International Power

APPENDIX G

Preliminary Hazard Analysis

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PRELIMINARY HAZARD ANALYSIS OF IPRA'S PROPOSED PEAKING POWER PLANT AT PARKES, NSW

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Preliminary Hazard Analysis of IPRA's Proposed Peaking Power Plant at Parkes, NSW

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EXECUTIVE SUMMARY

E1 Introduction

TransGrid sought generation proposals as alternatives to augmenting its regional grid where high voltage transmission system constraints in the Cowra/Forbes/Parkes area have been identified. To meet the TransGrid request for proposal International Power (Australia) Pty Ltd (IPRA) is proposing to build and operate a peaking power plant at Parkes in NSW. Due principally to the nature and quantities of fuels to be stored and utilised on site, the facility itself is classified as potentially hazardous. There are also minor quantities of lubricating & transformer oils, chemicals which are addressed in this PHA

The objective of this PHA is to present the hazards and risks associated with the proposed peaking power plant. Through the evaluation of likelihood and consequence of the major hazards, the risks to the community associated with proposed peaking power plant may be estimated and compared to Department of Planning risk criteria.

The aim of the PHA is to:

- Identify and analyse the acute hazards and risks associated with all processes involved with the handling and transporting of potentially hazardous material which form part of the new development;
- Assess the findings against the risk criteria currently in use by NSW Department of Planning;
- Identify opportunities for risk reduction, and make recommendations as appropriate.

The risk assessment has quantitatively determined the risk of fatality and injury to the public associated with the handling and processing of potentially hazardous material at the proposed development.

The report assesses the risks from the following facilities:

- The natural gas pipeline carrying natural gas from the AGL Central West Pipeline (CWP) to the power station (*the lateral gas supply pipeline*), and
- The Peaking Power Plant.

The methodology for the PHA is well established in NSW. The assessment has been carried as per the Hazardous Industry Advisory Paper (HIPAP) No 4, Risk Criteria for Land Use Planning and in accordance with HIPAP No 6, Guidelines for Hazard Analysis. These documents describe the methodology and the criteria to be used in PHAs as currently required by Planning NSW for major *potentially hazardous* development.

The risk assessment technique involves the following general steps:

- Identification of the hazards associated with the proposed project, including those which may potentially injure people off-site or damage the off-site environment;
- Identification of the proposed safeguards to mitigate the likelihood and consequences of the hazardous events;
- Estimation of the magnitude of the consequences of these incidents;
- Where the consequences may affect the land uses outside the site boundary, estimation of the probability with which these incidents may occur;
- Estimation of the risk by combining the frequency of the event occurring with the probability of an undesired consequence;
- Comparison of the risk estimated with the guidelines and criteria relevant to the proposal.

E2 Results

The main hazard associated with the proposed project is associated with the handling of natural gas, which is a flammable gas held under pressure.

Hazards may arise in fixed plant, storage, and pipelines. The failure modes assessed in the PHA derived from historical failures of similar facilities and equipment. For the facilities which form part of the development, the predominant mode in which a hazardous incident may be generated is associated with a leak. This would generally only have the potential to cause injury or damage if there was ignition, which resulted in a fire or explosion incident. The factors involved are:

- Failure must occur causing a release. There are several possible causes of failure, with the main ones being corrosion and damage to the equipment by external agencies;
- The released material must come into contact with a source of ignition. In some cases this may be heat or sparks generated by mechanical damage while in others, the possible ignition source could include non-flame proof equipment, vehicles, or flames some distance from the release;
- Depending on the release conditions, including the mass of material involved and how rapidly it is ignited, the results may be a localised fire (for example a so called jet fire), a flash fire or an explosion of the vapour cloud formed through the release.
- Finally, for there to be a risk, people must be present within the harmful range (consequence distance) of the fire or explosion. How close the people are will determine whether any injuries or fatalities result.

E3 Risk Assessment and Conclusions

The qualitative and quantitative analysis showed that:

- The risk of fatality at the nearest residential area is well below the criterion for new installations of one chance in a million per year (1 x 10^{-6}/yr) and remains within the site boundary or within the easement of the lateral gas supply pipeline.
- It follows that the 10 x 10^{-6} per year fatality risk contour (relevant for open spaces) remains well within the site boundaries or the pipeline easement and does not encroach into any open spaces. The criterion for open spaces is therefore satisfied.
- It also follows that the 50 x 10^{-6} per year fatality risk contour (relevant for industry and business) remains well within the site boundaries or the pipeline easement and does not encroach into any business or industrial zones. The criterion for industrial and business zoning is therefore satisfied.

As the risk of fatality does not extend anywhere outside the boundaries, it is considered that the proposed development does not have a significant impact on societal risk.

The risk associated with the transport of dangerous goods and potentially hazardous material to the site is very low.

E4 Recommendations

The risk assessment carried out in this study assumed that the facility will be operated with appropriate consideration to safety and safety management at all stages.

The following recommendations emphasise the assumptions made in this risk assessment. The recommendations are listed in the order in which they were listed in the study.

Recommendation 1: It is recommended that an assessment is carried out of the safety management system implemented and used at the site, specifically as it applies to the proposed hazardous materials handling, pipelining and storages within the first year of operation.

Recommendation 2: Any issues relating to temperature cycling to be taken into account during detailed design in order to avoid stress corrosion cracking.

Recommendation 3: High and low pressures of the natural gas supply to be associated with an automatic trip / emergency isolation of gas flow.

Recommendation 4: The use of leak detection in high risk natural gas piping to be investigated.

Recommendation 5: The detailed design of the turbine enclosure and associated equipment should clearly outline the basis of safety used to ensure that explosive situations do not arise (/the risk is rendered negligible). Reference should be made to European ATEX Directive (Ref 7) and the UK HSE PM84 (Ref 8) or other guidance / regulation of equivalent safety.

Recommendation 6: Fire protection inside the turbine enclosure to be determined, including use of explosion panels and use of fire retardant material.

Recommendation 7: A system should be put in place to ensure that any removal of critical safety function (e.g. for repair or exchange) is subject to careful scrutiny by plant management (decisions on whether to shut down plant or a gas turbine if a critical safety function is removed needs to be canvassed).

GLOSSARY

CBD	Central Business District
HAZID	Hazard Identification
HAZOP	Hazard and Operability Study
HIPAP	Hazardous Industry Planning Advisory Paper
HSE	Health and Safety Executive (UK)
IBC	Intermediate Bulk Container
LFL	Lower Flammable Limit
IPRA	International Power (Australia) Pty Ltd
MAOP	Maximum Allowable Operating Pressure
MPa	Mega Pascal (unit for pressure)
MSDS	Material Safety Data Sheet
MW	Mega Watt (unit for energy output)
NG	Natural gas
NOx	Nitrogen oxides
OH&S	Occupational Health and Safety
PHA	Preliminary Hazard Analysis
SCADA	Supervisory Control and Data Acquisition
SIL	Safety Integrity Level

REPORT

1 INTRODUCTION

1.1 BACKGROUND

TransGrid sought generation proposals as alternatives to augmenting its regional grid where high voltage transmission system constraints in the Cowra/Forbes/Parkes area have been identified. To meet the TransGrid request for proposal, International Power (Australia) Pty Ltd (IPRA) is proposing to build and operate a peaking power plant and associated infrastructure at a site approximately 10km west of Parkes, in central NSW.

Due to the potentially hazardous nature of hazardous materials utilised on site, the facility itself is classified as potentially hazardous.

As one element of the planning approval process, the NSW Department of Planning requires a Preliminary Hazard Analysis (PHA) to be prepared in accordance with the requirements of Hazardous Industry Planning Advisory Paper ((HIPAP) No. 6: *Guidelines for Hazard Analysis* (Ref 1) and for the risk to be evaluated and compared with their risk criteria, as specified in their HIPAP No. 4: *Risk Criteria for Landuse Planning* (Ref 2).

This document forms an appendix to the Environmental Assessment and provides details of the PHA undertaken for the proposed peaking power plant.

1.2 SCOPE AND AIM OF STUDY

The objective of this PHA is to present the hazards and risks associated with the proposed peaking power plant. Through the evaluation of likelihood and consequence of the major hazards, the risks to the community associated with proposed power station may be estimated and compared to Department of Planning risk criteria.

The scope of this report includes the following:

- Systematic identification and documentation of the major hazards, based on the information supplied and relevant experience with similar processes;
- Establishment of the consequence of each identified hazard and determination as to their offsite effects. This process is generally qualitative, with relevant quantitative calculations/modelling being completed where necessary;

- Where offsite effects are identified, the frequency of occurrence is estimated based on historical data. If such data is unavailable, assumptions and qualitative discussions are presented;

- Determination of the acceptability (or otherwise) risk by comparison of the qualitative or quantitative assessment of the identified risks with the criteria specified in the NSW Department of Planning HIPAP No. 4 (Ref 2); and

- Identification of risk reduction measures as deemed necessary.

At the time this PHA was conducted, design of the peaking power plant was in its preliminary stages. Detailed plant information was therefore not available for review. In situations where such information could impact on the PHA, assumptions have been made. These assumptions are intentionally conservative and have been stated in the report.

As a result of this conservatism, the results of the PHA are also inherently conservative, and this should be noted in their interpretation and application beyond the scope of this work.

2 SITE AND PROCESS DESCRIPTION

2.1 SITE LOCATION AND SURROUNDING LAND USES

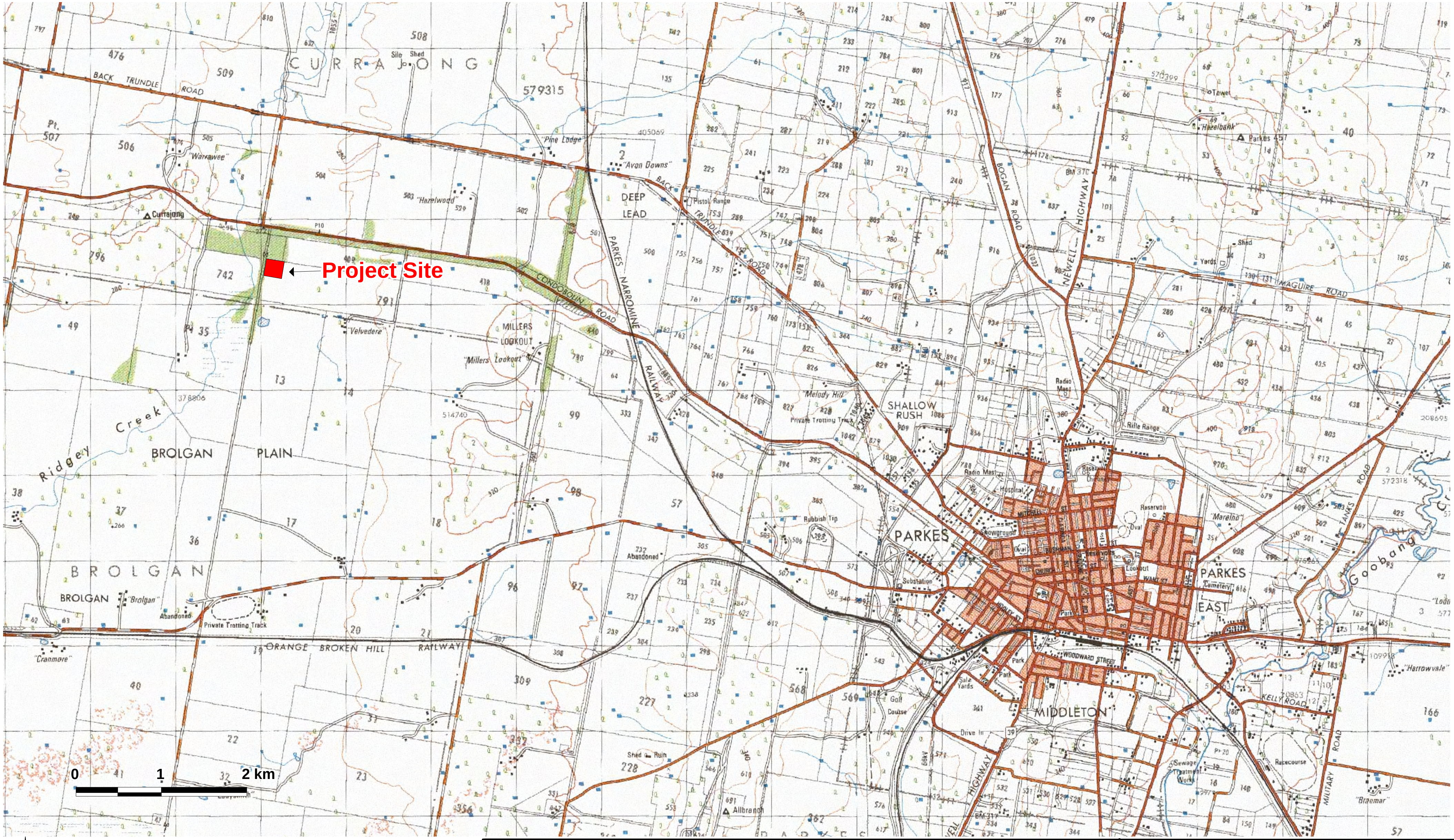
The site is located approximately adjacent to Condobolin Road approximately 10km west of Parkes. A location map is presented in

Figure 1 below. The preferred route of the lateral gas pipeline (from its off-take at the Central West Pipeline) is shown on the location map.

