

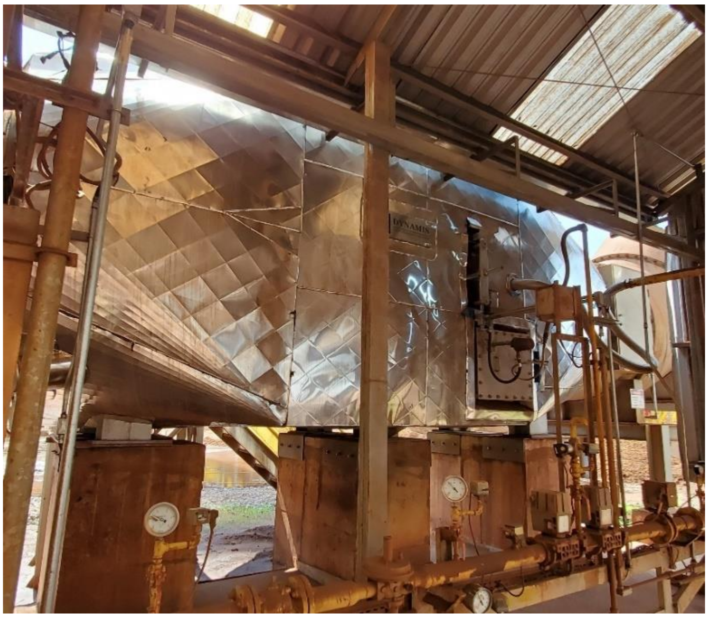

Fig. 3. Pellet Dryer Hot Gas Generator

Ecombustible Energy LLC is currently executing a testwork program to demonstrate the applicability of the use of eCombustible fuel as an industrial fuel in common thermal applications. A key priority in this testing program is to test the eCombustible fuel combustion performance with a burner design equivalent to the one currently installed at the commercial pellet dryer HGGs. The results of this testing will be evaluated and considered as input for potential retrofit requirements at the Barro Alto pellet dryer HGGs.

5 Key Environmental Benefit

Replacing LPG fuel with eCombustible, which is more competitive from an environmental and economic point of view, will provide benefits that are in line with Anglo American Nickel's strategic objectives, that is, the search for an increasingly "cleaner" operation, in terms of reduction of CO_2 emissions, as well as the reduction of operating costs. The reduction in CO_2 emissions with the use of eCombustible is estimated at approximately 2,869 t per month based on historical records. Table 1 shows a summary of the historical average monthly CO_2-eq emissions by area (pellet dryers, coal mill and refinery) from 2016 to 2020.

Table 1. Average Monthly CO_2-eq Emissions (t CO_2-eq/month)

Year	Pellet Dryers	Refinery	Coal Mill	Total
2016	2,047	364	530	2,941
2017	2,151	376	228	2,754
2018	1,961	362	530	2,853
2019	1,993	362	465	2,820
2020[1]	2,027	362	588	2,976
Average	2,036	365	468	2,869

[1]Data range from January 2020 to August 2020

The implementation of this project will be a milestone in the fulfillment of Anglo American's strategic objective of making its ferronickel operations the first in the world to be operated 100% with renewable resources and 100% with internally reused water. Upon successful completion of this project, Anglo American will consider implementing the eCombustible technology at the Codemin ferronickel smelter located in Niquelandia.

6 Environmental Impact

Potential impacts on flora and fauna are negligible as the plant and fuel will be installed and used in an area already industrially developed. Clearing of vegetation will not be necessary during the implementation of this project. The combustion of eCombustible fuel within the Barro Alto smelter burner applications generates water vapor as the main constituent of the combustion product. Production of other potentially controlled emissions (e.g., nitrogen oxides or NO_x) will be minimized by implementing appropriate engineering and/or operational solutions.

The main waste stream resulting from the operation will be wastewater from the water treatment system. The physicochemical characteristics and flowrate of this wastewater are estimated to fall within the environmentally-acceptable permissible limits to allow for its safe disposal within Barro Alto's existing process water handling system.

Regarding the mitigation of environmental impacts, Anglo American already practices control measures aimed at controlling impacts on the industrial site. These measures take place throughout Anglo American's site in Barro Alto and will extend to the location of the eCombustible plant.

7 Technology Integration

The eCombustible production plant will be built in a greenfield area conceded by Anglo American within the Barro Alto industrial complex as part of the agreement with Ecombustible Energy LLC. The project requires earthworks and construction of new foundations and reinforcements to support the equipment. An electrical equipment room, control room and small warehouses dedicated to the proper storage of chemical reagents will be included at the plant's construction site. eCombustible electrolyzers will not be permanently installed on site. Instead, they will be installed in containerized modules that allow for easier transport, installation and subsequent mobility (when necessary). The same containerized approach (or alternatively, a module-assembled approach) will be followed for other components (e.g., electrical equipment room, control room, warehouses) and auxiliary process systems (e.g., electrolyte cooling system and water treatment system). A security system will be installed around the perimeter of the eCombustible plant to prevent unauthorized persons from entering the area, as well as bollards around all tanks to prevent accidental vehicular collisions.

Existing pipeline infrastructure (including gas feed trains) currently used to transport LPG to all HGGs and burners will remain unaltered. This will allow the Barro Alto smelter to continue using LPG normally and at its discretion. New dedicated pipelines will be installed to transport the eCombustible fuel and oxygen to all end-users. These systems will be equipped with all the necessary instrumentation to guarantee the distribution of gases with quality and safety (e.g., flow meters, pressure, gas leak detectors). Additional piping requirements will include pipelines to supply raw water to the eCombustible system from existing infrastructure.

