

Preliminary Hazards Analysis (CSE, 2011)





CORKY'S | **SUSTAINABLE
ENERGY**

Project No. 1101

Mandalong VAM RAB Demonstration Project

Preliminary Hazard Analysis Report

1101-401-REP-001

For

Centennial Mandalong Pty Ltd

By

Corky's Sustainable Energy



1. Executive Summary

This document details the results of the Preliminary Hazard Analysis (PHA) undertaken for the proposed demonstration methane abatement facility for Centennial Mandalong Pty Limited (CEY).

The proposed plant will comprise:

- Site storage for compressed nitrogen;
- Use of existing onsite mine drainage gas in the form of methane;
- Not more than 100 litres of mineral hydraulic oil;
- Provision of a motor control centre;
- Installation of a thermal oxidiser to process the ventilation air
- Installation of a conditioning duct between the ventilation fan and the thermal oxidiser

As required under SEPP33 the development application for potentially hazardous or potentially offensive plant requires a risk report commenting on whether the proposed use will adversely affect the surrounding land uses or expose the general public to unacceptable risk levels.

The analysis has determined that the land use injury risk criteria is less than the guidelines of the NSW DoP for a proposed development for land use (residential and sensitive) as follows:

1. Incidental heat flux radiation is calculated to be less than 4.7kW/m at a frequency less than 50×10^{-6} pa;
2. Incident explosion overpressure is determined to be less than 7kPa a frequency less than 50×10^{-6} pa;
3. Toxic exposure concentrations are below both injurious levels and physiological irritant levels at a frequency less than 50×10^{-6} pa

The analysis therefore determines that the risk criteria for property damage and accident propagation imposed by the NSW DoP for a proposed development adjacent to potentially hazardous installations are not exceeded.

The findings of the PHA determine that the proposed methane abatement facility is acceptable subject to demonstration of appropriate safety features compliance to safety integrity levels to AS IEC 61511 (IEC 61508), compliance to MDG-41 for the hydraulic systems and the CMHSA as it is applied by Centennial Mandalong Pty Ltd.



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Revision History

Rev	Date	Description	Checked	Approved
A	16/05/2011	Preliminary Hazard Analysis to support EA	RP	DC
B	6/06/2011	Revision following review by Advitech	RP	DC



2. Introduction

2.1 Proposal

Corky's Sustainable Energy (CSE) is contracted by Centennial Mandalong Pty Ltd to design and construct a methane abatement demonstration plant adjacent to the operating underground coal mining infrastructure at the Mandalong Coal Mine. The facility will comprise a Ventilation Air Methane Regenerative After Burner (VAM RAB) thermal oxidiser which is positioned on the site to allow a sample of the ventilation air from the existing mine fan to be drawn through a conditioning duct for processing. The process removes green house gas emissions from the ventilation air which would otherwise be emitted to atmosphere.

The development of the system is split into 3 phases:

- Initial Phase – including design and prefabrication off site
- Phase 1 – construction, commissioning and initial experimentation phase
- Phase 2 – extended experimentation phase and post experiment study

Figure 1 indicates the approximate scale and location of the proposed development site.

2.2 Objective

This document details the results of the Preliminary Hazard Analysis (PHA) study undertaken for the design, construction, commissioning, experimentation operation and maintenance of the demonstration Ventilation Air Methane Regenerative After Burner (VAM RAB) plant for CEY. The objectives of the study were to:

- Conduct a PHA study of the proposed VAM RAB project in accordance with the requirements of Hazardous Industry Planning Advisory Paper No.6, Guidelines for Hazard Analysis;
- Identify whether the proposed VAM RAB facility will impact on the existing infrastructure at the Mandalong Mine Site (Fig 1); and
- Report on the findings of the study for inclusion in the Environmental Assessment (EA).

2.3 Scope

The scope of works is for a PHA study of the VAM RAB facility at Mandalong, NSW. The study includes the assessment of hazards and risks associated with the operation of the proposed plant.



The scope of the study includes the potential cumulative risk impact on adjacent critical infrastructure at the site. To assure compliance with the NSW Department of Planning (DoP) State Environmental Planning Policy No 33 (SEPP 33) CSE has undertaken a risk assessment using the guidelines of Hazardous Industry Planning Advisory Papers (HIPAPs) 4, 6 and the DoP's guidelines for Multi Level Risk Assessment.



Figure 1 - Proposed Mandalong Site Development



3. Methodology

3.1 Scope and Purpose

Clause 12 of SEPP 33 specifies that a PHA must be prepared for development applications for “potentially hazardous industry”. The purpose of the PHA is to:

- Identify all potential hazards associated with the proposal;
- Analyse all hazards in terms of their consequences (effects) to people and the biophysical environment and their likelihood of occurrence;
- Quantify the analysis and estimate the resultant risks to surrounding land uses and the environment; and
- Assess the risks in terms of the location, land use planning implications and existing criteria and ensure the proposed safeguards are adequate and thus demonstrate that the operation will not impose an unacceptable level of risk.

3.2 General Approach

The NSW Department of Planning (DoP) Multi Level Risk Assessment (Ref.2) approach was used for this study. The approach considered the development in context of its location and its technical and safety management control. The Multi Level Risk Assessment Guidelines are intended to assist industry, consultants and the consent authorities to carry out and evaluate risk assessments at an appropriate level for the facility being studied.

The Multi Level Risk Assessment approach is summarised in Figure 2. There are three levels of assessment, depending on the outcome of preliminary screening. These are:

- Level 1 – Qualitative Analysis, primarily based on the hazard identification techniques and qualitative risk assessment of consequences, frequency and risk;
- Level 2 – Partially Quantitative Analysis, using hazard identification and the focused quantification of key potential offsite risks; and
- Level 3 – Quantitative Risk Analysis (QRA), based on the full detailed quantification of risks, consistent with Hazardous Industry Planning Advisory paper No.6 – Guidelines for Hazard Analysis.

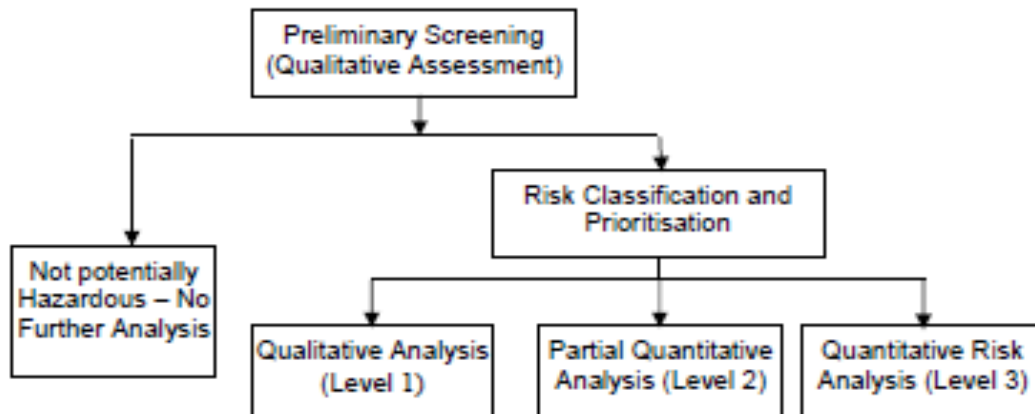


Figure 2 - Multi-level Risk Assessment Approach

The document “Applying SEPP 33” guideline may also be used to assist in the selection of the appropriate level of assessment. This guideline states the following:

“It is considered that a qualitative PHA may be sufficient in the following circumstances:

- *where materials are relatively non-hazardous (for example corrosive substances and some classes of flammables);*
- *where the quantity of materials used are relatively small;*
- *where the technical and management safeguards are self-evident and readily implemented; and*
- *where the surrounding land uses are relatively non-sensitive.*

In these cases, it may be appropriate for a PHA to be relatively simple. Such a PHA should:

- *identify the types and quantities of all dangerous goods to be stored and used;*
- *describe the storage/processing activities that will involve these materials;*
- *identify accident scenarios and hazardous incidents that could occur (in some cases, it would also be appropriate to include consequence distances for hazardous events);*
- *consider surrounding land uses (identify any nearby uses of particular sensitivity); and*
- *identify safeguards that can be adopted (including technical, operational and organisational), and assess their adequacy (having regards to the above matters).*

A sound qualitative PHA which addresses the above matters could, for some proposals, provide the consent authority with sufficient information to form a judgement about the level of risk involved in a particular proposal”.



The proposed VAM RAB facility will be located within the current boundaries of the operating Mandalong Mine Site. Sensitive land users are well clear of the site, the closest residential buildings estimate to be over 1km to the west and more than 300m to the east. The F3 Freeway is adjacent to the mine site more than 200m to the east of the proposed location. Detailed technical and management safeguards are currently used at the existing site and these will be implemented at the proposed VAM RAB plant.

Although the guidelines allow for the analysis for the VAM RAB plant study in this document to be qualitative in nature, enough data is available to undertake quantitative assessment. A key component of the Director General's Requirements (DGRs) is a review of the impact of the proposed facility on the existing land use. Hence, the selected approach for this study will be to assess the risks associated with the operation of the proposed VAM RAB facility and to ensure that the risks are within the guideline criteria and there is no cumulative impact. In the event assessed risks exceed the existing criteria, risk reduction measures will be developed and recommended as part of this study. The following paragraphs detail the risk assessment approach used, which is based on the HIPAP No.6 guidelines.