Developments immediately surrounding the site are predominantly rural enterprises on large and medium size holdings, and smaller rural home sites of about 10 hectares.

The proposed site is located on land currently identified as Lot 1 on Lot DP 602329. The proposed peaking power plant would occupy a site area of approximately 4.7 ha (on a lot of 200 metres by 235 metres).

The site is privately owned and is located at the southern boundary of an existing TransGrid-owned substation, thus optimising the connection flexibility to the 132kV substation.



Source: TOPOGRAPHIC MAP - LAND AND PROPERTY INFORMATION NSW

Client	Project	Title
INTERNATIONAL POWER (AUSTRALIA) PTY LTD	ENVIRONMENTAL ASSESSMENT - PARKES PEAKING POWER PLANT	**SITE LOCATION**
PLANAGER Risk Management Consulting	Drawn: AJW · Approved: CJ · Date: 18/12/2006	Figure: **1**
	Job No: **43177456** · File No: 43177456.037.wor	

2.2 POWER STATION OPERATION

The facility will operate as a peaking power plant with a nominal generating power capacity of between 120MW and 150MW.

Three turbines, each of nominally between 40MW and 50MW output would be installed. The turbines would be of proven technology, comprising small compact generators placed inside soundproof enclosures. Normal operation of the turbines would use natural gas for fuel. However, in order to ensure reliability in times of natural gas supply interruptions, the units will be able to be run using distillate fuel (i.e. the units will be designed and installed to have dual fuel capability).

These units would be capable of being operated individually or in conjunction, providing a high level of reliability of power generation for the region, expected to be in the order of 99% on an annual basis.

The peaking power plant will operate in open cycle mode during times of peak electricity demand which is estimated to be less than 10% of the time.

The operating regime for the peaking power plant in the short to mid term is anticipated to be:

- Typical operating hours per turbine per annum = nominal average 600 hrs;
- Total typical generation per annum = nominal average 75 GWh;
- Typical maximum generation in any single year = 115 GWh;
- Typical average gas consumption of 850 TJ per annum;
- Typical maximum gas consumption of 1,240 TJ per annum, and
- Backup distillate consumption (if required) of up to 6000 tonnes per annum with up to 1,200 tonnes of distillate at site at any one time.

2.3 SITE LAYOUT

The preliminary site layout is presented in Figure 2 below, and shows the supply Gas Pipeline entry to the site, the location of the gas receiving area on the site and the main entrance to the peaking power plant itself.

The TransGrid Substation (located to the north of the proposed peaking power plant is included on the layout drawing for reference.

Client INTERNATIONAL POWER (AUSTRALIA) PTY LTD	Project ENVIRONMENTAL ASSESSMENT - PARKES PEAKING POWER PLANT	Title **CONCEPTUAL SITE LAYOUT**
PLANAGER Risk Management Consulting	Drawn: AJW / Approved: CJ / Date: 18/12/2006 Job No: **43177456** / File No: 43177456.038.wor	Figure: **2**

Following completion of construction and commissioning, the major site features will include:

- The natural gas receiving area and pipelines supplying gas to the turbines;
- Three gas turbines each comprising compressor, combustor, power turbine and electricity generator, all inside acoustic enclosures;
- Three generator transformers (“step-up transformers”);
- Three inlet air filter houses;
- A building for control room, admin area, store and workshop;
- A liquids unloading area (including offload and lay-by area);
- Pipelines for distillate and water connecting the liquids unloading area with the respective storage tanks, and connecting the storage tanks with their respective points of use;
- Distillate storage tanks located inside a bund, and associated piping and equipment;
- Demineralised and fire water storage tank with associated pump(s);
- A Reverse Osmosis (RO) water treatment plant and associated equipment and minor chemicals storage;
- An interceptor pit to collect spills;
- Two waste collection ponds;
- Service connections to the electricity network,; and
- Service roads.

2.4 Operating Hours and Staffing

The proposed peaking power plant would be capable of operating for 24 hours per day. However, actual operational hours would be dependent upon periodic electricity demand and economic factors (the peaking power plant would be designed for peaking demand only, generally operating at less than 10% of the time).

It is expected that the peaking power plant would be staffed during day-shift only. 24-hour monitoring of the site may be provided from the remote monitoring centre. Personnel could be called to the site at any time in case of a process upset.

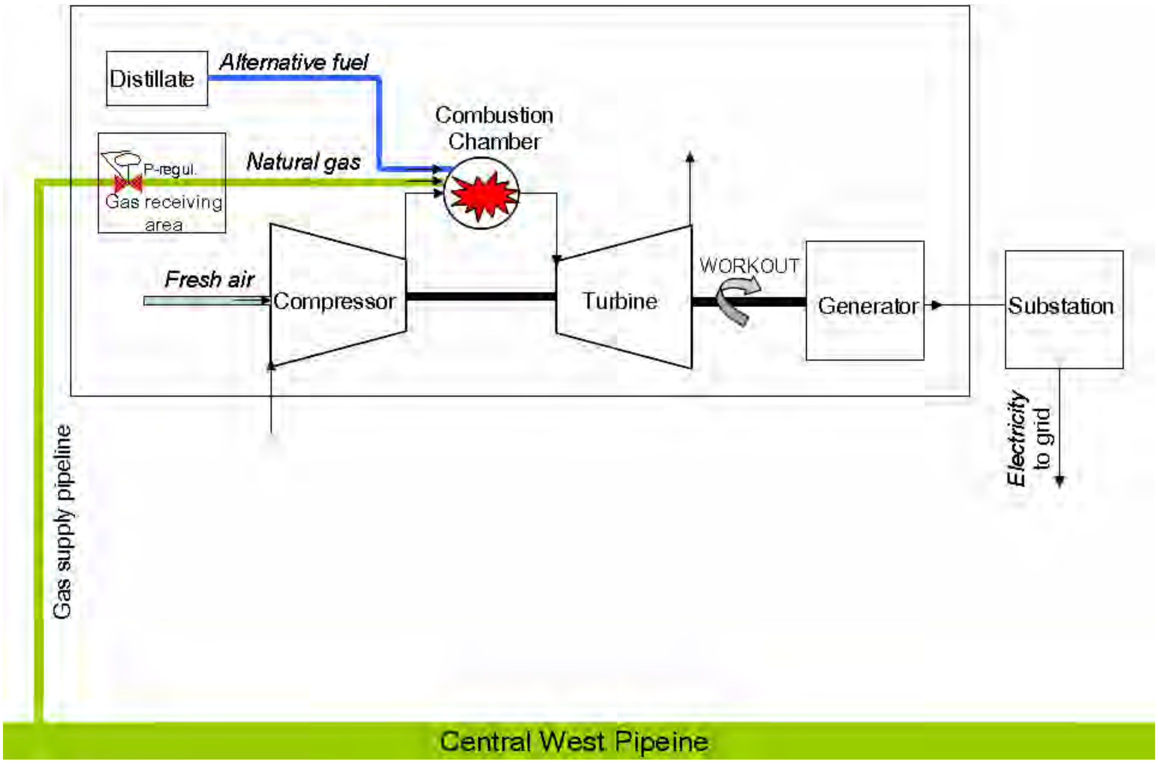
2.5 GAS TURBINE OPERATION

Gas Turbines or more correctly Combustion Turbines are rotary machines that compress air, combust fuel to heat that compressed air, and then extract energy from the flow of heated air. A combustion turbine thus largely consists of an upstream air compressor coupled to a downstream turbine, and a combustion chamber in-between.

Energy is extracted in the form of shaft power, to drive the compressor and to drive the electricity generator.

A block flow diagram of the gas turbine and fuel supply is shown in Figure 3 below.

Figure 3 – Block Flow Diagram of Turbine Station and Gas Supply



2.6 DETAILS OF PLANT EQUIPMENT

Below is a brief explanation as to the operation of the equipment on site. Details of associated safeguards are presented in Section 5.2 below.

2.6.1 Turbines

The development will comprise three industrial gas turbines with the electricity generated being fed via high voltage transformers and circuit breakers into the 132 kV transmission network through an existing switchyard adjacent to the site which includes high voltage transformers and circuit breakers. The gas turbines will be powered by natural gas, supplied from the Central West Pipeline, or (as backup) by distillate (supplied by road tankers and stored on site).

The nature of the proposed peaking power plant to meet peak demand influences the type and size of gas turbine selected. Required is a gas turbine that can handle intermittent operation, a high number of starts for short periods of operation and is reliable. As the peaking power plant will only run during peak periods at varying demand, it is essential that multiple gas turbines of smaller output are installed to maximise efficiency. This also increases the overall reliability of the peaking power plant.

Each gas turbine-generator unit generally consists of three heavy lift components the compressor-power turbine, electricity generator and high voltage transformer. Each gas turbine, draws air in through filters to remove particulate matter, into the compressor. Following compression, the air flows into the combustion chamber where natural gas is injected and burnt.

The combustion products from the combustion chamber enter the power turbine where it flows through rows of blades gradually reducing to atmospheric pressure. The power turbine in turn rotates the electrical generator. From the power-turbine the combustion products are discharged through a stack which contains a silencer section.

The type of gas turbine proposed is crank started by a diesel engine up to approximately one third of running speed, main fuel is then admitted to the combustion chamber and ignition is initiated. The gas turbine ramps up to operating speed and the start motor disengages and is shutdown.

2.6.2 Electrical generators

Attached to each gas turbine is an electrical generator that generates electricity when rotated by the gas turbine. The generators are large items of plant, assembled off site and delivered in one piece.

2.6.3 Transformers

The electrical transformer step the voltage from the generator at around 11 kilovolts to 132 kilovolts. The transformer(s) will be located adjacent to the existing TransGrid substation which is located immediately to the North of the site. The transformers will be connected to the substation with appropriate switchgear to ensure safe and reliable connection to the electricity network.

2.6.4 Gas Supply

Natural gas is the preferred fuel for the gas turbines. An approximately 10 km long lateral gas supply pipeline will transport the gas to the gas receiving area located at the North Eastern corner of the peaking power plant site.

The pipeline will be designed to deliver gas at a nominal maximum pressure of 10.2 MPa up to the gas receiving area where it will be reduced to 2.5 MPa prior to use by the gas turbines. This can be achieved using a pipeline of approximately 250 mm diameter.

The pipeline will travel from East to West from the Central West Pipeline so that gas flows to the West from Parkes to the peaking power plant, as shown in

Figure 1 above.

Under normal conditions, the pipeline and the regulator meter station will be pressurised and under the prime control of the gas pipeline operator.

Operation of the gas reticulation within the power station will be controlled by the on-site operator and / or (e.g. while the site is unmanned) by the operator at a remote monitoring centre. Telemetered information will be received from the gas receiving area and from each remote operated valve. All of this is recorded by a Supervisory Control and Data Acquisition (SCADA) system. Automatic trip schemes will shutdown gas flow in cases of overpressure / extreme flow. Further, both the pipeline operator and the power station operator will have access to critical data and will be able to open and close remote operated valves .

The pipelines will be compliant with AS2885 (Ref 3). The detailed design of the gas supply pipelines is not completed and the assumptions as to the technical details made for this PHA are given in Table 1 below and further in the listing below the table.

Table 1 – Summary of Preliminary Assumptions Made in the PHA for the Lateral Gas Supply Pipeline Design

Item	Pipeline Design
Pipe Diameter	250 mm NB (nominal bore)
Pipe Length	10,000 metres
Maximum operating pressure	10.2 MPa (max operating pressure: 10.2MPa) ANSI Class 300
Class Location to AS2885	R1 (broadly rural) with 40 hectare blocks with some R2 (rural residential) as per AS2885 definitions.
Pipe Thickness	5 to 6.4 mm
Depth of Cover	At least 750mm (or 450mm in rock if encountered)

The gas receiving area will be constructed inside the plant boundary.

The pipe downstream of the pressure regulator, up to the peaking power plant is assumed to be of 250mm diameter.

A valve station will be installed at the Central West Pipeline off-take point. This station is will include a below-ground valve and an above ground shut-off valve as well as provisions for pig launcher.

At the gas receiving area, another valve station will be installed. This valve station will include filter vessels, a number of manual valves, pressure and flow regulating valves, flow meters and provisions for pig launcher. There will also be an emergency isolating valve (automatic shut off valve).

