Electrify Everything - Designing a Fully Electric Gold Processing Facility for a Low-Carbon Grid

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Abstract

For grids which are supported by hydro-electric generation, and as renewable penetration of grids is increasing, using electricity in lieu of on-site combustion supports lower emissions related to minerals processing. Fuel for mining fleets is often a key focus of mines looking to decarbonise, but eliminating fuel use in processing facilities can also be pursued to achieve net zero targets. This case study outlines the design approach for a gold processing facility in British Columbia, Canada, which commenced construction in 2023. The design included electric elution heating, electric kiln and electric smelting, in lieu of the typical use of Natural Gas or Diesel as a heat source. This paper outlines the drivers for selecting electrical equipment in this case. The potential carbon emissions savings achieved per gold oz with this circuit design are presented, compared to a typical design with on-site combustion to provide heat sources for elution, kiln and smelting. The SO2 system also used electric heat and recycled steam rather than fossil fuels for both sulphur melting and pre-heat stages, as well as temporary no-load heat scenarios. This allowed for the entire process facility to have no fossil fuel power used in the entire process. A number of technical challenges were considered during the design to ensure safe and effective responses to electrical outages. These included, Electrical design (conduits), equipment size and layout, and start-up / shut-down philosophy. This paper outlines the process for identifying and mitigating hazards to manage identified risks.

Keywords

Decarbonisation, electric, smelting, elution, kiln, gold

Introduction

In a macro environment of escalating global concern for environmental sustainability, mine owners are facing an imperative to innovate and adopt lower impact approaches. For gold processing, one promising avenue to mitigate the carbon impact lies in the transition from conventional heating methods to the utilization of electric power where low emissions power is available. In this context, the adoption of electric power for gold processing not only stands as a testament to responsible resource management but also plays a pivotal role in contributing to a more sustainable and environmentally friendly future.

Artemis Gold's Blackwater Mine is located in central British Columbia, approximately 160 km southwest of Prince George and 446 km northeast of Vancouver, and will be connected with the BC Integrated grid, which has a low carbon intensity (11.5tCO2e/GWH in 2022). The project is an Open Pit CIL Mill design, with initial design throughput of 6 million tpa, and 321,000oz of gold production, and further expansion phases planned. The processing facility commenced site works in 2023, and was under construction at the time of writing. An commitment was made for the Stage 1 development phase: an initial investment to replace all diesel, natural gas and propane-powered or heated components within the process plant facility to reduce the carbon footprint of the Project. This paper outlines the circuits commonly utilising natural gas or diesel which have been designed with electric heating. Technical challenges to ensure the design operates safely in the case of electrical outages, along with solutions selected are discussed.

Engineering Design

The design included electric elution heating, electric kiln and electric smelting, in lieu of the typical use of Natural Gas or Diesel as a heat source. The SO2 system also used electric heat and recycled steam rather than fossil fuels for both sulphur melting and pre-heat stages, as well as temporary no-load heat scenarios. This allowed for the entire process facility to have no fossil fuel power used in the entire process. Figure 1 below shows a simple block diagram identifying the units typically utilizing fossil fuels that were transitioned to fully electric for this processing facility.