3.3 Hazard Identification, Analysis and Assessment Method

CSE undertook the risk analysis and assessment process using the guidelines provided in SEPP 33 Appendix 5 for multi level approaches to risk. The level of analysis determined appropriate based on the guidelines is Level 2 which offers both quantitative and qualitative elements to determine the risk criteria will not be exceeded. Essentially four major steps are involved in the analysis, namely incident identification, consequence analysis, probability and frequency estimations, leading to a quantitative risk assessment result. For identified scenarios where hazard mitigation is through intrinsic design, full quantitative assessment by analysis of data derived from research and development testing of the proposed technology was able to be used.

3.4 Establishment of Risk Criteria

Using the guidelines of HIPAP 4 for risk criteria for potentially hazardous development, the Risk Assessment Team included in the PHA a review of the risk analysis previously conducted for the VAM RAB plant for a similar application to an underground coal mine (at a different site location) as the basis for the consequence and probability analysis. Both qualitative and quantitative aspects have been considered and significant developments of the intrinsic design have already been adapted to ensure risk criteria are not exceeded. The following general principals from HIPAP 4 have been applied:

- The avoidance of all avoidable risks;



- Risks from major hazards are reduced to as low as reasonably practical, even where the likelihood of exposure to the risk is low;
- The effects of significant events (determined by FMEA, FTA and related assessments) are contained within the boundary of the site; and
- Incremental or cumulative risk from or to existing installations is not increased.

4. Site Description and Surrounding Land Use

4.1 Brief Site Description

The Mandalong Mine is an underground coal mine located to the west of the township of Morisset in the Lake Macquarie area and generally consists of the Mandalong Mine Access Site, the Mandalong Mine Services Site (formerly Cooranbong Colliery) and the Delta Entry Site. Centennial Mandalong Pty Ltd, a fully owned subsidiary of Centennial Coal Company Ltd has owned and operated Mandalong Mine since 2002.

Appendix 1, Drawing Number 1101-PLA-CC07, details the development which is proposed to be located immediately to the west of Ventilation Fan A bounded by the Fan Security Fence to the east, the Drainage Gas Vent Pipeline bund to the north and an internal site access road to the west. The drawing depicts the VAM RAB plant, conditioning duct and Motor Control Centre. All parking and site ablutions are provided at existing locations elsewhere on the mine site.

4.2 Surrounding Land Use

The proposed plant will be situated well within the boundaries of the current Mandalong Mine development. The immediate surrounding land uses comprise the infrastructure which supports the operation of the underground mine. Access to the plant will be via established private entry control points to the mine site from Mandalong Rd. The nearest residential areas are located more than 300m from the proposed plant beyond the areas buffered by the F3 Freeway to the east, Mandalong Rd to the south and transmission line easements to the west and north. There are no sensitive land users close to the proposed VAM RAB plant site.

5. Preliminary Hazard Analysis

5.1 Nature and Quantity of Materials Stored or Processed

The nature of the materials stored or processed on site is an important part of the PHA because it establishes whether fire, explosion or toxic releases are possible and to what degree. For



example the gaseous combustion products produced by fire, and if so, what risks are imposed on adjacent land users. The types and quantities of materials stored or processed are all less than the SEPP33 screening guidelines and are detailed in Table 2.

The VAM RAB plant utilises hydraulic oil (mineral based) and gaseous nitrogen (pressurised cylinder) as part of the normal plant operations.

The plant processes potentially flammable gaseous methane either in the form of drainage gas (piped from existing supplies at the mine site) or from ventilation air methane (VAM) sampled from the mine exhaust ventilation fan. When methane concentration from the mine is determined by sampling equipment to be approaching the lower explosive limit (LEL) the entire VAM RAB plant is bypassed and the ventilation air is vented to atmosphere via the current facility. No methane is brought to site for processing, the VAM RAB plant processes only by-products from the underground mining process.

As a result of the thermal oxidation process, potent green house gasses are removed from the ventilation air. The plant exhausts trace amounts of Carbon Dioxide (<10 ppm) and Nitrous Oxide (<5 ppm). The quantity of and consequence of exposure to these exhaust gasses is expected to be much less harmful than the exposure from the vehicles using the nearby freeway.

Table 1 - Material Types and Quantities

Material	Dangerous Goods Class	Quantity	Exceeds SEPP33 Criteria?	Plant Location
Methane (Natural Gas)	Flammable Gas - 2.1	Less than 1% of atmospheric volume	No – existing on site	VAM Conditioning Duct
Methane (Natural Gas)	Flammable Gas - 2.1	As required for gas gun and VAM addition	No – existing pipe line on site	Piped from Gas Plant
Nitrogen	Non flammable, non toxic Gas – 2.2	1 G Size Cylinder	No	Piped in duct
Hydraulic Fluid	Not regulated by ADG7. May be flammable if exposed to > 150oC	100 litres	No	MDG 41 certified Hydraulic System



5.2 Hazard Identification

5.2.1 Initial Risk Screening

The screening method defined in Section 7 and Appendix 4 of “Applying SEPP 33” as detailed in section 5.1 of this report has determined that all materials stored or processed by the plant are of quantities below which it can be assumed there is unlikely to be a significant off-site risk.

Rather than assuming SEPP 33 does not apply (per the guidelines), the risk assessment was continued to ensure that all risk scenarios from the HAZOP and resultant FMEA were considered against the land use planning criteria defined in SEPP 33.

5.2.2 Land Use Planning Criteria Definition

Following the FMEA analysis undertaken as part of the hazard identification process it was determined that the VAM RAB plant itself does not present any credible hazards which exceed the guidelines set out in HIPAP 4 when assessed against the societal, environmental or cumulative risk criteria detailed in section 2.4 – “Risk Criteria for Potentially Hazardous Development”.

Due to the criticality and potentially hazardous nature of the existing infrastructure at any site at which a VAM RAB is designed to be used, the risk criteria in section 2.5 – “Risk Criteria for Development in the Vicinity of Potentially Hazardous Facilities” was deemed to be applicable for this PHA. All hazards which were brought forward from the FMEA and HAZOP process were reassessed to ensure that the potential cumulative offsite risk of all credible incidents on the site for all existing, approved and proposed plant and equipment did not exceed the risk criteria defined in HIPAP 4 Section 2.5.

5.3 Risk Criteria Baseline

Section 2.5 of HIPAP 4 – “Risk Criteria for Development in the Vicinity of Potentially Hazardous Facilities” establishes the general principles to be applied when assessing land use safety implications for development in the vicinity of a facility with a potentially hazardous nature. The VAM RAB plant by the purpose of its design is to be located adjacent to critical surface infrastructure at the mine ventilation fan evase. The development of the surface infrastructure has precluded proximity and therefore exposure to commercial developments, sporting complexes and active open space (sensitive land use) leaving the Individual Risk Criteria as defined in HIPAP 4 Table 4 as Industrial at less than 50 in a million per year. The injury risk criterion for heat radiation, explosion overpressure and toxic exposure for qualitative and quantitative evaluation are as defined in section 2.5.3 of HIPAP 4:



5.3.1 Heat Radiation

Incident heat flux radiation at residential and sensitive use areas should not exceed 4.7 kW/m at a frequency of more than 50 chances in a million per year.

5.3.2 Explosion Overpressure

Incident explosion overpressure at residential and sensitive use areas should not exceed 7 kPa at a frequency of more than 50 chances in a million per year.

5.3.3 Toxic Exposure

Toxic concentrations in residential and sensitive use areas should not exceed a level which would be seriously injurious to sensitive members of the community following a relatively short period of exposure at a maximum frequency of 10 in a million per year.

Toxic concentrations in residential and sensitive use areas should not cause irritation to eyes or throat, coughing or other acute physiological responses in sensitive members of the community over a maximum of 50 in a million per year.

5.3.4 Societal Risk

Societal risk was considered despite the fact that there is very low residential density in the area.

5.4 Risk Assessment Program

Hazard identification and analysis was undertaken using and Failure Mode and Effects Analysis (FMEA) approach by a small team of engineers and managers each with differing experience and exposures to the technology under development. The risk assessment process included a review of the applicability of generic risks posed by the application of the VAM RAB technology to any underground coal mine. The hazards identified and control measures proposed are as a result of significant analysis (FMEA, FTA, CHAIR and HAZOP) and a high level of familiarity with the design, construction and operation of the plant. The Risk Assessment (Document 9006-008-400-001) is provided as enclosure 1 to this report. It should however be noted that this high level risk assessment includes the evaluation of hazards related to steam, hot water storage and heat recovery equipment which are not included as part of the proposed design for the Mandalong site, but have been included for completeness.

The Risk Management Plan for this project requires a comprehensive Risk Analysis (RA) program to be undertaken as the plant is to be situated adjacent to critical above ground infrastructure and there are a number of potential hazards which are controlled through the intrinsic design of both passive and active safety systems. These systems are to be subjected to intensive SIL analysis and



third party certified following an extensive qualification testing program. A detailed independent evaluation of the RA program has been undertaken and the resultant Risk Management Assessment Report is provided as enclosure 2 to this report.

5.5 Hazard Analysis Results

5.5.1 Potential Hazard – Heat Radiation

The VAM RAB is essentially a thermal oven operating on the same well established principals as a coke oven. The thermal process is isolated by refractory insulation which has been tested and evaluated under a number of test programs. A small scale pilot VAM RAB unit was operated for several days in November and again in December 2009. The test unit is full scale with respect to proposed height, VAM flow per cross sectional area, residence time, temperature profile and burn out efficiency. Further trials were completed in April 2010.

Using the measured hot side and cold temperatures and known refractory lining thicknesses a heat flux model can be conceived as shown in Figure 3.

