HAZARD RISK ASSESSMENT

Mt Grace Batchelor Magnesium Project

A hazard risk assessment was undertaken to identify and assess the consequences of unplanned incidents that may pose safety, environmental risks, or may result in material damage inside and/or outside the plant boundaries. All unplanned incidents that may result in a significant safety or environmental impact or cause interruption to the plant production have been considered and assessed. These are described in detail in **Table 1**.

A risk assessment factor combining the probability of occurrence with the cost as derived from safety and environmental impacts and production loss was calculated and the events grouped in descending order as shown in **Table 2**. These risk assessment factors are arbitrary units, which enable a qualitative comparison to be made between the probabilities of incidents. From this exercise it was clear that the events could be grouped as follows:

1. **High frequency, low impact events** such as kiln flame out and furnace feed port blockage have the greatest overall cost but are due predominantly to an interruption in the process flow and have small impacts on safety or the environment.

2. **Medium frequency and / or medium cost events** such as major blockages to the kiln or furnace feed system; or repairable damage to the reduction furnace due to stray arcing. These events pose a slighter greater safety and environmental impact than those in group one but again the impact is more one of process interruption and high maintenance repair cost.

3. **Low frequency events with high costs** constitute half of the events identified. The fact that the risk assessment factor is very low is indicative of the care taken in the design and operation of the plant. Efforts are focussed on preventing the occurrence of such incidents. Examples of these would be explosions and or fire in the kiln, reduction or casting department. In the unlikely event one of these incidents did occur the plant would be faced with a long-term outage combined with a serious safety and environmental consequence.

Table 1 Potential Incident Assessment

Unit Operation	Incident	Likelihood		Cause	Impact			Corrective Action	Preventative Measures
		Expected Frequency	Probability		Safety	Environmental	Process		
		# per unit time	*Expected number of days production between each incident*						
Mining (Open Pit)	Temporary unplanned cessation of mining	2 / year	180	Equipment failure or bad weather	No safety issue should arise	Nil impact	No impact as there will be a substantial amount in the ROM stockpile	Contractor to repair the equipment or if bad weather await improvement in conditions	Proper maintenance and servicing of equipment
Crushing & Screening	Temporary cessation of crushing	5 / month	6	Power outage, scheduled maintenance or equipment breakdown	No additional safety issue should arise	No impact expected	No impact as a stockpile of crushed and screen material will be maintained to feed to the kiln during any such delay	Repair as necessary and restart	Proper maintenance and servicing of the equipment
Calcination	Flame Out - burner flame extinguished	5 / month	6	Disruption to gas stream; electrical power surge or interruption; loss of combustion air; loss of pressure gradient through kiln.	Operator exposed to flame blow back potential. This is minimised by their position out of the line of fire while lighting the kiln	Partially calcined magnesite or limestone would be discharged as waste.	The feed to the reduction furnace would be interrupted resulting in either a slow down in the reduction furnace operation or interruption of furnace operation.	Divert the kiln output to waste, correct the failure source, relight the kiln burner and continue waste until the kiln attains steady state. The duration of the period that product is wasted is a function of the duration of the outage.	Work with utility suppliers to increase and maintain reliability and stability of service. Perform routine preventative maintenance on the kiln combustion and draft system to ensure component reliability.
Calcination	Explosion in the kiln or the off gas system	1 / 50 years	18,000	Accumulation of fuel or partially burned combustion products until the lower explosion limit is reached and a spark source is present	Death or injury due to shrapnel or concussion	Spillage of hydraulic fluid to the areas surrounding the kiln, generation of waste in the form of partially calcined product.	Plant shutdown due to a lack of feed material.	Rebuild the damaged equipment and restart the plant.	The kiln will be equipped with sensors and have an instrument control system that will immediately shut off the gas stream in the event that a fault is detected.
Calcination	Failure of the rotation mechanism resulting in thermal distortion of the kiln (this applies only if the kiln is a rotary unit).	1 / 50 years	18,000	Power outage to the kiln drive mechanism or mechanical failure of kiln drive unit.	In the event of severe distortion the kiln could fall off its support and crush equipment or people in its path.	Spillage of hydraulic fluid to the areas surrounding the kiln, generation of waste in the form of partially calcined product.	Plant shutdown due to a lack of feed material.	Replace the kiln on its trunions; use controlled point heating and cooling to return the unit to shape; replace the refractory lining and restart.	Adherence to a proper lubrication and maintenance schedule. Presence of an auxiliary drive unit powered by an alternate source from the main drive. This unit activates automatically in the event of a main drive failure. Proper training and periodic testing of the operator.
Calcination	Uncontrolled loss of scale or refractory lining, which blocks the product, discharge outlet. This could eventually stop kiln rotation which would lead to distortion.	2 / 3 months	46	Scale - Incorrect specification of the refractory lining or an incorrect temperature profile will result in the material being calcined reacting with the refractory material to form a scale deposit. This will be released in an uncontrolled fashion in the event of a thermal excursion or the mass of scale is too great to be retained on the sides of the kiln. Refractory - Severe thermal shock, incorrect refractory installation or specification, or incorrect operating conditions will result in the kiln lining detaching itself from the body of the unit and coming through the system.	Operators exposed to heat stress and potential burns.	Generation of a waste stream consisting of calcined product, scale and/or refractory.	Curtailment of the reduction and casting operation due to lack of feed.	Break or remove the large pieces that are blocking the kiln outlet. Divert the entire kiln outlet to waste.	Proper specification and installation of refractory material. Consistent control of the kiln operating conditions. Restriction of changes in kiln operating conditions to small incremental changes. Installation of an instrument system that incorporates a size recognition transducer, which alarms the operator of the presence of a large mass entering the kiln outlet. Removal of scale prior a catastrophic release. (This is performed using a large calibre gun to shoot the scale from the wall).