The pressure tapping points associated with the remote operated valves are assumed to allow a drop in line pressure to be quickly ascertained. For the purposes of the present risk assessment, closure of the valve at the entry to the peaking power plant or at the off-take point at the Central West Pipeline is assumed to be able to be triggered either automatically by the sensor upon low pressure, or by the operator in the control room. The SCADA system, which includes telemetered data from the valve stations instrumentation, would give the operator sufficient details upon which to make a decision to close the valve.

2.6.5 Alternative Fuel – Distillate

Distillate will be used as back-up fuel for the gas turbines as well as for start up. The distillate will be supplied to the site via road tankers, unloaded at the tanker unloading bay located to the West of the site, and pumped to one of two 600kL storage tanks located within a bund. The distillate will be supplied to the gas turbines via pipelines. Any spill at the tanker unloading bay or from the pipes supplying the tankers or the gas turbines will run into the interceptor pit located at the Western boundary, to the South of the unloading area (see Figure 2). Any spill from the oil filled step up transformers will be similarly intercepted.

2.7 SECURITY

The peaking power plant, including the gas receiving area, will be located within a fenced off area accessed through a security gate.

2.8 ACCESS ROADS

The peaking power plant will be accessed from Condobolin Road. Internal access roads will be constructed on hard surface inside the peaking power plant to allow vehicle and/or forklift access as required.

3 STUDY METHODOLOGY

3.1 INTRODUCTION

The methodology for the PHA is well established in Australia. The assessment has been carried as per the Department of Planning's HIPAP No 6 (*Guidelines for Hazard Analysis*, Ref 1) and HIPAP No 4 (*Risk Criteria for Land Use Planning*, Ref 1). These documents describe the methodology and the criteria to be used in PHAs, as required by the Department of Planning for major "potentially hazardous" development.

There are five stages in risk assessment (as per Ref 1):

Stage 1. Hazard Identification: The hazard identification includes a review of potential hazards associated with all dangerous and hazardous goods to be processed, used and handled at the power station and associated pipelines and facilities. The hazard identification includes a comprehensive identification of possible causes of potential incidents and their consequences to public safety and the environment, as well as an outline of the proposed operational and organisational safety controls required to mitigate the likelihood of the hazardous events from occurring.

The tasks involved in the hazard identification of the proposed facility included a review of all relevant data and information to highlight specific areas of potential concern and points of discussion, including drafting up of preliminary hazard identification word diagram. The hazard identification word diagram is then reviewed and complete in a workshop which included people with operational / engineering / risk assessment expertise. The review takes into account both random and systematic errors, and gives emphasis not only to technical requirements, but also to the management of the safety activities and the competence of people involved in them.

The final hazard identification word diagram is presented in Section 4.3.

Stage 2. Consequence and Effect Analysis: The consequences of identified hazards are assessed using current techniques for risk assessment. Well established and recognised correlations between exposure and effect on people are used to calculate impacts.

Stage 3. Frequency Analysis: For incidents with significant effects, whether on people, property or the biophysical environment, the incident frequency are estimated, based on historical data. A probabilistic approach to the failure of vessels and pipes is used to develop frequency data on potentially hazardous incidents.

Stage 4. Quantitative Risk Analysis: The combination of the probability of an outcome, such as injury or death, combined with the frequency of an event gives the risk from the event. In order to assess the merit of the proposal, it is necessary to calculate the risk at a number of locations so that the overall impact can be assessed. The risk for each incident is calculated according to:

Risk = Consequence x Frequency

Total risk is obtained by adding together the results from the risk calculations for each incident, i.e. the total risk is the sum of the risk calculated for each scenario.

The results of the risk analysis are presented in three forms:

- Individual Fatality Risk, i.e. the likelihood (or frequency) of fatality to notional individuals at locations around the site, as a result of any of the postulated fire and explosion events. The units for individual risk are probability (of fatality) per million per year. Typically, the result of individual risk calculations is shown in the form of risk contours overlaid on a map of the development area. For pipelines (as for other transport activities), the individual risk contours are best represented as risk transects, showing the risk as a function of the distance from the pipeline.

- Injury and irritation risk, i.e. the likelihood of injury to individuals at locations around the site as a result of the same scenarios used to calculate individual fatality risk.

- Societal risk takes into account the number of people exposed to risk. Whereas individual risk is concerned with the risk of fatality to a (notional) person at a particular location (person 'most at risk', i.e. outdoors), societal risk considers the likelihood of actual fatalities among any of the people exposed to the hazard. Societal risk are presented as so called *f-N curves*, showing the frequency of events (f) resulting in N or more fatalities. To determine societal risk, it is necessary to quantify the population within each zone of risk surrounding a facility. By combining the risk results with the population data, a societal risk curve can be produced.

The risk results are then assessed against the guidelines adopted by the Department of Planning (Ref 2).

Stage 5. Risk reduction: Where possible, risk reduction measures are identified throughout the course of the study in the form of recommendations.

3.2 RISK CRITERIA

Having determined the risk from a development, it must then be compared with accepted criteria in order to assess whether or not the risk level is tolerable. If not, specific measures must be taken to reduce the risk to a tolerable level. Where this is not possible, it must then be concluded that the proposed development is not compatible with the existing surrounding land uses.

3.2.1 Individual Risk Criteria

The individual fatality risk is the probability of fatality to a person or a facility at a particular point. It is usually expressed as chances per million per year (pmpy). It is assumed that the person will be at the point of interest 24 hours per day for the whole year. By convention in NSW, no mitigation is allowed, i.e. any possible evasive action that could be taken by a person exposed to a hazardous event, e.g. by walking out of a toxic cloud or a heat radiation. The assessment of fatality, incident propagation and injury risk should include all components contributing to the total risk, i.e. fire and explosion.

The Department of Planing uses a set of guidelines on acceptable levels or individual risk which are in line with the criteria used elsewhere in the world. These guidelines are published in the Hazardous Industry Planning Advisory Paper No. 4: *Risk Criteria for Land Use Safety Planning* (Ref 2). The criteria for maximum tolerable individual risk from a new development are shown in Table 2 below. The criteria have been chosen so as not to impose a risk which is significant when compared to the background risk we are already exposed to. This table shows the criteria for individual risk of fatality, injury and propagation of an incident. While the natural gas pipeline and the power plant itself are located in rural areas, the more rigorous criteria for residential areas (as shown in bold in the table below) has been applied as the relevant criteria for the proposed development.

Table 2 – Criteria for Tolerable Individual Risk From A New Development

Land Use	Maximum Tolerable Risk (pmpy[1])
Fatality risk criteria:	
Hospitals, Schools, etc	0.5
Residential areas, hotels, etc	**1**
Offices, retail centres, etc	5
Open space, recreation areas etc	10
Neighbouring industrial areas	50

Land Use		Maximum Tolerable Risk (pmpy[1])
Overpressure for Safety Distances:		
Property damage and accident propagation	14 kPa	50 Adjacent potentially hazardous installation, land zoned to accommodate such installations, or nearest public building
Injury risk levels	7 kPa	50 At residential areas
Maximum Heat Radiation:		
Injury risk levels	4.7 kW/m^2	50 At residential areas
Property damage and accident propagation	23 kW/m^2	50 Adjacent potentially hazardous installation or land zoned to accommodate such installations

In order to put these risks into perspective, published information on the level of risk to which each of us may be exposed from day to day due to a variety of activities has been shown in Table 3 below. Some of these are voluntary, for which we may accept a higher level of risk due to a perceived benefit, while some are involuntary. Generally, we tend to expect a lower level of imposed or involuntary risk especially if we do not perceive a direct benefit.

Table 3 – Risk to Individuals

Activity / Type of Risk	Published levels of risk (pmpy[1])
VOLUNTARY RISKS (AVERAGED OVER ACTIVE PARTICIPANTS)	
Smoking	5,000
Drinking alcohol	380
Swimming	50
Playing rugby	30
Travelling by car	145
Travelling by train	30
Travelling by aeroplane	10

[1] pmpy = per million per year

Activity / Type of Risk	Published levels of risk (pmpy[1])
INVOLUNTARY RISKS (AVERAGED OVER WHOLE POPULATION)	
Cancer	1,800
Accidents at home	110
Struck by motor vehicle	35
Fires	10
Electrocution (non industrial)	3
Falling objects	3
Storms and floods	0.2
Lightning strikes	0.1

3.2.2 Societal Risk Criteria

Societal risk is concerned with the potential for an incident to coincide in time and space with a human population. Societal risk takes into account the potential for an incident to cause multiple fatalities. Therefore, two components are relevant, namely:

- The number of people exposed in an incident, and
- The frequency of exposing a particular number of people.

In the absence of published criteria in HIPAP 4 (Ref 2), the criteria in the 1996 regional study of Port Botany by the Department of Planning[2] have been used for indicative purposes, as presented in Table 4 below.

Table 4 - Criteria for Tolerable Societal Risk

Number of fatalities (N) [-]	Acceptable limit of N or more fatalities per year	Unacceptable limit of N or more fatalities per year
1	3×10^{-5}	3×10^{-3}
10	1×10^{-6}	1×10^{-4}
100	3×10^{-8}	3×10^{-6}
1000	1×10^{-9}	1×10^{-7}

[2] then the Department of Urban Affairs and Planning

The societal risk criteria specify levels of societal risk which must not be exceeded by a particular activity. The same criteria are currently used for existing and new developments. Two societal risk criteria are used, defining acceptable and unacceptable levels of risk due to a particular activity. The criteria in Table 4 above are represented on the societal risk (f-N) curve as two parallel lines. Three zones are thus defined:

- Above the unacceptable/intolerable limit the societal risk is not acceptable whatever the perceived benefits of the development.
- The area between the unacceptable and the acceptable limits is known as the ALARP (as low as reasonably possible) region. Risk reduction may be required for potential incidents in this area.
- Below the acceptable limit, the societal risk level is negligible regardless of the perceived value of the activity.

3.3 RISK CALCULATIONS

In order to determine the cumulative risk from all identified hazards, the computer software tool ISORIS from the Warren Centre for Advanced Engineering (Ref 4) was used. First, base information on the incidents, including type, location, processing conditions and frequency were entered into a spreadsheet. This spreadsheet calculates the leak rate for each incident using standard orifice flow equations for vapour or liquid, as appropriate. The spreadsheet also determines the base consequences for each incident in terms of total radiant heat release rate and TNT equivalent. See Appendix 4 for a printout of the incident listing from the spreadsheet.

Information on the frequency, location and consequences of each incident was extracted from the spreadsheet and processed by the ISORIS program. This program is designed to take consequence and frequency information and determine risk levels to individuals at all locations within a user-defined grid. From the output of ISORIS risk contours can be drawn and overlayed on a site map.

ISORIS can determine risks to persons in the open or in buildings. For this study, risks in the open have been determined. In the case of radiation, persons are more at risk in the open due to the lack of shelter, while for explosions the risk is greater inside due to the potential for the building to collapse.

To assess injury risk and the potential for knock-on or domino incidents, ISORIS can also determine the frequency of exceeding a given level of heat radiation or explosion overpressure.

3.4 SAFETY MANAGEMENT SYSTEMS

3.4.1 Safety Management in General

In quantitative risk assessments, incidents are assessed in terms of consequences and frequencies, leading to a measure of risk. Where possible, frequency data used in the analysis comes from actual experience, e.g. near misses or actual incidents. However, in many cases, the frequencies used are generic, based on historical information from a variety of plants and processes with different standards and designs.

As with any sample of a population, the quality of the management systems (referred to here as "safety software") in place in these historical plants will vary. Some will have little or no software, such as work permits, planned maintenance and modification procedures, in place. Others will have exemplary systems covering all issues of safe operation. Clearly, the generic frequencies derived from a wide sample represent the failure rates of an "average plant". This hypothetical average plant would have average hardware and software safety systems in place.

If an installation which has significantly below average safety software in place is assessed using the generic frequencies, it is likely that the risk will be underestimated. Conversely, if a plant is significantly above average, the risk will probably be overestimated. However, it is extremely difficult to quantify the effect of software on plant safety. Incorporating safety software as a means of mitigation has the potential to significantly reduce the frequency of incidents and also their consequences if rigorously developed and applied. The risk could also be underestimated if safety software is factored into the risk assessment but is not properly implemented in practice. Practical issues also arise when attempting to factor safety software into the risk assessment – applying a factor to the overall risk results could easily be misleading as in practice it may be the failure of one aspect of the safety software that causes the accident, while all other aspects are managed exemplarily.

In this study it is assumed that the generic failure frequencies used apply to installations which have safety software corresponding to accepted industry practice and that this site has similar management practices and systems. This assumption it is believed, will be conservative in that it will overstate the risk from well managed installations.

3.4.2 Recommendations for Safety Management System

Recommendation 1: It is recommended that an assessment is carried out of the safety management system implemented and used at the site, specifically as it applies to the proposed hazardous materials handling, pipelining and storages within the first year of operation.