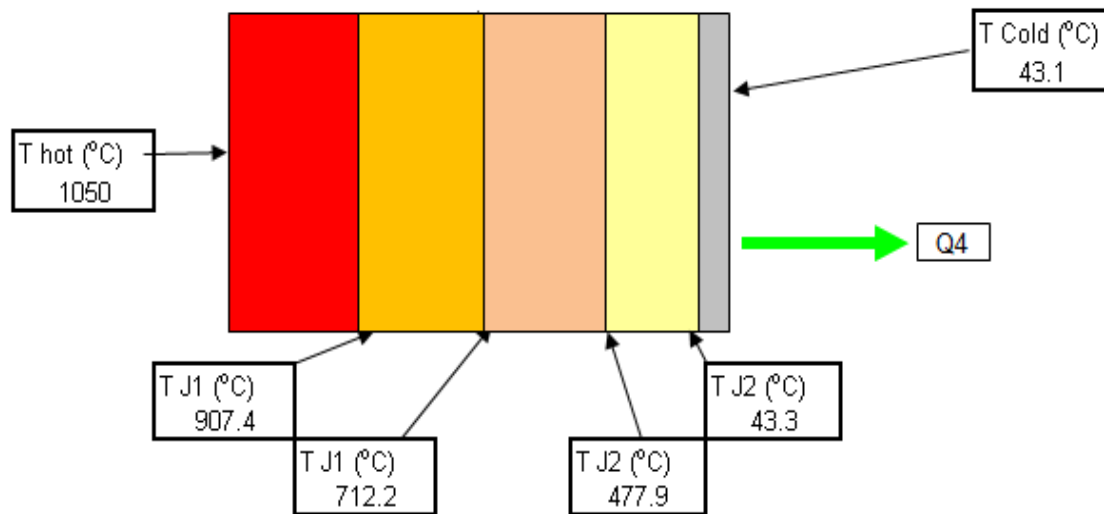


Figure 3 - Thermal flux model

The temperature control systems in the plant are designed to maintain the thermal oxidiser at optimum temperature levels and there are controls in place to reduce or remove input fuel in the form of methane based on temperatures sensed in the VAM RAB. These control systems will be SIL rated and certified to ensure that the incident frequency of failure of the system is less than 0.1 chance of fatality per 10^{-6} (equivalent to 0.1 in a million per year) – refer to enclosure 3 Fault Tree Analysis 1101-402-004.

The calculated heat flux (heat leakage per square metre) under the conditions shown was 1217 W/m^2 at the surface of the VAM RAB. It was therefore determined that the temperature control



measures and intrinsic design of the VAM RAB create a thermal fluxing level significantly less than the baseline heat flux levels described by SEPP 33 of 4700 W/m^2 at the site boundary and the risk exposure is also well under the “Individual Risk Criteria” as defined in HIPAP 4 Table 4 as “Industrial” at less than 50 in a million per year.

5.5.2 Potential Hazard – Explosion Overpressure

The VAM RAB has pressure venting and pressure relief systems which are designed to give high redundancy and large safety factors. The measured effect of pressure build up by intentionally causing an internal deflagration in the test plant has been used to design safety systems and blast relief systems which are design to separate the VAM RAB and conditioning duct from the critical infrastructure of the mine should the conditions for such a deflagration be met.

On multiple occasions the gas fuel mixture was deliberately adjusted to be in the flammability zone (5 to 12% methane equivalent). When this was done the result varied between a slow deflagration event that was so mild to be unnoticed, to a fast deflagration with an audible “woof” noise and operation of the pressure relief system.

The rate of pressure raise was measured to be very slow due to almost isothermal combustion as significant heat was transferred to the chequer brick structure within the VAM RAB. The resulting residual pressure in the test plant was less than 7KPa. See Table 2 for test plant results. Table 3 shows the scaled up results which are applicable to the proposed plant. Note that the demonstration scale plant at Mandalong has an extra layer of protection due to the addition of blast panels. The demonstration plant will be able to control internal pressure to below 7 KPa which is defined as the safe level for incident explosion overpressure for sensitive land use areas and half that of the incident explosion overpressure levels for adjacent potentially hazardous plant.

The safety systems for control of incident overpressure will also be designed and certified to SIL levels which ensure that the incident frequency of failure of the system is less that 0.1 chance of fatality per 10^{-6} (equivalent to 0.1 in a million per year) – refer to enclosure 3 Fault Tree Analysis 1101-402-004.



Table 2 - Pressure Venting Results

RAB pilot (hot)							
required RAB vent area	0.029	m ²		equ 7.1 p68-26			
	0.03	m ²		equ 7.3 p68-29			
inert volume	50%						
P _{stat}	0.01	barr		start venting pressure		1	kPa g
K _{st}	100	bar-m/ s					
	adjusted so match observation						
height down RAB	6	m	height full of unburnt VAM	4.5	m		
L/D	11.25		depth	width	CSA	hyd dia	
V	0.3	m ³	0.4	0.4	0.16	0.4	
	note: only one side of RAB is full of VAM the other side is burnt out						
Π	0.014						
P _{red}	0.07					7	kPa g
P _{max}	5			fig 4.8.2 p68-12		500	kPa g
outlet NB	0.25	m					
CSA	0.049	m ²	194%				
vent ducts	0.15	m					
CSA	0.018	m ²	70%				
total vent	0.067	m ²					

Table 3 - Up Scaled Pressure Venting Analysis

RAB venting							
required RAB vent area	1.036	m ²		equ 7.1 p68-26			
	0.85	m ³		equ 7.3 p68-29			
inert volume	67%						
P _{stat}	0.005	barr		start venting pressure		0.5	kPa g
K _{st}	100	bar-m/ s					
	adjusted so match observation						
height down RAB	8	m	height full of unburnt VAM	6	m		
L/D	1.59		depth	width	CSA	hyd dia	
V	34.8	m ³	4.4	3.3	14.52	3.8	
	note: only one side of RAB is full of VAM the other side is burnt out						
Π	0.014						
P _{red}	0.07					7	kPa g
P _{max}	5			fig 4.8.2 p68-12		500	kPa g
			FOS				
blast panels	2.2	m ²	259%				
bottom duct	1.47	m ²	174%				
vent ducts	0.4	m					
CSA	0.126	m ²					
four ducts	0.503	m ²	59%				
three ducts	0.377	m ²	44%				
two ducts	0.251	m ²	30%				



5.5.3 Potential Hazard – Toxic Exposure

The VAM RAB is designed to process the ventilation air from the mine exhaust ventilation fan. For the proposed plant, a portion of the air which would otherwise be vented to atmosphere is diverted to the plant for thermal oxidation. The output of the process is to be monitored for Carbon Dioxide (CO₂) content as a method for determining the green house gas reduction taking place in the process. CO₂ at less than 3 ppm have been measured when processing methane levels between 0.35% and 0.9%. Under the same conditions the nitrogen oxides (NO_x) concentration was measured as 2.5 ppm.

The design of the plant vent stack and separation from the site boundary is determined to be sufficient that these levels of gas emission are not likely to irritate or lead to physiological exposure levels of any concern.

5.5.4 Potential Societal Risk

The primary risk exposure for multiple fatality situations is the proximity to the mine site “public” areas (entry and visitor access point) and the F3 Freeway. The potential for cumulative off site risk to the adjacent power transmission lines was determined to be negligible. Incremental societal risk was assessed against the indicative criteria of HIPAP 4 Figure 3 and it was determined that the risks do not exceed negligible levels.

6. Conclusion

- All potential hazards have been identified via HAZOP and FMEA;
- All hazards which are controlled by inclusion in the design of safety systems will be qualified by testing and independently (third party) certified as part of the SIL assessment process;
- The quantities of dangerous goods identified as part of the hazard identification process are below screening thresholds; and
- Details of the hazards identified in the FMEA are provided in Enclosure 2 - 9006-008-400-001 Generic VAM RAB Risk Assessment (Rev B).

6.1.1 Effect on people and the environment

- Using the guidelines of HIPAP 4 an assessment was carried out to ensure that all major risks have been avoided, reduced to an acceptable level, contained within the boundary or not increasing any existing risks;



- All major potential hazards can be controlled to lower than specified incident frequencies by safety systems within the design which apply a safety factor of better than 1 in 100 million chance of a dangerous event, far exceeding the minimum guidelines of HIPAP 4 for residential and sensitive land use areas, therefore the use on industrial land use areas is well within safe levels;
- Heat flux radiation will not exceed the 4.7kW/m^2 ;
- Incident explosion overpressure will not exceed 7kPa;
- Toxic exposure is below irritant levels;
- The potential for accident propagation is able to be reduced by the safety factors applied to the design (SIL 2);
- Societal risk is reduced via limited access to the plant and the remote nature of the site from residential, commercial and sensitive areas; and
- Environmental risk is minimised as the plant contains no hazardous materials and is design to reduce the environmental impact of green house gas emission from the mine at site.

6.1.2 Estimate of Resultant Risk

- The resultant risks to surrounding land uses of the VAM RAB plant are negligible and will be quantified and qualified via the RA program prior to construction and operation of the plant;
- All major hazards can be reduced below the recommended levels through design controls and verification of the safety factors; and
- In depth risk analysis will continue as part of the detailed design and construction phases of the project.