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Reduction	Sintering of the magnesite in the containers feeding the reduction furnace.	1 / 3 month	91	The temperature of the magnesite discharged from the kiln is too high allowing the aggregate to bond at those points where one piece contacts another.	Operator exposed to heat exhaustion and potential for burning.	Generation of a waste stream consisting of calcined product in aggregated lumps.	Curtailing of the reduction and casting operation due to lack of feed.	Increase the cooling in the discharge portion of the kiln; decrease the calcination temperature; decrease the mass calcined per unit time; decrease the kiln rotation rate enabling material to be retained in the cooling zone for a longer period of time.	When increasing the calcination temperature or throughput of the kiln, closely monitor how frequently the magnesia feed is insufficient for the reductant fed, "no feed" using a spc run chart. Take corrective action prior to occurrence of a complete blockage.
Reduction	Blockage of the feed system at the entrance to the furnace.	3 / week	2	Air leakage in the feed system.	Exposure of operator to hot gases and materials. Muscle strain and carpel tunnel damage to operator.	Generation of waste stream consisting of feed material, magnesium oxide and magnesium nitride.	Interruption of the process, decreasing condenser efficiency and overall loss of product.	Clear blockage, shut down the furnace and pressure test the upper system for leaks.	Routine Non Destructive Testing of feed system, which identifies areas of potential weakness prior to a failure. Proper installation procedures to ensure connections are free from leakage. Proper operation of reduction system to ensure the feed system pressure is always higher than the furnace pressure.
Reduction	Hydrogen Explosion	1 / 50 years	18,000	Accumulation of Hydrogen gas in either the electrode tower or the feed system combined with a sudden ingress of air.	Shrapnel injury from fragments of the furnace being blown away.	Generation of waste material such as magnesium nitride and magnesium oxide in the condensing system through air ingress and magnesium burning following the explosive breach of the furnace.	Interruption of production until the damage to the furnace is repaired and the condenser cleaned.	Repair and replace damaged components; clean the condenser and restart the furnace.	Exclusion of moisture from feed entering the furnace. It is the dissociation of water by reaction with metallic magnesium that produces the hydrogen gas. Use a continuous inflow of argon gas to the areas where hydrogen may accumulate such that the quantity of hydrogen is kept low by means of dilution. Opening the furnace or feed system should only occur with the system shut down and sufficient argon flow has flushed the cavities clear of hydrogen.
Reduction	Hole burned into furnace sidewall	1 / 5 years	1,800	Electrode arc directed on to sidewall rather than hearth.	Burn from exposure to molten material.	Particulate fume release; generation of magnesium nitride and oxide waste.	Interruption of production until furnace either repaired or replaced.	Drain furnace of slag then either repair or replace furnace.	Maintain slag temperature high enough to ensure low resistance. Restrict arc length to ensure low resistance path through hearth.
Reduction	Furnace hearth explodes.	1 / 100 years	36,500	Water, slag and residual ferrosilicon reaction.	Shrapnel and molten material striking personnel on floor.	Particulate fume release; generation of magnesium nitride and oxide waste.	Interruption of production until furnace either repaired or replaced.	Repair or replace furnace.	Design hearth cooling system such that no interruption of the water flow occurs.
Reduction	Slag freezes with solid crust.	3 / month	10	Loss of power or improper control of arc or excess feed of raw material.	Operator exposure to arc flash, burn and muscle strain positioning startup electrode through feed port.	Release of particulate fume.	Interruption of production.	Insertion of start up electrode through feed port such that an arc melts the slag while preventing the arc travelling to the sidewall.	Proper process control. Having a redundant source of process power to minimise any interruption.
Reduction	Explosion	1 / 10 years	3,600	Spillage of molten material either metal or slag onto floor combined with the presence of moisture in the refractory.	Impact from flying debris.	Nil	Interruption to process during period of investigation and repair.	Repair damage and restart process.	Keep water from floor area surrounding furnace and molten material transport. Use process controls to prevent spillage from occurring. Note: molten metal explosion will result in greater damage than a slag explosion.