The eCombustible system consumes electrical energy for the operation of its various equipment and instruments. Most of the energy will be consumed by the electrolyzer cells to carry out the electrolysis process. Other devices with lower electricity consumption within the process are the magnetic reactor, the gas compressors and various pumps. The Barro Alto smelter will supply power via a high-voltage transmission line that will be installed from the existing main electrical substation to the eCombustible plant. This new line will be connected to a new local transformer, to be acquired and installed by Ecombustible Energy LLC, within the perimeter of the eCombustible production facility.

Inside the eCombustible production plant, there will be a facility to receive and treat the raw water necessary for the production of the eCombustible fuel. This subsystem is designed to treat the entire volume of water intended for consumption by the plant and will be responsible for reducing water hardness and removing other impurities that could affect the performance of the water electrolysis process. The technology to treat this water consists primarily of ultrafiltration and reverse osmosis systems.

The eCombustible production plant's location has been selected in collaboration with Barro Alto personnel by identifyingthe least environmentally impactful area (no need for vegetation suppression, no impact on fauna, flora and water courses), and the potential for future production expansion. Figure 4 shows the area selected for the construction of the new plant.

Fig. 4. eCombustible Production Plant Location

8 Safety Considerations

The design of the eCombustible fuel production and combustion systems follow a series of codes and standards to ensure compliance with safe design requirements. International, Brazilian and local codes and standards are used in the design process to minimize risks in the production, storage, handling and combustion of the eCombustible fuel. Additionally, multiple technical peer reviews have been undertaken by independent professional safety consultants. Anglo American's personnel have also actively participated in the development of Hazards Identification and Hazards and Operability workshops. The following subsections describe basic design features to address safety considerations for the main process areas.

8.1 Water Treatment System

Water holding tanks are installed to ensure a constant supply of raw water to the reverse osmosis system and clean water to the electrolytic cells to prevent fluctuations in water flow which can damage and/or affect the performance of electrolytic cells. The tanks themselves are equipped with level transmitters and drain valves to monitor the water level and drain as needed. To prevent damage to the electrolytic cells, the quality of the water (raw and treated) is monitored through various safeguards such as redundant conductivity meters, pH meters and manual water hardness tests. Both automatic and manual valves are installed in case of deviations and/or shutdowns. There are conductivity meters in the water recirculation line and pH meters in the treated water supply line installed to ensure that incorrect KOH solution dosing does not lead to low hydrogen production and/or contamination of cell membranes.

8.2 Electrolysis

High temperatures can lead to evaporative loss of electrolyte solution, reduced process efficiency and premature failure of cell stacks. An electrolyte cooling system is installed to remove excess heat from the electrolyte (with temperature transmitters at the inlet and outlet of the heat exchangers to monitor operating temperatures). Low electrolyte flow in pumps can lead to cavitation and a lower volume of electrolyte in cells. The latter, in turn, can lead to the burning of cell components, resulting in permanent damage. In addition, a lower circulating volume of electrolyte would result in a lower level of electrolyte in the oxygen and hydrogen holding tanks, which could lead to mixing of oxygen and hydrogen gases. The process is equipped with engineering controls to avoid mixing oxygen and hydrogen and therefore mitigating the risk of explosions. Level transmitters are installed on each gas holding tank accompanied by an automated shutdown procedure when a low level set point is reached. Sight glasses are installed in the tanks for manual checking of liquid levels. Pressure transmitters are installed at the pump discharge to monitor the discharge pressure. Electrical components are properly insulated and non-conductive material is used in piping and hoses to prevent personal injury. The electrical components of the electrolysis module are also physically shielded to protect against potential electrolyte leakage.

8.3 Gas Collection and Handling

Water separators are installed in the ventilation lines to capture water as electrolyte carryover in the gas can result in the accumulation of KOH (precipitate from the solution) in downstream ducts and equipment. There are pressure relief valves and emergency stacks with flame arrestors installed in the gas storage tanks in case of any mechanical blockage causing pressure build-up. Hydrogen and oxygen are kept in dedicated, adequately spaced holding tanks to minimize the risk of mixing and possible subsequent explosions. There are pressure sensors installed in both tanks, and the pressure differential is monitored between them to always ensure that the hydrogen holding tank has a higher pressure than the oxygen tank. This will reduce the risk of oxygen flowing from the oxygen holding tank to the hydrogen holding tank.

8.4 eCombustible Fuel Combustion

The flow of the eCombustible gas supply is monitored through redundant pressure transmitters and flow meters. Flame stability is monitored using UV/IR flame sensors and exhaust temperature sensors. The air to gas ratio is controlled to prevent flame loss and maintain optimal combustion conditions.

8.5 Electrical & Instrumentation System

All instrumentation is designed for Class 1, Division 2 per the National Electrical Code (NEC) in the areas of electrolyzer and gas storage and processing. Standard security system design is in accordance with applicable codes. All equipment will be properly secured to reinforced concrete bases that will prevent damage from rain, and concrete barriers are installed around key areas to prevent accidental vehicle collisions. There are hydrogen and oxygen sensors installed around each gas storage tank in the generating plant to detect potential leaks.

9 Path Forward

The implementation of the novel eCombustible technology at the Anglo American Barro Alto industrial complex promises to greatly enhance Anglo American's position as a producer of environmentally-sustainable nickel. Given that the technology is new, significant risk reduction and mitigation steps are being considered to ensure that risks to personnel, assets and the environment are kept as low as possible. The project team is currently developing final preparatory work to execute the construction of the eCombustible production plant in 2022.