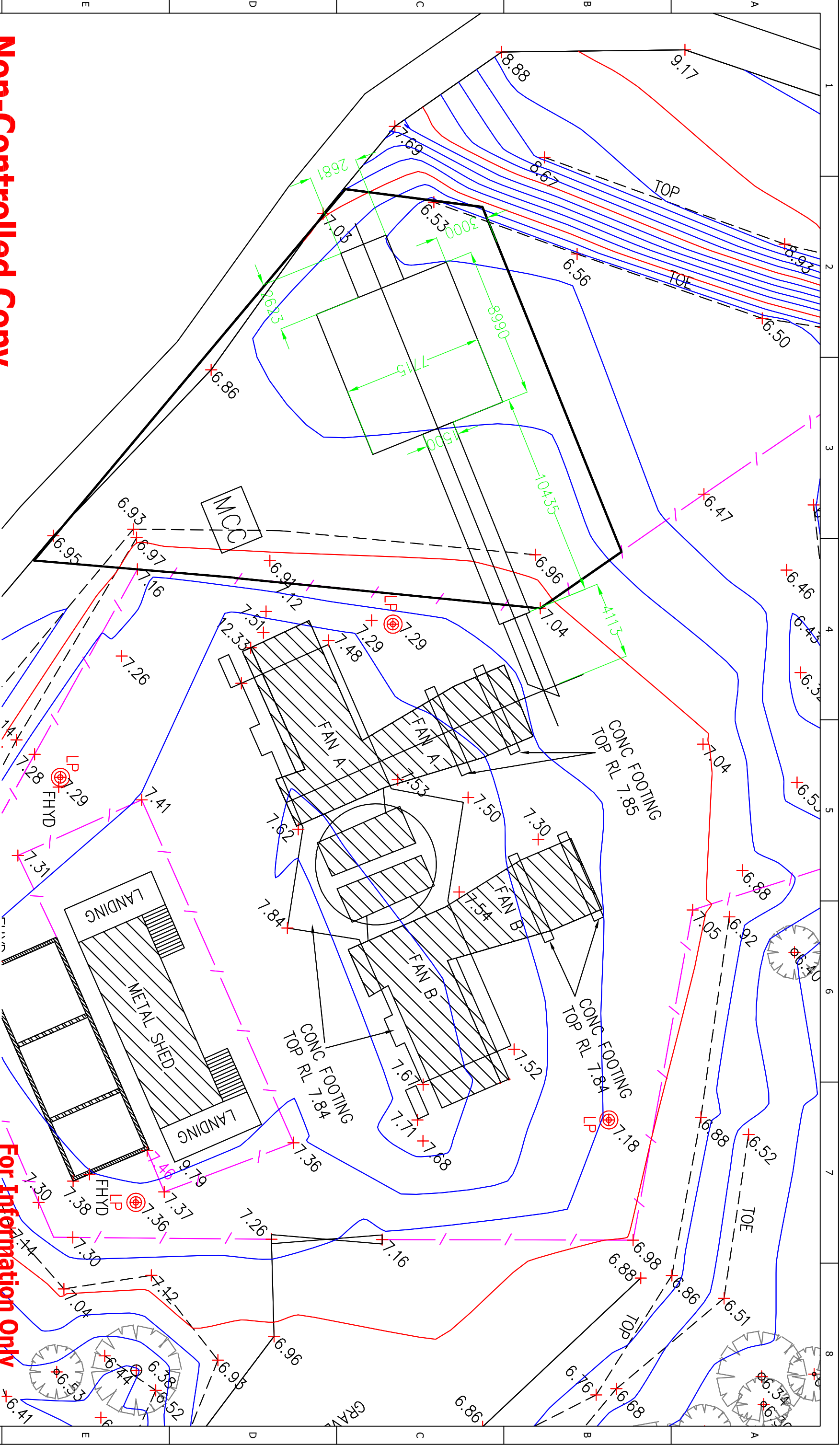
6.1.3 Adequacy of Safeguards

- The location of the proposed plant adjacent to the surface operations of an operating coal mine poses no implications on land use within the boundaries of the site under the guidelines of SEPP 33.
- Qualitative and quantitative analysis methods determine that the proposed plant will not pose unacceptable levels of risk under the guidelines of SEPP 33.



7. Enclosures

Enclosure	Document Identifier	Title	Revision
1	1101-PLA-CC07	Proposed Location Layout	B
2	9006-008-400-001	Generic VAM RAB Risk Assessment	A
3	1101-402-004	Fault Tree Analysis	A



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Rev	Description	Description	Description	Drawn	Sheet Size	Scale	Released by	Reviewed by	Project	Title	Drawing Number	Date	Drawn By	Rev
F					A3	NTS	Corky's Sustainable Energy P/L	Corky's Sustainable Energy P/L	CENTENNIAL PILOT VAM RAB	PROPOSED RELOCATION LAYOUT	1101-PLA-CC07	11/04/11	JJR	B
B	UPDATED DIMENSION			AKK										
A	INITIAL ISSUE			JJR										

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Project No. 9006-008

Generic VAM RAB

Generic VAM RAB Risk Assessment

9006-008-400-001



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Revision History

Rev	Date	Description	Modified	Checked	Approved
A	30/07/2010	Initial Issue	JAH		
B	16/05/2011	Review in reference to Mandalong project	LGH	RP	DC



Project:

Generic VAM RAB

Stage:

Design, pre-construction

Risk Assessment:

Electrical & Operations (Day 1)

Dates:

29th April and 28 to 30th July 2010

13th May 2011

Attendees:

Corky's Carbon Consultancy:

David Cork, Andrew Cork, Geoff Dunn, Jade Hamilton, Mylon Manusiu, Rod Peet

Electrical Projects Australia (EPA):

Paul Malanchuk, Murray Clay

Commander Site Safety:

David Gilroy



1. Risk Assessment

1.1 Functional safety assessment:

- Require high Safety Integrity Level (SIL) ratings without over-constraining and making operation difficult
- SIL assessment on duct to prevent conditions for deflagration (bypass and dilution)
- SIL assessment on duct to isolate VAM-RAB from mine (reversal and frangible panels)
- Additional rigour for the controls on this process

1.2 Critical Factors:

- The exhaust is non-toxic under normal conditions and presents no risk to operators or the wider community. The miners breathe this air as part of their standard work environment.
- Under abnormal condition the process is isolated and the risk exposure from a methane hazard is insubstantially different ($<10^{-8}$) from the current accepted methane hazard.
- The risk of fire and explosion is insubstantially different ($<10^{-8}$) from current fire and explosion hazard. High methane conditions leading to a deflagration event has been judged as the only significant risk to non-operators.
- Hot water/steam. **(included only if heat recovery is specified)**
- Pressure vessel. **(included only if heat recovery is specified)**

1.3 Factor of safety:

- The underground coal industry accepts a 1 in 1,000,000 probability of event occurring or better than 1 in 10,000,000 where there is consequence of multiple fatality consequence.
- Corky's VAM RAB plant has five layers of protection, it is designed to approach aeronautical standards of better than 1 in 100,000,000 chance of a dangerous event (multiple fatalities - deflagration back to mine) occurring.
- Safety critical components (layers of protection) may be beneficial to be rated even just to SIL 1 to make the SIL analysis calculations more accurate.
- Factor of safety = probability of initiating event \times SIL level (approved failure probability) of each layer of protection.



1.4 Layers of Protection Analysis (LOPA):

- Layer of protection analysis has been undertaken with several independent layers required to assure the safety factors required.
- The independent layers of protection (ILP) employed as part of the safety systems on all Corky's VAM RABs are described in Table 1 below and are discussed in the following sections.

Table 1. Independent Layers of Protection

LOP	Design elements
ILP1	SIL 2 Methane Bypass
ILP2	SIL 2 Dilution Doors
ILP3	SIL 1 Passive Design
ILP4	SIL 1 Isolation
ILP 5	SIL 2 Frangible Design

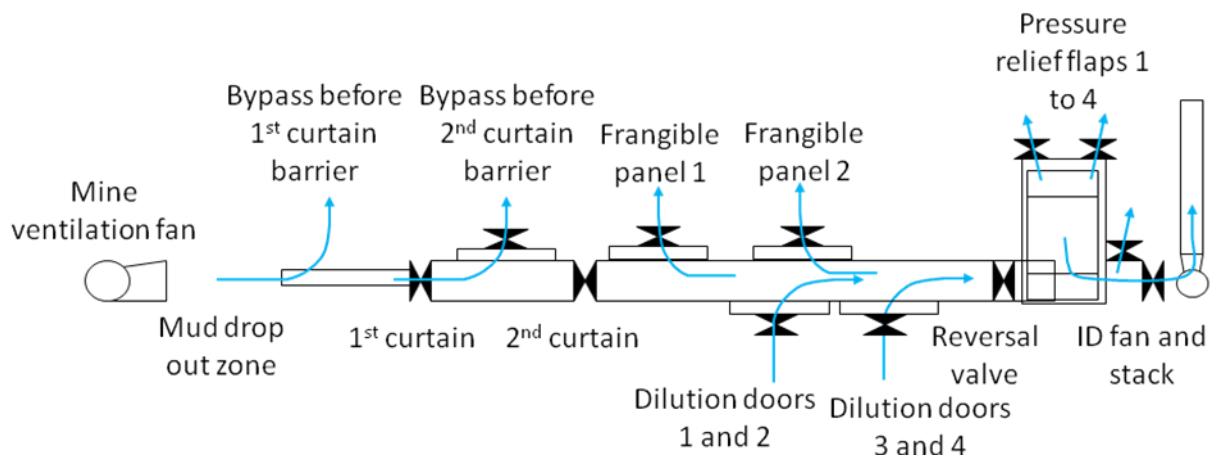


Figure 1: VAM RAB ILP Safety Features



1.4.1 ILP1: Methane Bypass

Aim: A vent before a barrier is used to exhaust methane to atmosphere in an emergency. Currently high methane concentration spikes are vented to atmosphere.