4 HAZARD IDENTIFICATION

4.1 HAZARDOUS MATERIALS

A list of the types and storage quantities of materials that are likely to be found at the proposed site is included in the following table. Quantities are indicative only.

Table 5 - Typical Chemicals Stored Onsite

Plant Area / Use	Chemical/Product	Anticipated Storage Qty
Natural Gas supply	Natural gas	Approximately 10,000 m long, up to 500mm diameter, 10.2 MPa pressure, atmospheric temperature.
Backup fuel	Low Sulphur Distillate	2 x 600,000 L in fixed tanks
Turbines	Turbine oils (combustible oil)	3 x 7,000 L in containment integral to each turbine
Transformers, pumps, air compressor, lubrication, fire pump	Insulating oil (non PCB)	1,000 L in one bulk container or drums
Water treatment plant (including an RO capability)	Caustic soda (50%)	1,000L in one bulk container
	Hydrochloric acid (36%)	1,000L in one bulk container
	Antiscalant	1,000L in one bulk container
	Citric acid	1,000L in one bulk container
	Sodium hypochlorite	Minor quantities in lockable chemical cabinet
Chemicals for maintenance / repair work and clean-up	Carbon dioxide	As required for fuel line purging, in cylinders
	Nitrogen	As required for natural gas line purging, in cylinders

Natural gas is composed predominantly of methane gas. The composition of natural gas from Moomba is shown in Table 6 below.

Table 6 – Composition of Natural Gas

Component	Mole %
methane	87
ethane	8.46
hydrogen	0.36
nitrogen	3.61
carbon monoxide	0.09
carbon dioxide	0.34
Ethylene	0.03
Hydrogen sulphide (H_2S)	0.04
oxygen	0.07
TOTAL	**100**

The properties of methane gas are presented in Table 7 below.

Table 7 - Properties of Methane Gas

Molecular weight (g/mol)	17
Relative density of the gas (atmospheric temp. and pressure)	0.6
Heat of combustion (MJ/kg)	50
Flammable range (vol. % in air)	5 to 15
Ratio of specific heats (Cp + Cv)	1.31
Flash point	-218^{o}C

4.2 SUMMARY OF HAZARDS IDENTIFIED

A total of 27 hazards were identified for the power station and associated gas pipeline, as listed in Table 8 below.

The *Hazard Identification Word Diagram* in Table 9 details these hazards, their potential initiating events as well as their proposed controls.

Table 8 - Summary of Identified Hazards

Number	Hazardous Event Potential	Offsite Impact Potential	Assessed in Section
1	Leak of natural gas from the gas supply pipeline	Y	5.2.1
2	Leak of natural gas to atmosphere from gas pipes on-site (outside the turbine enclosure)	Y	0
3	Venting of gas from process	N	-
4	Explosion within piping or inside a vessel	N	-
5	Leak of natural gas to inside the turbine enclosure	Y	5.2.3
6	Loss of containment of distillate during unloading and storage	Y	5.2.5
7	Loss of containment of distillate during fuel forwarding to gas turbine	Y	5.2.5
8	Loss of distillate inside turbine enclosure	Y	5.2.5
9	Unburned distillate inside the turbine during start-up	Y	5.2.3
10	Loss of lube oil inside turbine enclosure	Y	5.2.5
11	Loss of containment of corrosive liquids.	N	5.2.6
12	Violent reaction between incompatible materials	N	5.2.6
13	Loss of containment of water treatment plant effluent	N	5.2.6
14	Fire at transformers	Y	5.2.7
15	Flooding results in process upsets and damage to plant and equipment	Y	5.2.8
16	Land subsidence, earthquake or mining activity results in plant damage	Y	5.2.8
17	Aircraft crash results in process upsets, potential damage to process / piping / storage facilities resulting in hazardous releases	Y	5.2.8
18	Damage to plant through terrorism / vandalism / unlawful entry to site / sabotage	Y	5.2.8
19	Bush / grass fire	Y	5.2.8
20	Storm damage	Y	5.2.8
21	Incident during maintenance and repair work	Y	5.2.8
22	Flooding results in damage to pipeline	Y	5.2.9
23	Land subsidence, earthquake or mining activity results in pipeline damage	Y	5.2.9
24	Aircraft crash, train derailment or truck crash results in damage to pipeline	Y	5.2.9
25	Damage to pipe through terrorism / vandalism / unlawful entry to site / sabotage	Y	5.2.9
26	Bush / grass fire affects the above ground	Y	5.2.9

Number	Hazardous Event Potential	Offsite Impact Potential	Assessed in Section
	pipeline		
27	Transport of potentially hazardous material to and from the site (distillate, oils, corrosives)	Y	5.2.10

The main hazard associated with the proposed development is related to a leak and ignition of flammable natural gas or, to a lesser degree, to a leak of combustible liquids (distillate), as described in Sections 4.2.1and 4.2.2 below.

4.2.1 Flammable Natural Gas

A leak of flammable natural gas would generally only have the potential to cause injury or damage if there was ignition, which resulted in a fire or (in case of confinement) an explosion incident. The factors involved are:

- The pipelines, vessel or equipment must fail in a particular mode causing a release. There are several possible causes of failure, with the main ones being corrosion and damage by external agencies;

- The released material must come into contact with a source of ignition. In some cases this may be heat or sparks generated by mechanical damage while in others, the possible ignition source could include non-flame proof equipment, vehicles, or flames some distance from the release;

- Depending on the release conditions, including the mass of flammable material involved and how rapidly it ignited, the results may be a localised fire (for example a jet fire), a flash fire or an explosion of the vapour cloud formed through the release;

- Finally, for there to be a risk, people must be present within the harmful range (consequence distance) of the fire or explosion. How close the people are will determine whether any injuries or fatalities result. Environmental damage from gas fire incidents are generally associated with a failure to control fire water used.

Natural gas is a buoyant, flammable gas which is lighter than air (relative density of 0.6). On release into the open the non-ignited gas tends to disperse rapidly at altitude. Ignition at the point of release is possible, in which case the gas would burn as a jet (or torch) flame. On release in an enclosed area (for example within the gas turbine enclosure) an explosion or a flash fire is possible.

The gas is non-toxic, posing only an asphyxiation hazard. Due to its buoyancy, any release of credible proportions from operations of this scale, in the open, would not present an asphyxiation hazard. With standard confined space entry procedures and appropriate security arrangements to prevent unauthorised access to any of the facilities the risk associated with asphyxiation from natural gas should be minimal.

Locally, the pressure of the compressed gas may be hazardous in case of an uncontrolled release. These hazards, while of importance for people working at the site, do not have implications beyond the immediate location of the release unless the released gas is ignited. Therefore, the risk associated with of non-ignited compressed gas does not form part of the scope of the present risk assessment. This potential risk would however need to be closely managed through job safety analysis (JSA) and/or other risk assessment practices used by management and operators of the facility (in accordance with NSW Occupational Health and Safety Act and its associated legislation (Ref 5)).

4.2.2 Combustible Distillate and Lubricating Oils

Other potential hazards are associated with the handling and use of distillate and other combustible liquids (i.e. the oils used for pumps, compressors, turbines etc.).

4.3 HAZARD IDENTIFICATION WORD DIAGRAM

The Hazard Identification Word Diagram, included in Table 9 below, provides a summary of the hazardous incidents identified for the proposed site and their associated mitigating features. Each section of the peaking power plant and associated pipelines was reviewed in turn in a workshop, to determine the potentially hazardous scenarios relevant to that section. The sections reviewed were:

- Natural gas lateral supply pipeline to the peaking power plant property boundary, including gas receiving station;
- Turbine enclosure;
- Distillate storage and handling;
- Storage and handling of water treatment chemicals;
- Carbon dioxide (or other asphyxiant fire quenching gas) storage;
- Electricity generation;
- Finally, potential hazards that could affect the whole site and / or the supply pipeline were reviewed.

While the table below provides an overview of the preventative and protective features proposed and recommended for the site, these safeguards are further detailed in Section 1 below.

Table 9 – Hazard Identification Word Diagram

Event	Cause/Comments	Possible Consequences	Prevention/ Protection
SECTION OF PLANT: Natural Gas Supply Pipeline			
1. Leak of natural gas from the gas supply pipeline	1. Mechanical impact (e.g. 3rd party involvement digging or trenching, or other earth work).	Massive release of natural gas (NG). If ignition, then possibility of flash or jet fire. Physical explosion from the pressure of the pipeline creates projectiles (earth, sand, stones). Injury and property damage.	- Buried pipeline to AS2885 requirements (minimum 750 mm). Pipeline easement (15 to 25 metres width). - Rural zoning with some subdivisions at 10 ha. Mainly large farming developments with some smaller lots. - Signage along pipe route, including Dial-Before-You-Dig information. Drawings available to Dial-Before-You-Dig. - Resistance of pipelines to penetration through use of pipe appropriate thickness (5.o to 6.4 mm) and adequate design factor as per AS2885. - Automatic shut down through line break detection and valve closure at the lateral off-take from the Central West Pipeline if hole in pipe. Manual shut down of pipe (by activation of remote control valve) by remote monitoring centre. - Check valve and slam shut EIV at entrance to site; very minimal gas accumulation at the Gas Turbine Facility means minimal risk of reverse flow. - NG disperses readily upwards, minimising chances of ignition. Explosion not credible in unconfined situation. - Landowner liaison as per AS2885 requirements, including communications with Councils, Fire Services, Railways, RTA etc. and local contractors. Limited length of pipe and limited number of landowners makes for relatively ease of landowner liaison programs.

Event	Cause/Comments	Possible Consequences	Prevention/ Protection
Continued 1. Leak of natural gas from the gas supply pipelines	2. Leaking pipe due to corrosion. (Damage of pipeline coating due to excavation inspection damage leads to corrosion.)	Release of gas. If ignition, a jet fire is possible. Injury and property damage.	- Cathodic protection for external corrosion. Internal corrosion virtually absent with clean hydrocarbon. - Coating on external surfaces of pipeline (e.g. epoxy coating). - Routine inspection of pipeline (including regular patrol and provision for condition monitoring). Visual and sound indications if leak. - Pipeline to be constructed to facilitate internal (condition monitoring) inspection (minimise dips & no short radius bends). - Control of vegetation within easement to minimise risk of bush / grass fire (note that some areas of natural vegetation may be required to be maintained). - Inductive current and fault levels to be managed as per AS2885 and AS4853 and other specific standards requirements for pipelines in the vicinity of high voltage transmission lines. - NG disperses readily upwards, minimising chances of ignition.
As above	3. Operational error at Gas Turbine Facility causes pressure excursion leading to failure of the pipeline.	Release of natural gas. If ignition, then possibility of fire. Injury and property damage.	- Pipelines constructed and hydrotested to AS2885 requirements. - Pressure relief at pipeline metering station. - The supply pipeline can operate against closed head (i.e. the main valve at the entrance to the site may be closed).

Event	Cause/Comments	Possible Consequences	Prevention/ Protection
Continued 1. Leak of natural gas from the gas supply pipeline	4. Operational error at Central West Pipeline causes pressure excursion leading to failure of the lateral pipeline.	Overpressuring the supply pipeline causing failures, leaks and release of natural gas. If ignition, then possibility of fire. Injury and property damage.	- Overpressure protection at CWP. - Continuous observation of pressure of CWP pipeline from Agility's Control Centre at Young (NSW). Also, lack of pipeline control for several hours would be required before pressure could exceed critical levels. - Continuous monitoring of pressure of the pipelines supplying natural gas to the power plant by remote monitoring centre. - The supply pipeline to the Facility is to be designed to the same pressure rating as the main Central West Pipeline. - Automatic line-break protection isolating flow of natural gas to site.
As above	5. Construction defect or operational error (repeated) causes spontaneous loss of integrity of pipe.	Massive release of natural gas. If ignition, then possibility of flash or jet fire. Injury and property damage.	- All field-welds are x-rayed (100%). - Thickness of pipe material and the limited extent of temperature cycling at the station will be taken into account during detailed design. - Cathodic protection and pipeline coating. - Design for pipelines to prevent crack propagation. - Pipeline complying with AS2885 and other specific standards. - Pressure testing at commissioning to check pipeline integrity prior to putting it into operation.