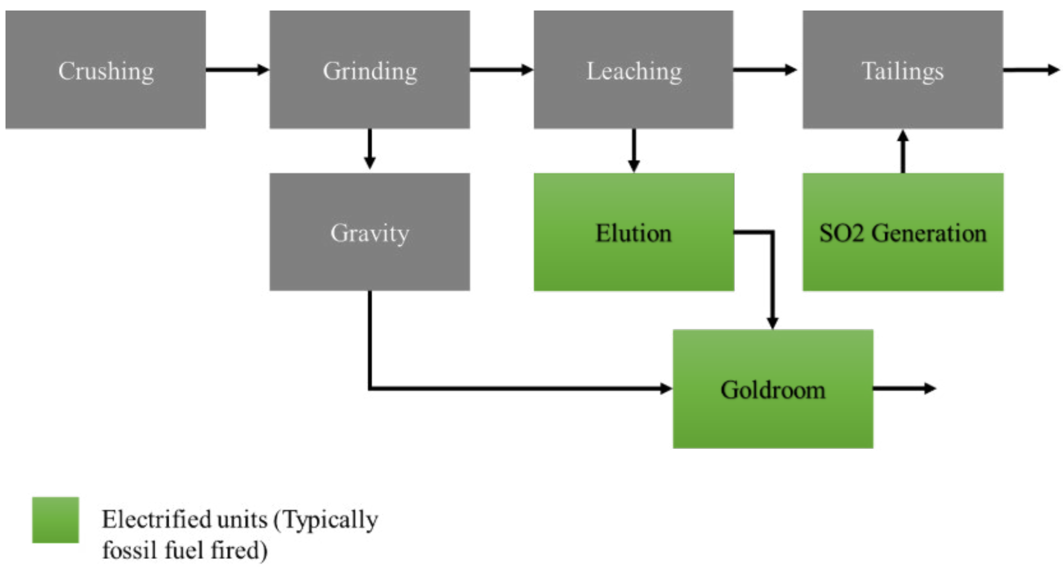

Figure 1 – circuits involving electric heating (elution heating, electric kiln and electric smelting, sulphur melting and pre-heat stages)

Power Requirements

There were four units that were changed from conventional fossil fuel to electric power, namely the smelting furnace, carbon reactivation kiln, elution heater and the sulphur burner start up and standby heater units. In total, over 6000kW of installed power was put in to replace typical fossil fuel units.

The heat up for the elution takes 4200kW to meet the cycle time required for processing at high throughput and gold grade, and once it reaches steady state, this circuit uses a lot less power. The heat up period is approximately 2 x 2 hrs per day, and then approximately 1/3rd of peak power is used to keep the circuit going for the next 7 hrs, followed by and then 3 hrs of cooldown/carbon transfer. The kiln operates 24/7 at around 600kW of consistent demand load. The smelting furnace operates for approximately 4 hrs per day at 250kW demand. The average demand power of the additional electric heating is approximately 3400 kW.

Technical Challenges

A number of technical challenges were considered during the design to ensure safe and effective responses to electrical outages. These included, Electrical design, equipment size and layout, and start-up / shut-down philosophy.

A key consideration for the electrical design is that low voltage power was typically required due to the heating requirement. These low voltage but high amp cables were quite large, and numerous particularly for the elution heater which required 4.2MW of electrical power at 600V. This required 18 individual large cables, which all had to fit into the same electrical termination boxes.

On top of the electrical termination challenges, much of this cable had to be run in conduits to maintain pathways for maintenance of equipment, vehicles and personnel. Due to the cable type and size, each conduit could only fit 3 cables per conduit, which meant there was significant planning prior to the first concrete pours to ensure that this type of equipment could be installed and maintained.

Beyond the electrical requirements, the equipment itself required some other challenges, with a standard fossil fuel fired direct heating unit being very compact, the electric indirect heating was larger and required significantly different maintenance windows. Due to the mine being built in Canada, this needed to all fit within a pre-engineered process plant building, which required engineers to really plan the access corridors and equipment placement to maximise building floor space utilization.

The regeneration kiln has no burner control unit, but this space is taken up with the electrical boxes for the electrical components plus the backup battery (located near the feed end of the kiln). The electrical boxes were advantageous to be as close to the unit as possible, while also taking up the minimum footprint and allowing access.

Back-up battery was essential for the kiln as the induction heating does not shut-off immediately (source is still hot) when a power outage occurs, thus the rotation drive will remain on to keep the kiln tube from heating / cooling unevenly and warping.

Startup and shutdown philosophy was a key consideration in the design. An electrically heated circuit has the additional risk, unlike conventional designs, of unplanned electrical outages. In order to mitigate the impact of unplanned electrical outages from a processing, personnel safety, and equipment protection perspective, and number of design features were incorporated. The table below outlines the key risks identified, and mitigations incorporated in the design.