- There are two sets of vents and barriers so there is 100% redundancy
- The vents fail safe open and barriers fail safe closed
- Total Vent area is twice the duct cross sectional area
- Have system target SIL 2 (risk reduction factor 100 to 1000)
- Test system every week
- Closest vent is no closer than 10 m from base of VAM RAB to provide minimum separation for safe plume dispersal
- Double auto isolation valves / double blocker valves (V.05.002 & V.05.003) to shut off high % pre drainage gas methane. Valves are solenoid operated – on or off only.

1.4.2 ILP2: Methane dilution

Aim: Dilute VAM after barrier to purge the duct from VAM RAB with air and stop methane concentration rising to the Lower Explosive Limit LEL near the VAM RAB

- Doors fail safe open
- Stop methane approaching Lower Explosive Limit LEL near the VAM RAB
- Four VAM dilution doors near VAM RAB
- Progressively triggered by methane being over a nominal amount typically two doors open by 1% and all doors open by 1.5% methane
- Total dilution door area is twice the duct cross sectional area
- Have twice the dilution doors needed so there is 100% redundancy
- Multiple independent trigger sources with no common cause failures
- Have system target SIL 2 (risk reduction factor 100 to 1000)
- Test system every week

1.4.3 ILP3: Passive Design

Aim: Even if all the other safety systems fail, no flame will burn back through VAM RAB to ignite the VAM in the duct

- Total system target SIL 1 or better (risk reduction factor 10 to 100)
- VAM flow per cross sectional area leads to low Reynolds number (between 2000 and 3000) which leads to lower flame speed and slower pressure rise should methane reach the VAM RAB above the LEL
- Geometry leads to buffer volume after combustion to lower rate of pressure rise should methane reach the VAM RAB above the LEL



- Chequer height and density ensure that combustion is more like isothermal conditions than adiabatic condition. The combustion takes place in chequers ensuring that there is low flame speed
- Having temperature control ensures that there is a large temperature difference between inlet base chequers and any back burning gas. This coupled with chequer height and density ensures that burning gas is quenched
- Vents at top and bottom of RAB ensure low back flow reducing thermal load on inlet chequers SIL 2 rated (risk reduction factor 100 to 1000) tested weekly
- Having an induce draft fan rather than an pushing fan ensures low back flow reducing thermal load on inlet chequers SIL 2 rated tested weekly

1.4.4 ILP4: Isolation

Aim: The reversal valves close after duct (post barrier) and RAB have been purged, isolating the VAM RAB

- Have system target SIL 1 (risk reduction factor 10 to 100)
- Trigger by hot top or cold top, trigger by hot middle or cold middle temperature
- Trigger by methane being over a nominal amount typically 1.5%
- Fails safe closed
- Cycle on every reversal under process control – probability of failure on demand is reduced

1.4.5 ILP5: Frangible Duct

Background: A pressure wave was observed on the experiment test rig but no flame was seen in duct during the deflagration trial.

Aim: Use deflagration pressure wave to isolated RAB from methane source by opening frangible panels and dilution doors if not already open.

- Electronically trigger venting by 500 Pa overpressure at base of RAB
- Physically trigger venting by 1000 Pa overpressure acting on frangible duct and dilution doors
- Frangible panels fail safe open
- Have twice the Frangible panels and dilution doors needed so there is 100% redundancy
- Have system target SIL 2 (risk reduction factor 100 to 1000)
- Test system every week
- The frangible panels stop back pressure causing gas movement towards the mine

1.5 Risk Factors:

- Fault trees have been developed:
 - Focus on top level hazards.
 - Drill down to SIL (electrical) / CAT (mechanical) levels components from there.
 - SIL assessment to be confirmed by third party expert



2. Fault tree Analysis (FTA)

2.1 FTA-101 – Deflagration event

2.1.1 Series of events that will cause a deflagration:

- Initiating event (high methane event in mine or modulating valve supplying drainage gas in experiment fails open)
- Failure of bypass system
- Failure of methane dilution systems
- 5-15% methane explosive range
- Ignition source. Static prevented by equipotential bonding of duct or hot chequers
- Failure of passive design
- Then failure of frangible systems
- Propagation of RAB explosion to culvert requires back pressure and failure of all pressure relief systems. Note: this is not a problem during experimentation as system not connected to mine.

Probability $<10^{-8}$ Effects one operator no increased exposure beyond 20 m

2.2 FTA-102 electrical signal failure

2.2.1 Power failure:

- System fails safe. That is vents open barriers closed.
- Mine methane build up during power outage
- UPS (Uninterruptible Power Supply) on PLC
- Removes power from fan/pumps/solenoid valves
- Shuts down and cools
- Try to contain heat for when power resumes (can take up to a week or 2 to fully heat up RAB)
- Monitoring of event “nice to have” but not essential
- Purge mine to normal methane level before reconnecting VAM RAB

Probability $<10^{-8}$ Effects one operator no increased exposure beyond 20 m

3. Description

3.1 Experimentation

Background: The RAB is not connected to the mine during trials, using simulation VAM (pre drainage gas at 95% methane) to be used instead. This period allows control loops to be tuned and operators trained.

- Methane addition to duct during experimentation is controlled by SIL 3 rated PLC system.
- Methane addition fail safe close.
- PLC shuts valves – fail shut on all 3 drainage gas valves (culvert modulating valve, double



blocker solenoid valve and on gas gun solenoid valve).

- If a high methane level is detected the double blocker valves shut and air velocity is increased.
- Modulating valve remains open or gets stuck, leading to higher than expected methane then double blocker valves shut off gas supply and VAM duct dilution doors open to vent
- Methane and oxygen sensors notify PLC of high methane event
- PLC alarm
- PLC and UPS on power failure
- Maintenance procedures are the main control to ensure safe operation of equipment.
- Need to look at modulating valve for experimentation in terms of instrument failure including line or modulating valve – feedback loop.
- Consider 'common mode' failures in FTA as controlled by PLC.
- Standard: AS-61508
- Experiment to document drainage gas flow meter values and modulating valve interactions.

3.2 Heat up Procedure:

Aim: Lift temperature of Chequer pack safely

3.2.1 Packaged Burners:

- Two 300 kW thermal burners used
- Used to heat the system up to around 850°C, and have their own control system and burner valve trains.
- Low induced draft fan suction is used on start up for burner
- PLC turns burners on or off

3.2.2 Gas gun:

- Gas gun only required to control low methane environment (as extra energy is required for it to combust VAM under these conditions).
- Higher methane concentrations have enough energy to sustain the operating temperature as it is 'self sustaining'.
- A target of 850°C must be reached before the burners are removed and gas gun is turned on (150°C buffer)
- Acts as a pulse system and as a solenoid valve can either be set on for a specified time period or is off. Does not modulate.
- If drops below 750°C, the burner will be shut off and the manual pre heating procedure will need to be followed to re-establish the 850°C before gas gun can be turned on. Re-heating checks will also be developed so as to determine the reason why the optimal temperature was not achieved.

3.3 Temperature Control - RAB flaps (E.01.007, E.01.008, E.01.014, E.01.015 on PID-001)

- Pressure venting at starts at 0.5kPa
- Lid weight/angle designed to freely vent at this level (passive)
- Temperature control automated with hydraulics system
- Average of temperatures from temperature transmitters (high redundancy) on top section of RAB (TT-0107, TT-0108, TT-0109, TT-0126, TT-0127, TT-0128, TT-0129 on PID-001) control when the Flaps open.



- At 1025 °C they are all ¼ open
- At 1050 °C they are all ½ open
- At 1075 °C they are all ¾ open
- At 1100 °C they are all fully open
- When back to 950 °C, they are all closed once more
- Loose connection for spikes and reset on counter weights
- Linked to PLC to tell it to drive manually
- Linear transducers on all 4 to tell PLC if they are closed, ¼, ½, ¾ or fully open
- 9/10 of time the VAM RAB is under suction due to induced draft fan and all flaps are closed
- The dilution doors act as back up heat relief by reducing the concentration levels of methane before the VAM reaches the RAB

3.4 Hot Water Tank Over Pressure (not on all plant)

3.4.1 Hot Water Tank Over pressure (FTA-201)

- Water is purely for cooling RAB in high methane experiments
- Generates steam which can be used to generate electricity or in energy saving processes
- Dirty water through heat exchanger and then acts to pre-heat the VAM gas in the culvert before it enters the RAB unit, making it easier to combust.
- Does hot water system need shut down process if RAB event
- 4 Pressure relief vents (2 on the hot water tank and 2 on the heat exchanger) to prevent steam over pressure
- If exceeds pressure then opens spring loaded Pressure Relief Valves (fail open)
- 1 vacuum breaker on each vessel, required when the system cools
- UPS on Pump 2 low levels methane – controls cooling water to protect steam coil on power failure and used for low methane experiments only
- 2 main pumps on boiler feed line. These are designed to 60% of the capacity.
- Pump 1 - 1.1kW
- Pump 3 – VSD trim 1.1 kW
- On a full demand plant, these would be 100% capacity and have a back up redundant pump.
- This configuration allows for more accurate experimental control.
- Need shutdown / power up process for essential control
- What is UPS time frame?