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Casting	Fire in casting furnace.	1 / 20 years	7,300	Crucible containing magnesium developed a hole, which spilled molten magnesium into furnace chamber.	Burns to operators and heat exhaustion to individuals fighting the fire.	Particulate emissions, generation of magnesium oxide and magnesium nitride waste stream.	Interruption in process due to loss of casting facility.	Extinguish fire through smothering with flux and sand; repair or replace casting furnace and any other damaged equipment.	Monitor crucible wall thickness using ultrasonic thickness testing and replace any unit that falls below 2.5 cm. Inspect crucible to ensure no cracks develop in the sidewall, replace or repair if some found. Install and maintain the burner system to ensure no hot spot develops on the crucible wall.
Casting	Eruption of gas, flux and metal from a crucible of molten metal in the cast house.	1 / 20 years	7,300	Addition of flux containing moisture combined with the flux being drawn below the level of the metal due to excessive agitation at the time.	Burns to operator in line of fire of the effluent exiting the crucible.	Particulate and hydrogen chloride emissions; generation of waste stream consisting of magnesium oxide, flux and magnesium nitride.	Interruption of process until problem resolved and damaged equipment replaced.	Repair damaged equipment and resolve root cause of the incident.	Monitor flux moisture levels; store flux properly; develop procedure that ensures flux cannot be drawn beneath the molten metal level unless the flux is melted.

Table 2 Risk Assessment Factors

Incident Description	Risk Assessment Factor
Kiln – Flame Out	18
Reduction Furnace Feed Blockage	18
Reduction Furnace Slag Freeze	3.6
Kiln Scale Blockage	1.3
Reduction Furnace Hole in Furnace	0.5
Reduction Furnace Sintered Feed	0.5
Crusher Failure	0.3
Kiln Distortion	0.2
Mining Interruption	0.08
Cast House Fire	0.07
Kiln Exhaust Explosion	0.05
Reduction Furnace Spill Explosion	0.04
Reduction Furnace Hearth Explosion	0.03
Cast House Eruption	0.03
Reduction Furnace Hydrogen Explosion	0.01