Event	Cause/Comments	Possible Consequences	Prevention/ Protection
SECTION OF PLANT: Gas Receiver and Metering Facility and On-Site Gas Transport at the Peaking Power Plant Site			
2. Leak of natural gas to atmosphere from gas pipes on-site (outside the gas turbine enclosure).	1. Mechanical impact, weld failure, operational error corrosion, etc.	Release of natural gas. If ignition source available (or if ignited at source), then flash fire or jet fire possible. Injury and property damage.	- Use of fully welded pipework wherever practicable. Minimise pipe-runs. Pipes designed as per AS2885 (or equivalent) requirements. - Training and induction of employees and subcontractors, including emergency response training. - Preventative maintenance programs (inspection, testing and maintenance). Pipework is located above ground. - Compliance with AS2885 requirements for site layout (e.g. no buildings of combustible material close to metering station). - Open layout promotes natural dissipation of leaked gas. - Control of ignition sources including non smoking, hot work permits, hazardous zone requirements and signage, restricted access, rubbish management, traffic control etc. - Site is attended during working hours Monday to Friday. - Excess use of NG (e.g. flow through meter when site is shut-down) may highlight a problem. - Site is attended 5 days per week Monday to Friday during daylight hours. A leak will be detected through visual and audible signals. Further, the gas is odorised.

Event	Cause/Comments	Possible Consequences	Prevention/ Protection
Continued 2. Leak of natural gas to atmosphere from gas pipes on-site (outside the turbine enclosures).	2. Mechanical impact by vehicle on metering station / gas receiver station (within Site boundary) damages pipework, valves etc.	Release of natural gas. If ignition source available (or if ignited at source), then flash fire or jet fire possible. Injury and property damage.	- Fenced area. Signage. Visual obstruction managed. - No public roadway in the vicinity. Site layout and control of on-site access. - Bollards or other physical barriers protecting above ground pipework at critical risk locations. - Pipework and supports designed to relevant standards. - Control of on-site access. Access by third parties only while site is attended. Site restrictions on speed and access. Specific green card (permits) required for truck drivers (WorkCover general induction).
As above	3. Valve gland leak or flange leak or maintenance failure at valves.	Release of natural gas. If ignition, then possibility of fire. Injury and property damage. Possibility of propagation to other parts of the plant.	- Routine inspections and servicing / maintenance of pipe and valve points. - Control of ignition sources. - Valve stations within fenced site. - Welded connections wherever practicable. - Layout of the site to mitigate risk to nearby plant and structures from fire / heat radiation.
3. Venting of gas from process.	1. Maintenance work, shutdown, depressurisation of the Gas Turbine Facility.	Release of flammable gas or heat to process area, fire hazard. Risk to people on site if venting not properly designed and managed.	- Releases to be piped to safe area and vents to be directed to elevated point. - Planned venting of process piping to be managed. - Broad requirements for procedures, including inert gas purging etc., included in AS2885.
4. Explosion within piping or inside a vessel.	1. Failure of maintenance activities creates ingress of air into natural gas piping and vessels and subsequent start-up without adequate purging.	Possible explosion. Due to the limited quantities of gas involved the effects of the explosion would however not be expected to pose a threat to nearby businesses or to any residential areas in the vicinity.	- Piping normally operated at a positive pressure, preventing ingress of air. - Prevention of ingress of air will be considered throughout the design and operation of the facility (for example in the preparation of start-up, shut-down and maintenance procedures). - Procedure requirements as per AS2885.

Event	Cause/Comments	Possible Consequences	Prevention/ Protection
SECTION OF PLANT: Gas Turbine Enclosure and Gas Turbine			
5. Leak of natural gas inside of gas turbine enclosure.	1. Mechanical impact, weld failure, operational error , flange leak, corrosion, sabotage etc.	Release of natural gas (NG). If ignition source available (or if ignited at source), then flash fire or jet fire possible. Personnel hazard and property damage. If confinement sufficient then an explosion is possible with overpressure effects and projectiles.	- RECOMMENDATION: The detailed design of the turbine enclosure and associated equipments need to demonstrate that explosive situations do not arise and need to clearly outline the basis of safety used to this end. Generally, the basis of safety includes a combination of well controlled ventilation flows, flammable gas detection with automatic response and explosion relief. - Control of ignition sources as per Australian Standard Hazardous Zone requirements or equivalent. - Preventative maintenance and testing procedures and schedules to be developed. Training of operators and maintenance workers. Permit to Work and operational procedures, including communication requirements and controlled access processes. Emergency procedures. - System to be put in place to ensure removal of safety critical functions is subject to careful scrutiny. - Signage with emergency numbers displayed at various locations throughout the site. External agencies Police, Ambulance and Fire Brigades
As above	2. Violent mechanical failure of rotating machine (turbine).	Projectile may be ejected with high energy. Personnel hazard if person in the vicinity. If a gas pipe is hit by the projectile or associated equipment / instrumentation then it may fail, causing gas release and fire / explosion if ignition source. Fire risks and injury potential.	- Preventative maintenance of rotating machines and pressure plant. - Condition monitoring. - Use of proven technology in the choice of turbine. - Plant and equipment to be designed to relevant Australian and International Standards. - Automatic trip of gas pipeline through closure of the slam shut trip valve at the entry to the enclosure (activated through machine protection system).

Event	Cause/Comments	Possible Consequences	Prevention/ Protection
SECTION OF PLANT: Storage and Handling of Distillate			
6. Loss of containment of distillate during unloading and storage	1. Loss of containment during unloading from truck to the diesel tanks. 2. Mechanical failure, damage to tank etc. 3. Overfilling of tank.	Loss of containment of distillate from tank (up to 600kL in each tank). Environmental damage if spill is not contained on site. Risk of fire (even though distillate is very difficult to ignite at atmospheric conditions). Personnel hazard and damage to property.	- Spill containment as per AS1940 (including bund to 100% of largest tank volume). - Protection of storages and pipeline from mechanical damage. - Regular inspections and maintenance. - Spill during tanker unloading would be captured in the interceptor pit (capable of capturing 5000L spills at the tanker unloading bay). - Emergency response plan and spill protection as per AS1940. People trained in emergency response. - Emergency services call-out as required. - Fire protection (fire extinguishers, separation distances etc.) as per AS1940. - Valving and piping associated with the storage as per AS1940 Section 7. - Control of ignition sources as per AS1940 requirements. - Overfill protection through level switch and auto shut off of transfer. - Operator present during tanker unloading operations.

Event	Cause/Comments	Possible Consequences	Prevention/ Protection
7. Loss of containment of distillate during fuel forwarding to gas turbine	Mechanical failure. Corrosion. Impact damage to pipe. Flange leaks etc.	Loss of containment of distillate from pipelines. Environmental damage if spill is not contained on site. Risk of fire (even though distillate is very difficult to ignite at atmospheric conditions). Personnel hazard and damage to property.	- Pipeline run inside trench which is drained back into oil separation pit (interceptor pit). - Routine maintenance and inspection. - Exposed pipe can be readily assessed. - Route selection precludes impact exposure. - Design to appropriate codes and standards.
8. Loss of distillate inside gas turbine enclosure	Mechanical failure. Corrosion. Impact damage to pipe. Flange leaks etc.	Loss of containment of distillate from pipelines. Environmental damage if spill is not contained on site. Risk of fire if distillate comes in contact with hot surfaces. Personnel hazard and damage to property.	- Routine maintenance and inspection. - Exposed pipe can be readily assessed. - Design to appropriate codes and standards. - Turbine enclosure is drained back to into oil separation pit (interceptor pit).
9. Unburned distillate inside the gas turbine during start-up	1. Fuel is not fully shut off during shut-down (e.g. due to valve passing).	Non-controlled start-up of gas turbine. Possible explosion within the gas turbine combustion zone. Explosion overpressure contained within combustion zone with limited impact outside the gas turbine enclosure.	- Explosion overpressure relief through inherent design of the gas turbine. - Preventative maintenance programs prevent passing valves.

Event	Cause/Comments	Possible Consequences	Prevention/ Protection
SECTION OF PLANT: Storage and Handling of Lube Oil			
10. Loss of lube oil inside gas turbine enclosure	Mechanical failure. Corrosion. Impact damage to pipe. Flange leaks etc. Spillage during top ups.	Loss of containment of lube oil from pipelines or reservoir (16kL containment integral to each gas turbine). Environmental damage if spill is not contained on site. Risk of fire if lube oil comes in contact with hot surfaces. Personnel hazard and damage to property.	- Routine maintenance and inspection. - Exposed pipe can be readily assessed. - Design to appropriate codes and standards. - Gas Turbine enclosure is drained back to into oil separation pit (interceptor pit).
SECTION OF PLANT: Water Treatment Plant			
11. Loss of containment of corrosive liquids.	1. Mechanical failure, damage to storage vessel (IBCs). 2. Loss of containment during delivery. 3. Loss of containment during transfer from storage to water treatment. 4. Human error.	Loss of containment of corrosive liquid to ground (max 1000L in each container) (33% hydrochloric acid, 50% sodium hydroxide, anti-scalant, citric acid). Possible danger of exposure to people in the vicinity. Environmental hazard if not contained on site.	- IBC storage area will be bunded as per AS3870 requirements (110% of volume of storage tank). If spill into bund the material will be neutralised and cleaned up in accordance with company procedures. - Material Safety Data Sheets available on site. Emergency procedures. - Water treatment will be located adjacent to the corrosives storage area, minimising risk of loss of containment. - Routine inspection. Preventative maintenance of plant and equipment. Operation of plant will be done by competent and trained personnel. - Operator attendance during transfer operations of IBCs into storage area. - Emergency shower and eye wash station at storage area. - Personal Protective Equipment (PPE) requirements as per MSDS specifications.

Event	Cause/Comments	Possible Consequences	Prevention/ Protection
12. Violent reaction between incompatible materials.	1. Incompatible materials contact due to operational error (acid into caustic or caustic into acid).	Violent exothermic reaction. Possible damage to tank fittings leading to loss of containment. Personal injury hazard.	- Clear labelling on containers and pipes. - Segregation of incompatible materials.
13. Loss of containment of water treatment plant effluent.	1. Mechanical failure, damage, corrosion of piping, valves or storage, operator error, overfill of storage.	Environmental hazard if not contained on site.	- Neutralised effluent is discharged into evaporation pond which is sealed to prevent ground water contamination. - Loss of containment at external (unbunded) areas would be captured and drained to evaporation pond. - Routine inspection. Preventative maintenance of plant and equipment. - Emergency response plan.
Power Generation			
14. Fire / explosion at transformers	1. Faulty connection or internal fault in transformer.	Fire in plant switchyard. Material damage. Potential for propagation to bush / grass outside site boundary. Personnel injury potential.	- Isolation of electrical energy sources. - Clearance zone around HV electrical equipment provides separation distance from neighbouring combustible material (grass, bush, etc.). - Bunding ensures oil spill are contained. - Fire remains localised. - Fire protection system available on site to minimise damage from fire. - Monitoring and alarm systems to ensure early warning. - Emergency response plan, mustering point for evacuation. Emergency services contacted as required. Signage for emergency services. - Blast walls at the transformers to control a potential blast from destroying neighbouring equipment or endanger people.

Event	Cause/Comments	Possible Consequences	Prevention/ Protection
SECTION OF PLANT: Whole Site			
15. Flooding results in process upsets and damage to plant and equipment.	1. Uncontrolled flooding of site	Potential for damage to process / storage facilities resulting in release of hazardous material (particularly natural gas and corrosive liquids and oils)	- Site elevation and surface run-off design to ensure potential for flooding is minimised. Appropriate level of flood study will be integrated into the design.
16. Land subsidence, earthquake or mining activity results in plant damage.	1. Land subsiding in area creates failure of pipelines resulting in potential for rupture or massive leak.	Release of natural gas. If ignition, then possibility of flash or jet fire. Injury and property damage.	- No mining activity in the immediate site area. - Geotechnical study will be performed and the outcomes of this study will be integrated into the design of the plant. - Seismic review will be performed and the requirements will be incorporated into the design.
17. Aircraft crash results in process upsets, potential damage to process / piping / storage facilities resulting in hazardous releases.	1. Aircraft crash	Potential damage to process / storage facilities resulting in hazardous releases, fire / explosion. Relatively small quantities of gas held within the Power Station and very large site – effect unlikely to go off-site.	- Occupied site relatively small – aircraft crash unlikely. - General aircraft and airline safety measures makes airplane crash unlikely. General train transport safety measures makes train derailment relatively unlikely. - Energy generated through aircraft, truck and train crash is dissipated through design. - Pipe buried at a minimum depth as per AS2885 requirements. - Pipe thickness makes deformation more likely than rupture. - High tensile strength of material of construction. - Automatic shut-off valves at each end of the pipeline minimises amount of gas released if gas pipe is damaged. - Site is remote from residents. - Communication with CASA is undertaken within the IES.