3.4.2 Testing

- Pressure/fan suction
- Water control
- Boiler inspection

3.4.3 Pump Failure

- 2 pumps on each line
- 1 fails, lower blower
- Isolate pump
- No observed safety issue



3.4.4 RAB over temp – major failure

- Shortens asset life
- Not observable from outside
- May notice slight temp difference (you can place your hand on it comfortably and think that it's warm)
- Should shut off gas/relieve pressure and temperature before reaching fluxing temperature
- 120°C safety margin to prevent refractory fluxing @ high temp
- Refractory mass accepts spikes in temp, no significant temp

3.4.5 RAB Flaps

- Regular maintenance – Pull chains to ensure movement and ensure joints are greased regularly.
- Stuck open – cause plant to chill. Can be noticed by:
 - Visual inspection
 - Cooling signal from PLC/visual inspection will indicate

3.5 VAM culvert/Air stack

3.5.1 Gas Flow

- Induced draft in stack by ID fan
- Production of CO is a risk, however this will be emitted only on start up, and will be released high from the air stack and presents no risk to ground level workers.
- Draws methane (below LEL) through duct (classified as hazard zone 2 inside duct and 250mm around the outside radius). Gives potential as back source.
- Through heat exchange (chequers)
- At 1.2% methane, excess energy of 3.5MW. Process temperature controlled though water system (some plants) or vent/dilute.
- Drainage gas enters the duct. The ID fan draws air at 15% capacity through the duct. Periodic peak only 600kW energy.
- Incoming gas at the duct entrance with almost the same composition as air. The air may be dusty. The duct acts to slow and capture water vapour which would otherwise make the system less efficient.
- Larger applications – preheat/warm air by around 10°C to around 55°C to turn liquid into gaseous water which stops it from condensing, allowing it to flow through the RAB system.

3.5.2 Cleaning

- There will be some cleaning requirements. Manual cleaning by entering the culvert with plenty of room to vacuum the walls, or possibly hose out if it gets too dirty.
- Culvert is to be classified as a restricted work area (not confined space)
- RAB to be in VAM bypass for cleaning

3.5.3 Design

- Duct to be tested in experimental phase to determine if it is long enough.
- Unit is not high maintenance and when experimentation is completed will become 'unmanned'.



3.6 Water systems – heat removal (not on all plants)

- (PFD-001), Hot water tank 5,000 L/s at 120°C
- Treating as approved pressure vessel
- Annual inspect. Only 6 month initially.
- 3 pumps to move water to steam coil
- Pumps 1 and 2 are designed to 60% of duty each, required for 1.3% methane experiment
- 0.3% methane run – requires pump 2 (small dosing pump with very low flow rate)
- 0.75% methane run – requires pump 3 to control heat removal (most mines will not have this high a concentration of methane)
- 1.2% methane run – requires pump 1 and 3, with 3 to trim water to control heat removal. (almost all mines will not have this high a concentration of methane)
- For full scale (high methane) plant, pumps will be each scaled to 100%, so as to have one redundant pump as an increased safety factor. For experimental analysis over a short 6 month period this was not considered necessary, rather the design required more accurate means of measuring and controlling flow for the different experimental parameters.
- Low pressure, superheated steam.
- Caging to create a barrier is required around hot pipes etc. (need to dump heat hence there will be no lagging around pipes)
- Heat exchanger uses dirty mine water across fins to cool water in the Hot water tank.
- Power station facility would use higher quality, more reliable water supply. This is not applicable for experimentation, as if there is no water supply, the experiment can simply be put on hold and kept warm then resumed later when there is water.
- Heat exchanger unit to duct at 60 to 67°C, increasing VAM gas (or air + drainage for experiment) to around 55°C, allowing H₂O in the gas stream to be converted from liquid to gaseous H₂O.
- Droplet size remaining in service after duct is determined by duct length, for example; 5 micron. This will indicate if duct design is long enough. Use standard sized duct sections (say 1.37 m).
- Size is the only variation to model site and is not critical to process analysis.
- Cooling water from pumps 6 & 7 spray onto tubes using pig tail swirls, as recommended by Corky's. Corky's has explained that the pig tail swirls system is very robust for dirty water, mud etc. and are easy to clean.
- Pumps 8 and 9 allow water to flow to duct – low duty.
- Pump 8 and 9 – from PT-0302 overflow pipe maintain steady level at base of Heat exchanger (refer to PID-003). This is controlled to trim head of water. With twice the cross sectional area of the pipe, the water will want to flow out of the pipe at the base of the heat exchanger unit, and not the overflow pipe.
- Balance tanks – average flow faster than needed.
- In the event of sudden water failure – gives 30 minute control time
- Usually consistent how balance tank gives buffer
- Power failure (normal) – will shut off fan and drainage gas. Thus there will be no flow and no methane in system. RAB unit will slowly lose heat.
- 2 × Pressure relief valves on top of hot water tank and heat exchanger.
- Prevent unit under pressure bursting
- On heat up, air is displaced and O₂ reduced.



- If temperature falls below 50°C air wants to come into sealed unit, therefore a vacuum breaker is also required.
- Interaction of water streams in heat exchanger: streams are separate systems so a change in one stream will not affect the other. The clean water is demineralised and is a closed loop and will return to the Hot Water Tank from the steam coils and the heat exchanger coils. This stream is self correcting and is not dependant on the cooling water stream, as it itself rejects heat.
- Pumps 4 and 5 may not be on under Low methane conditions – experiment investigates potential rise and fall of local temperatures and utilises pumps as needed.

3.7 Experimental plan

3.7.1 Testing

- As a lot of the design is new or untested, the experimental phase will test the following:
 - Safety systems (RAB flaps) – new
 - Heat control – new (heat recovery on some plants)
 - Dust/mud/lime stone in VAM – new – no data
 - Higher levels redundancy for safety
 - Use of mine methane – new

3.7.2 Pre Drainage Gas

- There will be a up to 4.5 MW (pre drainage gas) required for experimentation
- Stack – 1 MW lost to atmosphere
 - Heat exchanger –
 - Up to 3.5 MW capture as steam (some plants)
 - 1.1 MW during low methane operation

3.7.3 Heat Control

- Previous designs had low insulation and heat was lost to atmosphere. The current design has an increased amount and better quality insulation to better control heat. Great risk of over heating.
- Heat losses include water vapour in the VAM gas. 12 kg air/m³ that is fully saturated equals 2.5 MW heat sink and affects heat exchanger constraints
 - Water and other undetected factors such as mud and lime stone are also not included in heat/energy calculations, increasing the factor of safety (FOS). I.e. the process should be cooler than anticipated and presents less risk.

3.7.4 Checkers

- There is a 150°C buffer to minimise or prevent the effects of glazing of the chequer bricks. Operation is optimally between 850 and 1000°C, and glazing will typically occur at temperatures above 1160°C. The aim is to keep the RAB operating in the optimal range for:
 - the protection of physical properties and
 - to maintain a 20 year life expectancy

3.7.5 Burners & Heat Up

- Packaged burners are to operate to 950°C. They are not perfect and can be unreliable. Only needed for start up.



- Heat distribution will then be from the gas gun which will be operated for 6-12 hours.
- Then once the RAB is within the optimal temperature range, commence heating and running experiment with VAM (or air + drainage gas for experimentation period).

3.7.6 Reversal Mechanism

- The reversal mechanism should require little maintenance except for replacing chains, due to wear, every few years. This is from DC's experience at BHP's steelworks for the very similar coke ovens.

3.8 Construction

3.8.1 Pre-assembly

The RAB tower will be pre assembled off site including Hydraulics:

- On site inspection for progress.
- Occupational Health and Safety for this process.
- Standard Operating Procedures (SOPs) and manuals to be written.
- Guarding to be installed where required (i.e. around ID fan, hot pipes).

3.8.2 WorkCover standards – Mines DPI

- Use preferred suppliers of mine.
- Corky's list to identify if mines preferred equipment is not used.
- All equipment and procedures to be approved by mine site.

3.9 Mechanical Notes

Mechanical failure of valves is usually a result of dirt on the seats.

- Bypass leakage – the second of the double block valves should cover this.
- 2E (1001-PID-005) - V.05.015 – isolation valve at end of line to be closed for maintenance.

3.9.1 Chamber Safety Features

In order for operators to work inside chamber there are a number of safety features to be utilised including:

- Double isolation valves
- Venting
- Standard Operating Procedures to be produced, covering
 - Padlock V.05.015 closed
 - Isolation cocks closed
 - Remove plug strainer
 - Double block and bleed
 - V.05.002 and V.05.003 affected by supply parameters – BK to confirm.
- Experimental needs to cover for 4.5 MW
 - 1.2% methane is 4.5 MW
 - 0.3% methane is 1.1 MW



3.10 Hydraulics System

- MDG 41 safety certification for hydraulics
- Current design to standard MDG audit
- Certification to be provided.
- Hydraulics audit

4. OHS & E

4.1 Site Management

- Corky's to do initial ranking of FMEA.
- Construction to be completed by specialists
 - Must use mine risk matrix and comply with site standards
 - SSMP – underpins Corky's
- Principal contractor
 - Corky's SSMP
 - NSW WorkCover
 - OHS / CMSA as applicable
 - Small crew
- Mine to review and sign off.

4.2 Plant Task Observations by Mine

- announced and unannounced.

4.3 Plant and Equipment

- Checked and tagged.
- Machine maintenance records.
- Tickets and permits – HK to review and advise.
- Boilermaker/Electrical/Forklift.
- Signoff (BOOMS) required – environmental survey.
- Classification (Erection only).
- Site safety and rules
- Parking and sign in – must log in with mine.
- R.A. of construction process
- Site inductions by mine nominated company.
- High risk – 12– review. Not expected to be high.
- Documentation to include mine specific procedures.
- Feedback monitoring into a maintenance schedule
 - Impellor
 - Bearings



4.4 Toolbox – daily or weekly

- Amenities:
 - Ablutions – port-a-loos supplied by mine.
 - Crib rooms - process control.
- Construction – daily (minimum).
- No Smoking on site.
- Experimental – weekly (minimum).
- Water – Mine to supply.
- Shift log handover
- Fire fighting. site to supply.