Table 1 – Startup and shutdown risks and mitigations

Material Risk Identified	**Mitigation**
Power Outage causes rotation drive of kiln to stop while induction heaters still hot	Backup battery on kiln rotation drive
Plant experiences unplanned downtime – SO_2 burner cannot stop quickly or refractory will crack	Standby electric air heater will keep refractory at high temperature to minimize damage and start up timing
Power outage causes liquid pumps to stop while induction coils still at high temperature	Backup power generation study completed to ensure power is back online within short window and additional pressure reliefs added
Power outage causes steam jackets to not function around molten sulphur piping	Standby heat generation and startup heat generation (both electric) on backup power for when SO_2 burner unit is down

For the SO_2 burner unit, going to electric had significant challenges as a lot of the circuits are all intertwined with the burner management unit, which is typically started up on fossil fuels and then swapped to molten sulphur, which allows for startup heat, and standby heat to be managed through the burner control unit.

In the electric SO_2 burner unit, we have an electric air heat-up unit, which pre-heats air until we can start burning sulphur. This heated air is pushed through the burner unit so that the ancillary units can start operating, such as the steam generation for steam-jacketed pipes, the air pre-heat air recycle and ensuring the post-burner cooling circuit is controlling properly before sulphur burning to ensure we limit the amount of sulphurous acid created.

Operational Considerations

The electric elution system is expected to be improved from an operational perspective compared to a fossil fuel-powered system, because even the best of those systems have some leakage in their ducting, causing odour and particulate impacts. This all-electric installation, is expected to be much cleaner to operate.

Operators will need to ensure they are aware of the heat-up and cool-down periods for induction heating sources, as this can be significantly longer than fossil fuel. All of the machinery is well insulated and guarded so this should not cause any significant operational challenges, however for tight shut-down windows this should be considered for safe maintenance planning.

Cost Impact

The capital cost of this change was in the low 7 figures order of magnitude CAD additional direct costs, with additional costs for installation or managing associated technical challenges. The cost of power in BC is around 6.5c / kwh, so the operating cost was lower, and had a payback period of around 12 months in total based on standard efficiencies and unit consumption details.

Estimation of Reduced Carbon Dioxide Equivalent Impact

With an average demand power of the additional electric heating of 3400 kW, and design operating hours of 8060 a year, the following table illustrates the difference in scope 1 and 2 emissions for conventional vs electrical heating design.

Table 2 – Comparison of CO2e emissions impact of conventional and electric heating design for a range of grid scenarios

Design Case	Energy source	Qty/annum	Carbon intensity	tCO2e/ annum
Conventional heating	Natural Gas	44,300 GJ/ annum	53.1 kgCO2e/GJ *	2350
Electric heating	Grid power (BC Integrated Grid)	27.4 GWh** (3400kw x 8060hrs/ annum)	11.5 tCO2e/GWH	315
Electric heating	Grid power (high Example predominantly coal grid)	27.4 GWh	850 tCO2e/GWH	23,300
Electric heating	Grid power (Example coal plus renewables grid)	27.4 GWh	250 tCO2e/GWH	6850

**Note: Scope 1 - Natural gas emission factor does not include emissions associated with extraction and delivery of the gas.*

***Note: This calculation is for scope 2 emissions for power predicted to be used by the electrified circuits highlighted green in Figure 1 only (elution heating, electric kiln and electric smelting), and using published grid intensity data.*

With an annual reduction of in the order of 2000 tCO_2e/annum, equivalent to carbon equivalent emissions of ~440 conventional vehicles, this is an appreciable impact on the operating CO_2 equivalent emissions of the Blackwater Mine. For processing facilities connected to grids with high emissions factors, electrification of fuel-based heating circuits may not provide a benefit. A comparison in the table for grids with different emissions factors demonstrates this. A project and location specific review of carbon emission reduction opportunities is required.

Conclusion

The reduced impact for CO_2e emissions from electric rather than conventional heating in a gold circuit can be significant where grid connection to a very low carbon grid is available. For grids with higher emission factors, an assessment of the options from both an emissions and cost perspective is required. Technical challenges around shutdown and startup philosophy for these circuits require additional consideration, however, practical approaches have been defined to address risks. As momentum increases with decarbonisation, electrification of more process heat application is an area of opportunity in certain locations.

References

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