Event	Cause/Comments	Possible Consequences	Prevention/ Protection
18. Damage to plant through terrorism / vandalism / unlawful entry to site / sabotage.	1. Malicious damage.	Massive release of natural gas. If ignition, then possibility of flash or jet fire. Release of distillate. Possible fire.	- Fenced site with access control and security systems. - Security management plan to be put in place. - Standard checks of employees prior to employment.
19. Bush / grass fire	1. Bush / grass fire outside site boundaries affects site. 2. Fire / gas release on site propagates to outside site boundary.	Possible threat to nearby structures, dwellings etc. and risk to people in the vicinity. Possible damage to plant and equipment.	- Bush /grass fire asset protection zone as agreed with rural fire services. - Emergency response plan and communication with rural fire brigades. - Work management processes includes care to take during times of bush fire risk.
20. Storm damage	1. High winds or neighbouring structures or trees affecting the site. 2. Projectile from site equipment / structures causes off-site damage. 3. Lightning	Damage to plant and equipment. Release of hazardous materials (corrosives, flammable gases, oils). Hazard to neighbouring areas, people etc.	- Engineering design standards to cope with winds, storms and lightning strikes. - Preventative inspection and maintenance of site.
21. Incident during maintenance and repair work	1. Faulty equipment / error of operation.	Fire, personnel injury. Potential propagation of fire to nearby structures. Plant damage.	- Trained staff. - Equipment used are checked and maintained. - Fire extinguishers available. - Buildings designed to Building Code requirements. - Dedicated hazardous material storage. - Gas cylinders (oxyacetylene) stored in accordance with standards. - Work control processes used.

Event	Cause/Comments	Possible Consequences	Prevention/ Protection
SECTION OF PLANT: Natural Gas Pipeline General			
22. Flooding results in damage to pipeline	1. Uncontrolled flooding at drainage lines, creek crossings or depressed areas etc	Potential damage to pipeline. If damage then possibility of release of natural gas. If ignition, then risk of flash or jet fire. Injury and property damage.	- Geotechnical study to be integrated into the design of the pipeline. - Routine inspection of pipeline.
23. Land subsidence, earthquake or mining activity results in pipeline damage.	1. Land subsiding in area creates failure of pipeline resulting in potential for rupture or massive leak.	Potential damage to pipeline. If damage then possibility of release of natural gas. If ignition, then risk of flash or jet fire. Injury and property damage.	- No mining activity in the immediate site area. - Geotechnical study will be performed and the outcomes of this study will be integrated into the design of the pipeline. - Seismic review will be performed and the requirements will be incorporated into the design.
24. Aircraft crash, train derailment or truck crash results in damage to pipeline	1. Aircraft crash	Potential damage to pipeline. If damage then possibility of release of natural gas. If ignition, then risk of flash or jet fire. Injury and property damage.	- General aircraft and airline safety measures makes airplane crash unlikely. Also: - Energy dissipated through design. - Pipe buried at a minimum depth as per AS2885 requirements. - Pipe thickness makes deformation more likely than rupture. - High tensile strength of material of construction.
25. Damage to pipe through terrorism / vandalism / unlawful entry to site / sabotage.	1. Malicious damage.	Potential damage to pipeline. If damage then possibility of release of natural gas. If ignition, then risk of flash or jet fire. Injury and property damage.	- Buried pipe for the most part. - Where above ground, fenced site with access control. - Standard checks of employees prior to employment.

Event	Cause/Comments	Possible Consequences	Prevention/ Protection
26. Bush / grass fire affects the above ground pipeline	1 Bush fire	Possible threat to nearby structures, dwellings etc. and risk to people in the vicinity. Possible damage to plant and equipment.	- Clearance zone at off-take compound with control of vegetation. - Pipeline material likely to withstand a passing fire.
TRANSPORT RISKS			
27. Transport of potentially hazardous material to and from the site (distillate, oils, corrosives)	1. Transport accident causes release to the environment	Release of hazardous material onto the roadways and into the environment causing pollution. If ignition source then possibility of fire (note that distillate and oils are not easily ignited).	- Relatively small number of transport movements (less than 30 potentially hazardous substances deliveries per year). - Distillate transported to site in using tankers designed to relevant standards. - Use of licensed service providers. - Qualified drivers. - Access roads to site to be of adequate construction for the use and to be maintained / repaired. - General transport risks of such material are handled by transport company's safety requirements. Clean up and incident management as per transport company procedure.

5 POTENTIAL HAZARDOUS INCIDENTS AND THEIR CONTROL

Safety management systems allow the risk from potentially hazardous installations to be minimised by a combination of hardware and software factors. It is essential to ensure that hardware systems and software procedures used are reliable and of the highest standard in order to assure safe operation of the facility.

Safety features of particular interest to the present project are detailed below.

5.1 HARDWARE SAFEGUARDS, GENERAL

Hardware safeguards include such factors as the layout and design of the plant and equipment, and their compliance with the relevant codes, technical standards, and industry best practice.

All systems handling dangerous goods will need to comply with the following Acts, Regulations and Codes in their latest edition. Below are listed some of the most relevant:

- NSW Occupational Health and Safety Act and its associated legislation including but not limited to the Dangerous Goods Regulations, Construction Safety Regulations, and the Factories Shops and Industries Regulations.
- NOHSC:1015(2001) - National Occupational Health & Safety Commission (NOHSC): Storage and Handling of Workplace Dangerous Goods.
- AS 4041 - 1992 SAA Pressure Piping Code (was CB18).
- AS 1074 - Steel Tubes & Tubulars.
- AS 1836 - Welded Steel Tubes for Pressure Purposes.
- AS 1210 - Unfired Pressure Vessel Code.
- AS 2919, AS 3765.1 or AS 3765.2 - Protective clothing.
- AS3600 - Concrete Structures (for foundation and plinth).
- AS 1692 - Tanks for flammable and combustible liquids.
- API 620 - Design and construction of large welded low-pressure storage tanks.
- API 650 - Welded steel tanks for oil storage.
- AS1345 - Identification of the Contents of Pipes, Conduits and Ducts.
- ANSI Z 358.1 – For safety shower and eyewash facilities.
- AS 3780 – Storage and Handling of Corrosives.

Pipe fittings, supports, and all other ancillary items will also need to comply with appropriate Australian Standards whether referenced above or not.

5.2 HARDWARE SAFEGUARDS, SPECIFIC

5.2.1 Leak of Natural Gas from the Supply Pipeline

Australian Standard AS2885 (Ref 3) sets the minimum standard for high-pressure pipelines in Australia. This code gives detailed requirements for the design, construction and operation of gas and liquid petroleum pipelines. It has gained wide acceptance in the Australian pipeline industry. AS2885 also sets the classification of locations which guide the designer in the assessment of potential risks to the integrity of the pipeline, the public, operating and maintenance personnel as well as property and the environment.

AS2885 accommodates changes in population density by its location classification scheme concept. The classification scheme allows broad division of the pipeline design requirements according to whether the pipeline is to be installed in rural, semi-rural, suburban or urban areas. For each of these classifications the minimum design requirements in terms of wall thickness and depth of cover are specified. The pipeline will run in areas classified as *Class R1 - Broadly Rural* for most part of the length of the run. Some areas are or are expected in the near future to be classified as *R2 – Rural Residential.*

Allowance is made in AS2885 for the improvement in safety performance possible through the use of thick walled pipe with a low design factor. AS2885 also mandates that the integrity of the pipeline be maintained throughout the pipeline operating life.

The proposed safeguards for the lateral pipeline are detailed below. The safeguards have been grouped together under the potential hazardous events associated with the pipeline (as defined in the Hazard Identification Word Diagram in Table 9 above). These incidents have been collated by a group of six European gas transmission companies, based on pipeline incidents relevant to pipeline design and operation in Europe (Ref 6). The data was collated covers a length-time of more than 970,000 km-yrs. Experience within Australia (Agility, AGL etc.) indicates that the learning from these incidents can be directly translated to the Australian conditions.

- External interference is historically by far the main cause of loss of gas and accounts for about 40% of all incidents leading to a release of gas.

  This potential is minimised in the present development through the fact that AS2885 requires the pipeline to be buried to 750mm (or 450mm in rock).

  Further, signage will be provided along the pipe route, including Dial Before You Dig information.

The pipeline presents a certain resistance to penetration through use of appropriate pipe thickness (5.0 to 6.4 mm) and adequate design factor as per AS2885.

In the very unlikely event of a damage to the pipeline which causes a major leak, a valve would be activated at the Central West Pipeline off-take end (preventing uncontrolled flow from this pipelines). If the leak is substantial, the activation would be automatic. If the automatic trip is not activated then shut down would be manual by closing the remote operated isolation valve.

Note also that natural gas disperses readily upwards, reducing chances of ignition. Explosion is not credible in an unconfined situation.

Valve stations are potentially more at risk of a loss of containment due to the presence of small bore attached piping, which is required for pressure tappings. These small-bore pipes are historically known to be more vulnerable to failure.

The major mitigating features at valve stations are firstly the fact that the valve site is conspicuous and therefore reduces significantly the accidental mechanical interference for which a buried pipe is vulnerable. Secondly, the instrumentation off-take line will most likely be installed with a restriction orifice, which would severely restrict the potential outflow caused by damage to the instrumentation. Thirdly, the layout and siting of the valve stations will be subjected to a rigorous Hazard and Operability Study (HAZOP) which will result in improvements to the design to limit their hazard potential.

- *Construction defect / material failure:* This is a known cause of failure of pipelines and accounts for approximately 15% of all incidents. The Australian Pipelines Code (AS2885) will be adopted as a minimum requirement for the design and construction of the pipelines. The pipelines will be constructed of seamless piping of 250 mm diameter (NB) and will be 100% radiographed (including all welds).

  The thickness of the pipe-wall, the relatively low operating pressure and the material grade used re factors that makes this pipeline unlikely to be susceptible to unzipping (Ref 3). Further, inherent design safeguards will be provided by ensuring that the piping is manufactured from high tensile steel of known quality, and subject to quality control inspections to ensure high standard.

  Recommendation 2: Any issues relating to temperature cycling to be taken into account during detailed design in order to avoid stress corrosion cracking.

- *Corrosion:* Corrosion accounts for approximately 15% of all historical incidents. The result of the corrosion is mainly pinholes and cracks.

The gas supply pipelines will be coated with polyethylene (or other) coating. A corrosion protection team will survey the pipeline each year to identify any areas where cathodic protection has become ineffective. Potential corrosion leaks will be detected by visual inspection and protected against by cathodic protection systems. Note that internal corrosion virtually absent with clean hydrocarbon.

In the unlikely event of a corrosion leak, it can be detected through the fact that the vegetation is browning off around ground leak (lack of oxygen) and that a small hole will be sonic – possible detection through high pitched sound.

- *Hot tap by error*: Hot-tapping or hot tapping by error (i.e. hot-tapping the wrong pipeline) is possible and has occurred in the past in the world (approximately 15% of all incidents). This possibility is prevented through the fact that hot tapping is a highly specialised field in Australia and only very few, highly trained, groups can perform this task.

- *Ground movement.* Earthquakes account for about 5% of all historical incidents could potentially cause a failure of a pipeline due to the high forces involved. Earthquakes are not particularly common in this area. This scenario is further discussed in Section 5.2.9 below.

- *Other / unknown causes.* Rare or unknown causes form about 10% of all historical incidents. They are mainly of the pinhole crack category. The following potential incidents have been canvassed for the present development:

  - *Valve gland nut leak or flange leak or maintenance failure at valves and scraper stations.* The pipeline is designed with the minimum number of flanges and welded connections are used wherever possible. Periodic surveillance will be carried out of the pipe and valve points. All valves will be exercised periodically. There are no valves in public areas. Icing up at leak point improves detection.

  - *Nearby explosion.* The potential for a domino incident due to an incident at neighbouring natural gas pipeline was canvassed. The preventative features for this type of incident include internal risk management procedures / systems in use by the natural gas pipeline owner(s) and operators; the pipelines integrity plans (incl. systems in use to monitor integrity of pipeline and coating inspection); their thickness and grade; and the 24 hour monitoring of natural gas and ethane pipelines. Further, natural gas disperses readily upwards, minimising chances of ignition and making explosion not credible in unconfined situation; and the fact that all pipelines will be buried at a depth of at least 750mm (450mm in rock).

  - *Terrorism / vandalism.* The lateral pipeline will be subject to regular and periodic surveillance. Further, the pipeline is buried and no valve points at public areas. Valve systems are surrounded by security fencing.

- *Operational error causes pressure excursion leading to failure of the pipeline*. The pipeline is to be hydrotested at a minimum of 1.4 times the MAOP (maximum allowable operating pressure) and can operate against closed head (i.e. the main isolating valve at the entrance to the power station may be closed). There is 24hour monitoring of the lateral gas pipeline from the remote monitoring centre.

Recommendation 3: High and low pressures of the natural gas supply to be associated with an automatic trip / emergency isolation of gas flow.

5.2.2 Gas Receiving Station and Gas Pipes Within the Peaking Power Plant Site

A. Pipeline / Vessel Leaks

The failure modes at the power station associated with transport and use of natural gas are derived from historical failures of similar equipment and are described in the following sections.