4.5 Personal Protective Equipment, Manual Handling and Hazardous Substances

- First aid room at mine office.
- Safe operating procedures (SOPs) and procedures to identify.
- Hazardous materials are not expected
- SMF - refractory
- Material safety data sheets.
 - Hydraulic oils
 - Piping insulation (superwool)
- Snakes and spiders expected.

4.6 Environment

- EMP – no
- No sacred sites.
- Dust – water cart.
- Site - barriers not expected.
- Dig permit (part of multi work permit (MWP) through Clients procedures).

HAZARD ANALYSIS RECORD SHEET – CONSTRUCTION PHASE
General Hazards

No.	Hazard Identified (Guideword or Prompt - V)	Failure Mode (Causal Object- O)	Failure Effects (Plant or Persons – S)	Failure Causes	Current Controls	S (1-10)	O (1-10)	D (1-10)	RPN (SxOxD)	Hazard Introduced	Action Proposed	Target Date	Person Resp.
1	RESPIRATORY	Dust in the Air	Injury to persons	Dust Cutting/welding	Dust masks available Most cutting and welding to be completed off site Ventilation	1	1	4	4		PPE will be provided		
2	FALLS	Site access ways RAB Unit	Injury to persons	Access to RAB top (Under construction) Stepping over barriers/off walkways Not using a harness if higher than 1.8m	No access sign (compounded area) Use of scaffold Cherry picker Mine site standards to be met Walkways Staircases Use harness if higher than 1.8m. This is covered in site induction	3	1	2	6		No access signs Harness available Procedure and enforce use of harness		
3	TRIP HAZARDS	Site access ways	Injury to persons	Trip hazard on access way	Put things away after things are used Tidy site at end of each work day	2	2	2	8		Site induction include 15min of tidying site at the end of each day		
4	BURNS	Cutting/welding	Injury to persons	Cutting/welding without PPE	PPE Required Procedures Implemented	1	1	1	1		PPE will be provided		
5	INDUCTION BREACHES	Visitors to site Contractors	Injury to persons	Employees media rubbernecks	Induction Register Site log in book Communication	1	1	1	1		Induction Register Site log in		
6	EXPOSURE	Outside working	Injury to persons	Sun dehydration	Sunscreen Hats Rest breaks Water tanks available	1	2	2	4		PPE will be provided		
7	OHS & E REQUIREMENTS	Construction Assembly &	Injury to persons Damage to plant & equipment	Mechanical Failure Safety features	Refer to RA Minutes FMEA VAM 280710 S3b Clause 1.5 Refer to RA Minutes FMEA VAM 280710 S3b Clause 6	1	1	1	1		OH&S records Site manager to ensure safe worksite		
8	MANUAL HANDLING	Heavy construction components	Injury to persons	Construction of the RAB unit	Lifting lugs and ancillaries to position unit Trial assembly off site Lift schedule to be completed by contractor Contractors onsite complete lift risk assessment	2	2	3	12		Contractors to complete lift risk assessment		

HAZARD ANALYSIS RECORD SHEET – EXPERIMENTAL

No.	Hazard Identified (Guideword or Prompt - V)	Failure Mode (Causal Object- O)	Failure Effects (Plant or Persons - S)	Failure Causes	Current Controls	S (1-10)	O (1-10)	D (1-10)	RPN (SxOxD)	Hazard Introduced	Action Proposed	Target Date	Person Resp.
I. GENERAL SITE HAZARDS													
1	INDUCTION BREACHES	Visitors	Injury to persons Not following emergency procedures	Employees media rubbernecks	Induction Procedure Induction for visitors Communication Induction register Site Log/ sign in and out	1	1	1	1				
2	PROCEDURE FAILURE	Procedures	Injury to persons Damage to plant & equipment	Omissions Non-routine work	Step by step procedures with photographs Training session to discuss procedures and run through	2	1	2	4		REFERENCE TO A SWMS RECOMMENDED		
3	FATIGUE	Site Shift Work	Injury to persons Car crash after long shift No response to alarms or emergency situation	12hr shifts	Functional resourcing Rotate rosters. Modify if required Plan to have Van located nearby to sleep at after shift and drive home refreshed in the morning	2	2	2	8				
4	RESPIRATORY	Breathing	Injury to persons	Dust	Dust masks available Exhaust flows high up stack	1	1	1	3				
5	FIRE	RAB Unit	Injury to persons	Explosion or plant failure Burner valve train failure	Fire fighting equipment Fire extinguishers No smoking area Cleared and compounded area Designated electrical areas Electrical building standards: <ul style="list-style-type: none"> FM200 system Fire detection External siren Evacuation alarms 	1 3	1 1	1 2	1 6	No VAM VAM present	CHECK WITH CLIENT		
6	BURNS FROM RAB	RAB flaps chains	Injury to persons	Hot surfaces present while checking movement of RAB flaps daily Hot RAB unit	Chains mean that do not have to access the hot RAB top except for replacement of chequer bricks every 10-15yrs Wear leather welding gloves when pulling chains daily to check movement of RAB flaps. Procedure written Sign placed at 'point of occurrence' Refractory mass means that you can touch RAB – hot but not able to burn ID fan guarded	1	1	1	1				

No.	Hazard Identified (Guideword or Prompt - V)	Failure Mode (Causal Object- O)	Failure Effects (Plant or Persons - S)	Failure Causes	Current Controls	S (1-10)	O (1-10)	D (1-10)	RPN (SxOxD)	Hazard Introduced	Action Proposed	Target Date	Person Resp.
II. GENERAL SITE HAZARDS													
7	BURNS FROM STEAM SYSTEM	Hot Pipes	Injury to persons	RAB over temp. Steam system heating up pipes Cooling water not removing enough heat Cooling water supply cut Pump failure Burst pipe Leaking pump seal	Insulate pipes/cover or install guarding Sign placed at 'point of occurrence' Pipes located too high to reach, or contained in skid, off pathway Steady stream of "dirty water" LV pump Temperature alerts RAB Pilot shutdown Adjust flow rates on operational plant Open RAB flaps before over heats Shuts off methane supply to start cooling RAB if too hot Visual inspection/maintenance	1	1	1	1				
8	GAS POISONING	Exhaust air	Injury to persons/asphyxiation	CO in exhaust on start up	Exhaust flows high up stack Less CO than traffic	1	1	1	1				
9	PINCH ABRASION LACERATION	Moving parts	Injury to persons	Visitor or maintenance person venturing off marked path	Guarding around fan Guarding around reversal valves Signs/ warnings Slow moving	1	1	1	1				
10	FALLS/ SLIP AND TRIP	Heights	Injury to persons	Land Subsidence Stepping over barriers/off walkways Maintenance No induction Chequer brick replacement Oil leakage Uneven ground Pipe work	Structural design completed by L&D Walkways Staircases/handrails Site induction/maps to explain access ways Brick replacement procedure. To be completed by Corky's at project handover. Maintenance of hydraulic oil system Designated, level concreted walkways Guarding and barriers for piping	1	1	1	1				
11	EXPOSURE	Employees	Injury to persons	Sun dehydration	Hats supplied Sunscreen supplied Water supplied	2	2	1	4				
12	NOISE	Fan Deflagration	Impair hearing	Fan operating at high speed Deflagration (pop noise) or steam over pressure	Small fan, much smaller than existing VAM exhaust fans Bearings and oil specified to suit the conditions After commissioning noise survey to be conducted	1	1	1	1				

No.	Hazard Identified (Guideword or Prompt - V)	Failure Mode (Causal Object- O)	Failure Effects (Plant or Persons - S)	Failure Causes	Current Controls	S (1-10)	O (1-10)	D (1-10)	RPN (SxOxD)	Hazard Introduced	Action Proposed	Target Date	Person Resp.
13	ELECTRIC SHOCK	Electric cables	Injury to persons	Power Access requiring long extension cables Lack of suitable GPO's	Localised GPO's RCD circuits 3 phase RCD Lockable isolation points Dissipation point Regular maintenance Use of air and battery tools where possible Design to Client site standards	1	1	1	1				

HAZARD ANALYSIS RECORD SHEET – EXPERIMENTAL

No.	Hazard Identified (Guideword or Prompt - V)	Failure Mode (Causal Object- O)	Failure Effects (Plant or Persons - S)	Failure Causes	Current Controls	S (1-10)	O (1-10)	D (1-10)	RPN (SxOxD)	Hazard Introduced	Action Proposed	Target Date	Person Resp.
III. 1001-PID-001 – RAB UNIT													
1	deflagration (RAPID BURN) during preheating	RAB Unit	<ul style="list-style-type: none"> Injury to persons Damage to plant & equipment 	Gas gun operating at temp < 750°C can cause build up of methane and subsequent deflagration Heating too fast can damage equipment Manual verification	Pre Commissioning RA Start fans low level (15%) Package burner ignition ► 120°C (H ₂ O)- 550°C - 8 hrs ► 750°C progress to 850°C – PLC limits and interlocks burners Drawing 600kw (10% normal) Preheat checkers @ top (750) Engage reversals > 750°C Gas guns ignite at 850° C (150°C buffer) Gas gun turned off if falls < 750°C (electrically interlocked) Engage drainage gas/VAM at > 950°C Refer to RA Minutes FMEA VAM 280710 S3a Clause 2.3 for more info.	1	1	1	1				
2	deflagration (RAPID BURN) during experiment	RAB Unit	<ul style="list-style-type: none"> 5-15% methane explosive range. LEL decreases at high temperatures Deflagration Injury to persons Damage to plant & 	<ul style="list-style-type: none"> Drainage gas isolation valve (V.05.002 & V.05.003) failure to maintain seal or fail open (unlikely) AND modulating valve fail open 	Isolate gas from RAB: Double auto isolation valves / double blocker valves fail shut Reversal valves to shut off inlet to RAB Dilute methane down: 2 x VAM duct dilution doors	2	2	2	8				

HAZARD ANALYSIS RECORD SHEET – EXPERIMENTAL

No.	Hazard Identified (Guideword or Prompt - V)	Failure Mode (Causal Object- O)	Failure Effects (Plant or Persons – S)	Failure Causes	Current Controls	S (1-10)	O (1-10)	D (1-10)	RPN (SxOxD)	Hazard Introduced	Action Proposed	Target Date	Person Resp.
			equipment	<ul style="list-style-type: none"> Unburnt gas build up (Corky's fan failure and mine fan failure) Failure of methane dilution systems Ignition Source (Static) Failure of pressure relief systems Refer to RA Minutes FMEA VAM 280710 S3a Clause 2.1.1 	Pressure relief flaps top RAB to vent excess heat Relieve pressure/fail safe: Chequer pack acts as a 'gauze' screen 4 x RAB flaps Frangible design enables rapid venting Refer to RA Minutes FMEA VAM 280710 S3a Clause 1.4.1 & 1.4.2 <ul style="list-style-type: none"> Refer to RA Minutes FMEA VAM 280710 S3a Clause 2.1.1 Methane delivery pipe is small								
3	FAILURE OF RAB FLAPS	RAB Temperature and Pressure Relief Flaps	<ul style="list-style-type: none"> When all flaps are stuck shut, this causes RAB to escalate in temperature and pressure. Possible plant damage and fluxing over time, leading to decreased plant life Removes a layer of protection against deflagration 	<ul style="list-style-type: none"> Failure of 2 RAB flaps Fail unsafe Hydraulic failure Flaps jam shut Lack of routine maintenance (opening daily with chains) 	<ul style="list-style-type: none"> Other pressure relief's such as 4 x RAB flaps and dilution doors 2 RAB flaps provide almost sufficient vent area to prevent deflagration Hydraulics provide back up energy source on power failure and can control for up to 2hrs after power outage 	3	1	3	9				
4	MANUAL HANDLING	Burners	<ul style="list-style-type: none"> Injury to persons Burns 	Removal of Hot/ Heavy burners	Procedure outlining safe way of completing start up in a step by step manner Wear heat retardant gloves Hang on hook and lower down Two person lift	3	2	3	18				

No.	Hazard Identified <small>(Guideword or Prompt - V)</small>	Failure Mode <small>(Causal Object- O)</small>	Failure Effects <small>(Plant or Persons - S)</small>	Failure Causes	Current Controls	S <small>(1-10)</small>	O <small>(1-10)</small>	D <small>(1-10)</small>	RPN <small>(SxOxD)</small>	Hazard Introduced	Action Proposed	Target Date	Person Resp.
IV. 1001-PID-002 – HEAT TRANSFER & 1001-PID-003 – HEAT REJECTION UNIT (not in most plants)													
1	OVER PRESSURE (HOT WATER/ STEAM)	Hot Water Tank or Heat exchanger	<ul style="list-style-type: none"> • Steam coil damage • Tube damage in heat exchanger • Plant damage 	<ul style="list-style-type: none"> • RAB over temperature • Pump failure • Failure of 2 pressure relief valves • Lack of maintenance • Unguarded cooling water pipes getting too hot 	<ul style="list-style-type: none"> • 2 x pressure relief valves on each vessel • Testing every 6 months as required by law • Guarding and insulated pipes, or guarded and out of reach. Cooling pipes are required to dump heat, so insulation is not ideal. • Refer to RA Minutes FMEA VAM 280710 S3a Clause 6 	2	2	1	4				
2	VACUUM	Hot water tank or Heat exchanger	<ul style="list-style-type: none"> • Vessels implode, or collapse • Plant damage 	<ul style="list-style-type: none"> • Vessel cooling - hot steam cooling creates a pressure drop • Failure of vacuum breaker • Lack of maintenance 	<ul style="list-style-type: none"> • Vacuum breaker on each vessel • Testing every 6 months as required by law 	2	2	1	4				
3	DESIGN	Steam/ Water system	<ul style="list-style-type: none"> • Design failure to remove heat from system • Lack of control of temperature in RAB Unit • Inconclusive experimental results/ unable to maintain steady state 	<ul style="list-style-type: none"> • Water quality • Pump failure • Cooling water control failure, ie balance tanks and stop cock control 	<ul style="list-style-type: none"> • Manual isolation valves to isolate pumps for maintenance • Ability to put experiment on hold and keep RAB hot to fix problems or wait for cooling water supply to resume 	1	1	1	1				
4	LIFE OF PLANT	Vessels	<ul style="list-style-type: none"> • Scrapped after 6 month experimental period, so effects are negligible • Corrosion of unit • Deterioration of plant • Visually offending or not blending into the environment 	<ul style="list-style-type: none"> • Lack of suitable maintenance • Incorrect environmental colour scheme 	<ul style="list-style-type: none"> • No dew points • No chemicals anticipated • Follow Mine site standards re: paint specifications (protective coatings) 	1	1	1	1				

No.	Hazard Identified (Guideword or Prompt - V)	Failure Mode (Causal Object- O)	Failure Effects (Plant or Persons - S)	Failure Causes	Current Controls	S (1-10)	O (1-10)	D (1-10)	RPN (SxOxD)	Hazard Introduced	Action Proposed	Target Date	Person Resp.
V. 1001-PID-004 – RAB HYDRAULICS (REVERSAL MECHANISM)													
1	REVERSAL FAILURE	Reversal System	<ul style="list-style-type: none"> No people consequence Heat differential created Loss of ignition No process unit goes out Penalty EPA (operational) 	<ul style="list-style-type: none"> Sediment in ground causing movement Valve stays Open (Failure/Sticking) 	<ul style="list-style-type: none"> Proximity switch on doors Inspection regime on chains etc Online repairs RA & SOP Designed to fail to safety Thermal mass of checkers offsets complete heat loss 	1	1	1	1		Discuss with client the effects of sediment		
2	OIL LEAKAGE	Hydraulics	<ul style="list-style-type: none"> Injury to persons 	<ul style="list-style-type: none"> Pressure causing hydraulic oil to leak Failure of hydraulic controls 	<ul style="list-style-type: none"> Certified technician Newcastle Hydraulics design Pressure tested Oils on site to standards Water/ glycol coolant 	1	1	1	1		Ensure certificate received and filed Getting working pressure on hydraulics		
VI. 1001-PID-005 – DUCT													
1	DUCT NOT LONG ENOUGH	Culvert / Duct	<ul style="list-style-type: none"> Water and dust not given enough time to settle out Clogging up fan 	<ul style="list-style-type: none"> Design 	<ul style="list-style-type: none"> Experimental phase to test the size of the duct to determine if it is long enough 	1	1	1	1				
2	INJURY CLEANING CULVERT	Culvert / Duct	<ul style="list-style-type: none"> Injury to persons 	<ul style="list-style-type: none"> Lack of lighting Door closure No gas testing prior to entry No confined space training No isolation procedure followed 	<ul style="list-style-type: none"> Internal lighting between doors Intrinsically safe lighting installed (miners light) for maintenance work Hazardous zoning 2 (intermittent flammable gas) in culvert All shift workers to complete confined space training Isolation procedure and training induction Cleaning procedure using vacuum 	1	1	1	1				
3	FAILURE OF FRANGIBLE DESIGN	Culvert / Duct	<ul style="list-style-type: none"> Removes a layer of protection against deflagration down mine shaft Injury to persons Damage of plant 	Design failure	<ul style="list-style-type: none"> Designed for the roof to lift and fail safely, allowing the RAB system to be isolated from the mine Tied down chains to prevent complete collapse or roof flying off top Wind strength capable design roof screw down to 3kpa pressure increase Sandwich panel construction Steel external frame 	5	1	1	5				
4	FAILURE OF DILUTION DOORS	Dilution doors	<ul style="list-style-type: none"> Removes a layer of protection against deflagration 	Failure of both dilution doors Fail unsafe Jam shut	<ul style="list-style-type: none"> Each door is wired separately. Each door provides sufficient vent area to dilute VAM by 25%. When both open, halves concentration of methane. 	5	1	1	5				

HAZARD ANALYSIS RECORD SHEET – OPERATIONS / LONG TERM

No.	Hazard Identified <small>(Guideword or Prompt - V)</small>	Fail Mode <small>(Causal Object- O)</small>	Failure Effects <small>(Plant or Persons - S)</small>	Failure Causes	Current Controls	S <small>(1-10)</small>	O <small>(1-10)</small>	D <small>(1-10)</small>	RPN <small>(SxOxD)</small>	Hazard Introduced	Action Proposed	Target Date	Person Resp.
6	REPLACEMENT OF CHECKER BRICKS	Checker bricks	<ul style="list-style-type: none"> Injury to persons 	<ul style="list-style-type: none"> Changing bricks / repairs incorrectly or while plant is still hot Falling from top Not following procedure or getting experienced personnel to perform task 	<ul style="list-style-type: none"> Only required every 10-15 years if operation is maintained below fluxing temperature of around 1100°C Corky's is to change bricks during the operation commissioning phase Procedure to explain safe checker brick replacement Training package explaining procedure in induction Pre-built hand rails Work on declines Scaffold for access 	3	2	2	12				