- **Piping Failures:** Pressure piping may fail as a result of corrosion, erosion, mechanical impact damage, pressure surge ("water hammer") or operation outside design limitations of pressure and temperature. Pressure surge or significant deviations of pressure or temperature may cause a flanged joint to be overstressed, resulting in a small leak. Larger holes through to complete line fracture may conceivably result from mechanical impact or pressure surge.

- **Pressure Vessel Failures:** Storage and processing equipment in pressurised gas service will be operating at pressures of between 0.2 – 10.2 MPa (normal operating pressure at the turbines is 2.5 MPa). Vessels, such as the filter, may suffer from failure due to corrosion, erosion or mechanical impact. Major incidents involving the vessels include catastrophic failure and smaller leaks.

Corrosion and erosion caused failures usually result in small leaks which are detected early and corrected. Leak duration may be of the order of ten minutes for such events. Further, pressure surge or significant deviations of pressure or temperature may cause a flanged joint to be overstressed, resulting in a small leak.

Larger holes through to complete nozzle / pipe fracture may conceivably result from mechanical impact or pressure surge. These events are likely to be detected more rapidly, resulting in quicker isolation of the leak.

The potential to release natural gas will be minimised by:

- Use of fully welded pipework wherever possible;

- Minimizing pipe-runs (pipe lengths);

- Pipes of robust design (designed to comply with the requirements of Australian Standard AS4041 - Pressure piping);
- Overpressure protection provided by three methods:
    - o Rapid control valve closure under alarm conditions;
    - o Emergency isolation valve installed at the inlet to each control valve run; and
    - o Pressure relief valve.
- An actuated isolation valve will installed at the inlet to the facility; and
- Control and communications equipment to provide remote monitoring and central control of system by operating staff.

Recommendation 4: The use of leak detection in high risk natural gas piping to be investigated.

A fire protection system will be installed in the facility. The fire control system will be developed to meet all requirements of Building Code of Australia and NSW Fire Brigade. Elements of the system will include:

- Provision of water supply to the boundary of the site;
- Provision of permanent water storage, to meet the supply volume objectives;
- Provision of booster pumps – duty and standby, if required, to meet the specified pressure objectives;
- Provision of fire hydrants and hose reels if required and as nominated by above requirements.

B. Pipe / Vessel Internal Explosion

An explosion within piping or inside a vessel is theoretically possible during start-up, shut-down and maintenance operations. Due to the limited quantities of gas involved the effects of the explosion would however not be expected to pose a threat to nearby businesses or to any residential areas in the vicinity. Therefore, the probability of an explosion due to ignition of an explosive mixture within piping and vessels is considered negligible and will not be analysed further in this PHA. This conclusion is based on the following observations:

- All piping will normally operate at a positive pressure, thereby preventing ingress of air in the event of a pipe or other equipment failure;
- Prevention of ingress of air will be considered throughout the design and operation of the facility (for example in the preparation of start-up, shut-down and maintenance procedures).

5.2.3 Gas Turbine Enclosure

A. Introduction and legislative framework

Despite the best efforts during design and management of the peaking power plant, natural gas turbines are not beyond mishap. Assuming that the gas turbines will be enclosed in acoustic chambers to reduce noise and permit turbine cooling by ventilation, a degree of confinement would be introduced. Ignition of fuels released into the turbine enclosure can cause fire and, because of the confinement, even explosions. Note that the explosive event is not credible in an unconfined scenario, where the gas turbines are not enclosed inside acoustic enclosure.

Gas Turbines typically rely on complex fuel supply pipes with multiple high-pressure joints to deliver the primary fuel, natural gas. *The large number of flanges and joints, combined with high pressures, presents an explosion hazard within the housing in the event of fuel leaks,* noted Mr Hunt, a chemical engineer at Eutech who led the risk assessment study[3] undertaken as a result of an explosion in a gas turbine acoustic housing at Teeside Power Station, UK in 1996 (Ref 15).

Since the Teeside explosion, guidelines and codes of practice have been developed, and are now in use, notably the European ATEX Directive (Ref 7) and the UK Health and Safety Executive's Guidance Note PM84: *Control of safety risks at gas turbines used for power generation* (Ref 8), both which are gaining wide acceptance in Australia.

The HSE Guidance Note PM84 covers the design and operation of gas turbine installations, making specific and practical recommendations with regard to operational functions such as alarm and engine trip conditions, and the maximum acceptable volume of clouds of explosive mixtures of gas and air.

Although it is not a specific legislative requirement to comply with these guidelines, they provide plant operators and legislators with a framework for assessing whether operation of a plant is satisfactory from a general Health and Safety standpoint (Ref 9). It is therefore appropriate for installations to adhere to the guidelines as far as is reasonably practicable, or other guidance / regulation of equivalent safety.

B. Basis of safety requirements

Basis of safety of gas turbine operation is generally achieved through a combination of:

- Elimination or control of sources of ignition as far as reasonably possible, following legislative requirements and Australian Standard requirement (e.g.

[3] At 12:25 a.m. on July 17, 1996, a fire and explosion occurred in the unit 106 turbine enclosure at the Teeside Power Station, attributed to a naphtha leak, in a plant that has natural gas, propane and naphtha fuels.

for control of sources of ignition in potentially explosive atmosphere). Note that it may not be technically possible to reduce the temperature of all hot surfaces to eliminate the potential for an ignition of natural gas released into the gas turbine enclosure; and

- Limitation of the volume of the explosive atmosphere by the application of all or a combination of:
    - o **Dilution ventilation.** Note that dilution ventilation reduces the size of any flammable cloud to below that which would result in a hazardous explosion if ignited. In order that the dilution ventilation ensures a negligible risk of an explosive atmosphere at all times, the ventilation system should have additional safety features such as e.g.: a 100% standby fan; an uninterruptible power supply to the ventilation fans; interlocks so that the gas turbine cannot start without sufficient ventilation; proven automatic isolation of fuel supply if ventilation fails;
    - o **Flammable gas detection** combined with automatic shut-down of turbine and alarms;
    - o **Explosion relief**,
    - o **Explosion suppression**.

Preventative maintenance procedures and schedules will be developed for the proposed site, covering all critical safety functions such as leak detectors, ventilation fans, alarm systems etc. as appropriate.

Operators and maintenance workers at the plant will be trained to recognise the critical nature of critical safety functions (such as a leak detector, ventilation fan etc.).

Permit to Work systems will be put in place for work inside enclosed areas (including gas turbine enclosure).

Emergency procedures for personnel will be developed and drills will be carried out throughout the life of the operating plant to ensure personnel are trained up in the procedures required during an emergency.

A fire protection system will be installed in the facility, including inside the turbine enclosures, and around the generator transformers.

Recommendation 5: The detailed design of the gas turbine enclosure and associated equipment should clearly outline the basis of safety used to ensure that explosive situations do not arise (/the risk is rendered negligible). Reference should be made to European ATEX Directive (Ref 7) and the UK HSE PM84 (Ref 8) or other guidance / regulation of equivalent safety.

Recommendation 6: Fire protection inside the gas turbine enclosure to be determined, including use of explosion panels and use of fire retardant material.

Recommendation 7: A system should be but in place to ensure that any removal of critical safety function (e.g. for repair or exchange) is subject to careful scrutiny by plant management (decisions on whether to shut down plan or a gas turbine if a critical safety function is removed need to be canvassed).

C. Assumptions Used for this PHA

It is assumed that the basis of safety design for the turbine will include:

- A highly reliable ventilation system, designed to remove even small leaks before lower flammable limits are reached;
- A number of gas detectors linked to automatic shut off of the gas supply;
- Separation distance between each gas turbine of at least 20 metres;
- Explosion panel(s) which will blow out in an explosion, thereby reducing the risk of a confined explosion.

5.2.4 Violent mechanical failure of rotating machine creates projectile(s)

In case of a mechanical failure of the turbine, projectile may be ejected with high energy, creating a personnel hazard if in the vicinity. Further, if a gas pipe is hit by the projectile or associated equipment / instrumentation then it may fail, causing gas release and fire / explosion if ignition source present.

All rotating machines will be subject to regular and periodic preventative maintenance, including vibration monitoring. If any issues are identified, the machine would be shut down and repaired (as required).

Note that buried pipelines are not at risk from such projectiles.

5.2.5 Storage and Handling of Combustible and Flammable Liquids (combustible distillate and oils)

The following combustible liquids will be stored and handled on site:

- Distillate (two 600,000 L tanks) used as back-up fuel of the gas turbines;
- Combustible oils (1,000 litres in IBCs as well as in a 16,000 L containment integral to each gas turbine) will be used in the pumps and turbines).

All the requirements for risk management of these flammable and combustible materials will be as per AS1940 (*Storage and handling of flammable and combustible liquids,* Ref 10), including:

- Bunding requirements as per AS1940, i.e. 100% of the largest tank, with bunding design and construction as per Section 5.9.3 in AS1940.
- Any valve controlling the drainage from the bunds is to be located outside the bund.

- Overflow line from all tanks is / will be open to atmosphere and directed to bund.

- Run-off from external (unbunded) areas would be captured in the first flush stormwater system which is designed to retain the first flush runoff from these areas.

- Fire protection (fire extinguishers, foam, hose reel requirements, separation distances etc) as per AS1940.

- Valving and piping associated with the storage as per AS1940 Section 7.

- Control of ignition sources as per AS1940 Section 9.7.6.

- Communication systems.

- Visual inspection of tanks, lines and equipment. Preventative maintenance program.

- Overfill protection through level switch and auto shut off of transfer.

- Overflow line and vent line on top of diesel tank to minimise risk of ovepressurisation of tank.

- Foundations, supports, bearing etc. designed and constructed in accordance with AS1940. Tanks and associated equipment are protected from external impact by the bund wall (concrete) which is designed to comply with criteria in AS1940.

- Spill during tanker unloading, in case of leaks of the pipeline during fuel forwarding to the turbines or inside the turbine enclosure would be captured in the interceptor pit (capable of capturing 5000L spills).

- Disposal of spills in accordance with established procedures.

Provided that the requirements from AS1940 and the above recommendations are adhered to, the risk of an incident involving the combustible material stored and handled is small.

5.2.6 Water Treatment

The main risk associated with the water treatment plant is related to the storage and handling of corrosive liquids[4] stored in 1,000L IBCs. Loss of containment of corrosive liquids to ground could cause a possible danger of exposure to people in the vicinity and an environmental hazard if not contained on site. This risk will be minimised by a combination of:

[4] 33% hydrochloric acid, 50% sodium hydroxide, anti-scalant, citric acid

- Preventative measures: minimising pipe lengths by placing the storage areas adjacent to their points of use, preventative maintenance and periodic inspections of plant;

- Protective measures: bunding of storages to AS3870 requirements (110% of volume of storage tank, ensuring the operator is in attendance during transfer operations of IBCs into storage area, provision of emergency shower and eye wash station at storage area, and ensuring Personal Protective Equipment (PPE) requirements are adhered to as per MSDS specifications).

- Emergency measures: if spill into bund the material will be neutralised and cleaned up in accordance with company procedures.

Loss of containment of water treatment plant effluent may cause an environmental hazard if not contained on-site. It is proposed that neutralised effluent is discharged into an evaporation pond which is sealed to prevent ground water contamination. Loss of containment at external (unbunded) areas would be captured and drained to evaporation pond. Routine inspection and preventative maintenance of plant and equipment will work to minimise the risk of an uncontrolled loss of containment.

5.2.7 Power

Fire or explosion at transformers may be caused by a faulty connection or internal fault in the transformer. Such a transformer incident may cause fire in the plant switchyard, material damage, potential for propagation to bush or grass outside site boundary and personnel injury.

- Preventative measures include monitoring and alarm systems to ensure early warning.

- Protective measures include automatic isolation of electrical energy sources; provision of clearance zone around high voltage (HV) electrical equipment for separation distance from neighbouring combustible material (grass, bush, etc.); and bunding to contain oil spill.

- Emergency measures include blast walls at the transformers to control a potential blast from destroying neighbouring equipment or endanger people; fire protection system to be available on site to minimise damage from fire; and emergency response plan and mustering point for evacuation and emergency services contacted as required.

5.2.8 Whole Site

Flooding: Site elevation and surface run-off design to ensure potential for flooding is minimised. Appropriate level of flood study will be integrated into the site design.

Land subsidence, earthquake or mining activity results in plant damage: No mining activity in the immediate site area; Geotechnical study will be performed and the outcomes of this study will be integrated into the design of the plant; Seismic review will be performed and the requirements will be incorporated into the design. Structures and plant will be designed to withstand earthquake effects using well-established procedures in accordance with relevant Australian or international standards. (Note that geological stability has not been assessed as part of the present PHA).

Aircraft crash on Power Station site: General aircraft and airline safety measures makes airplane crash unlikely. This scenario, while theoretically possible, does not appear credible for the present development.

Bush / grass fire: A bush or grass fire outside site boundaries may, if not managed, affect the site, and a fire on the site may cause risk outside site boundaries, possible threat to nearby structures, dwellings etc. and risk to people in the vicinity. A bush /grass fire asset protection zone will be decided in consultation with rural fire services. Further, emergency response plan and work management processes will include care to take during times of bush fire risk.

Storm damage: The risk of damage to plant and structures from storms will be managed through the design phase (through the use of engineering design standards to cope with winds, storms and lightning strikes), and throughout the operation of the plant (through preventative inspection and maintenance of site).

Incident during maintenance and repair work: Incidents during maintenance and repair work may result in a fire, personnel injury and plant damage. This risk is managed through the use of the use of a robust Safety Management System (see Recommendation 1), including trained staff; adequate work processes; adequately checked and maintained equipment; buildings designed to Building Code requirements (including use of fire extinguishers); the use of a dedicated hazardous material storage; gas cylinders (oxyacetylene) stored in accordance with standards, etc.

5.2.9 Whole Pipeline Overview

Flooding: A geotechnical study will be integrated into the design of the pipeline. Further, the pipeline route will be subject to routine inspections and, if required, to maintenance and repair of cover as required (e.g. if erosion is identified).

Land subsidence, earthquake or mining activity results in pipeline damage: No mining activity in the immediate site area. Geotechnical study will be performed and the outcomes of this study will be integrated into the design of the pipeline. Seismic review will be performed and the requirements will be incorporated into the design.

Aircraft, train or truck crash on Lateral Gas Supply Pipeline: The lateral gas supply pipeline, being buried, is unlikely to be damaged in case of an aircraft, train or truck crash. There will be no above ground facilities adjacent to train or road crossings. The preventative and protective features of this site makes the risk of such crashes negligible. This scenario, while theoretically possible, does not appear credible for the present development.

Damage to pipe through terrorism / vandalism / unlawful entry to site / sabotage: The pipe will be buried for the most part. Further, where above ground structures (i.e. at the off-take point at the Central West Pipeline), the site will be fenced with access control.

Bush / grass fire: A bush fire is highly unlikely to affect a buried gas pipeline. The bush fires that have burned over for example the main Moomba to Wilton natural gas pipeline have not damaged the gas pipeline or any of its above ground facilities. A bush /grass fire asset protection zone will be decided in consultation with rural fire services. Clearance zone will be provided at the off-take compound with control of vegetation. The risk of damage to the pipeline from a bush fire or grass fire to the pipeline or above ground facilities is very low if not negligible.

The potential for a gas release is extremely small. The proposed development does not increase in any significant way the risk of a bush fire in the forested areas through which the pipeline travels. As a consequence, local fire brigades will not have any significant demand on their resources.

5.2.10 Road Transport Risks

Once the site has been built and put into operation, the frequency of road transportation to the site of dangerous goods and potentially hazardous material will be relatively low.

It is expected that about thirty to forty (30 - 40) deliveries per year will be sufficient for the operation of the site, mainly consisting of the distillate deliveries and the occasional delivery of corrosive liquids to the Water Treatment Plant, oil top up for rotating machinery and possibly the transport of some other material used for maintenance or cleaning.

Road transportation would use Condobolin Road and then turn left into the site. The entrance road to the site is to be of adequate construction for the use and to be maintained and repaired as required.

General transport risks of these materials are handled by transport companies' internal safety requirements. Clean up and incident management will be as per the transport company's procedures.

The quantities and transport movement of potentially hazardous materials for this site are well below those listed in the *Transportation Screening Threshold* table (Table 2 in the guidelines on applying SEPP 33 (Ref 11)) as defined by the Department of Planning.

The review of road transport risks concludes that the risk associated with the transport of dangerous goods and potentially hazardous material to the site is very low.

5.3 SOFTWARE SAFEGUARDS

IPRA have a commitment to Occupational Health and Safety (OH&S) and have numerous policies and procedures to achieve a safe workplace. Written safety procedures will be established. An established incident reporting and response mechanism will be established, providing 24 hour coverage. The plant itself will develop procedures specific to the plant and its environment and they will be incorporated into the safety system.

The plant will need to comply with all codes and statutory requirements with respect to work conditions. In addition, special precautions are observed as required by the site conditions, in particular, standards and requirement on the handling of pressurised, flammable gases. All personnel required to work with these substances are trained in their safe use and handling, and are provided with all the relevant safety equipment.

Emergency procedures will be developed. All staff will need to be trained in these procedures and they will be incorporated in the plant's quality system. The emergency procedures will include responses to emergency evacuation, injury, major asset damage or failure, critical power failure, spillages, major fire, and threats.

The site will have a manager with overall responsibility and who is supported by experienced personnel trained in the operation and support of the plant.

A Permit to Work system (including Hot Work Permit) and Control of Modification systems will be in use on site to control work on existing plant and to control existing plant and structure from substandard and potentially hazardous modifications.

Injury and incident management will be proceduralised and people will be trained in how to report incidents.

Protective Systems will be tested to ensure they are in a good state of repair and function reliably when required to do so. This will include scheduled testing of trips, alarms, gas detectors, relief devices and fire protection systems.

All persons on the premises will be provided with appropriate personal protective equipment suitable for use with the specific corrosive substances.

A first aid station will be provided comprising an appropriate first aid kit and first aid instructions, i.e. MSDSs, for all substances kept or handled on the premises. At least one person on the premises is trained in first aid; and a list of persons trained in, and designated as being responsible for the administering of, first aid is shown on the noticeboards on the premises. Further, the relevant and up-to-date MSDS will be kept in safe location next to the storage tanks.

6 CONSEQUENCE ANALYSIS

6.1 EVALUATION TECHNIQUES

As none of the material used, produced or handled are toxic, the evaluation of consequences requires only the determination of fire radiation and explosion overpressure. For both fires and explosions, it is necessary to determine the leak rate and duration for each incident. Radiation effects are then determined using the point source method while overpressure effects are determined using the TNT equivalent model in Ref 12.

The explanation of the nomenclature used in the equations below is listed in Table 12 at the end of this Chapter.

6.1.1 Leak Rates

The rate at which a liquid leaks from a hole can be determined using a standard orifice flow equation:

$$\dot{m} = 0.8A\sqrt{(2\rho deltaP)}$$

For the case where two-phase flow occurs, the calculation technique is much more involved. An acceptable approximation is to divide the liquid flow rate determined in the equation by 3 to allow for two-phase flow.

For gas or vapour flows (as for natural gas), the appropriate equation is:

$$\dot{m} = 0.8AP\sqrt{\frac{M\gamma}{zRT}(\sqrt{\frac{2}{\lambda+1}}^{\frac{\gamma+1}{\gamma-1}}}$$

Note that this applies to the condition known as critical or choked flow, which applies when the internal pressure is more than double the atmospheric pressure (approximately).

6.1.2 Duration

The duration of a leak will depend on the hardware systems available to isolate the source of the leak, the nature of the leak itself and the training, procedures and management of the facility. While in some cases it may be argued that a leak will be isolated within one minute, the same leak under different circumstances may take 10 minutes to isolate.

The approach used in this study for failure scenarios identified is to assume three possible event durations and to assign to each the same probability of occurrence. For this analysis, the three leak durations considered were 1 minute, 5 minutes and 10 minutes for manual responses to leaks.

Where automatic response has been designed into the plant (e.g. in the form of process trips) such response has been taken into account (with the relevant probability of failure of the trip etc.). The trips associated with the site, as relevant for the present PHA are the two trips actuated in case of a major leak at the lateral supply pipeline or within the power station (see Section 5.2.1 above).

Leak from vessels are assumed to last until the inventory of the vessel has been released, up to a maximum duration of one hour.

The mass of flammable gas contained in a cloud which could flash or explode is set at the total amount which would leak out in 3 minutes. This is based on the assumption that a cloud travelling in the direction of the wind will either encounter a source of ignition within this time[5] or would disperse to concentrations below the Lower Flammable Limit (LFL).

6.1.3 Radiation Effects - The Point Source Method

Radiation effects are evaluated using the point source method, which assumes that a fire is a point source of heat, located at the centre of the flame, and radiating a proportion of the heat of combustion. The radiation intensity at any distance is then determined according to the inverse square law, making allowance for the attenuating effect of atmospheric water vapour over significant distances (e.g. 100m or more).

$$I = \frac{Qf\tau}{4\Pi r^2}$$

The rate of heat release, Q, is given by:

$$Q = \dot{m}H_C$$

6.1.4 Explosion Effects - The TNT Model

For explosions, the amount of gas or vapour resulting from the leak is important. For gases this is the total quantity leaking out for the duration of interest.

The equivalent mass of TNT is then determined using the following relationship:

$$m_{TNT} = \frac{\alpha H_C m_V}{4600}$$

The overpressure effect from the vapour cloud is determined using a correlation developed for TNT, which relates the scaled distance (a function of actual

[5] In a relatively moderate wind force of say 4 m/s, the cloud would after 3 minutes have covered a distance of 240 metres.

distance and mass of TNT) to the overpressure. The scaled distance is given by the relationship in equation:

$$\lambda = \frac{r}{(m_{TNT})^{1/3}}$$

6.2 Impact Assessment

The above techniques allow the level of radiation or overpressure resulting from fires and explosions to be determined at any distance from the source. The effect or impact of heat radiation on people is shown in Table 10 while Table 11 shows the effects of explosion overpressure.

Table 10 - Effects of Heat Radiation

Radiant Heat Level (kW/m^2)	Physical Effect (effect depends on exposure duration)
1.2	Received from the sun at noon in summer
2.1	Minimum to cause pain after 1 minute
4.7	Will cause pain in 15-20 seconds and injury after 30 seconds' exposure
12.6	Significant chance of fatality for extended exposure High chance of injury
23	Likely fatality for extended exposure and chance of fatality for instantaneous (short) exposure
35	Significant chance of fatality for people exposed instantaneously

Table 11 – Effect of Explosion Overpressure

Overpressure (kPa)	Physical Effect
3.5	90% glass breakage. No fatality, very low probability of injury
7	Damage to internal partitions & joinery 10% probability of injury, no fatality
14	Houses uninhabitable and badly cracked
21	Reinforced structures distort, storage tanks fail 20% chance of fatality to person in building
35	Houses uninhabitable, rail wagons & plant items overturned. Threshold of eardrum damage, 50% chance of fatality for a person in a building, 15% in the open
70	Complete demolition of houses Threshold of lung damage, 100% chance of fatality for a person in a building or in the open

For the case of pipelines, the hazard must be treated as a linear hazard in the respect that it remains constant along the length of the route, and it only changes if there are special features in the pipeline such as valve stations. For a given location (at a distance **d** away from the fire), the heat radiation could exceed specified levels if **d** is less than, or equal to, the hazard range (or in this case the "effect distance"). Hence, this PHA has determined the hazard range of incident scenarios occurring anywhere along the interaction length of the pipeline.

Table 12 – Nomenclature for Section 6

Label	Explanation
A	Area of hole, m^2
C_p	Average liquid heat capacity, kJ/kg.K
f	Fraction of heat radiated
H_c	Heat of combustion, kJ/kg
H_v	Heat of vaporisation, kJ/kg
I	Radiant heat intensity kW/m^2
M	Molecular weight
m	Mass, kg
m_v	Mass of vapour (in cloud), kg
m_{TNT}	Equivalent mass of TNT, kg
$\dot{m}$	Mass flow rate of leak, kg/s
P	Pressure, Pa
P_1	Upstream absolute pressure, Pa
Q	Heat release rate, kW
R	Universal gas constant, 8.314 J.K/mol
r	Distance from fire/explosion, m
T	Temperature, K
T_1	Storage temperature, K
T_b	Boiling point, K
t	Duration of leak/time, seconds
z	Gas compressibility factor
α	Explosion efficiency factor
γ	Ratio of specific heats (~1.4)
λ	Scaled distance
ρ	Density, kg/m^3
τ	Atmospheric transmissivity

6.3 CONSEQUENCE CALCULATIONS – NATURAL GAS INCIDENT

This initial outflow rates estimated for natural gas releases are shown in Table 13. The results predict that the rate of decrease in outflow rate for a full bore rupture is dramatic with a drop to less than half of the initial flow within seconds and further rapid decay. However, the present PHA has assumed that the initial release rate remains until isolation can be achieved - this is a highly conservative approach.

Table 13 – Release Rates

Release rate [kg/s]	Hole Size					
	Small leak (3mm)	**Flange leak (13 m)**	**Interme-diate leak (25 mm)**	**Major leak (80 mm)**	**Massive leak (100 mm)**	**Full bore (guilo-tine)**
Upstream of the Pressure Regulator						
Instantaneous	0.4 kg/s	3 kg/s	10	104	163 kg/s	1,000 kg/s (first few seconds)
Downstream of the Pressure Regulator						
Instantaneous	0.03 kg/s	0.6 kg/s	2	30	47 kg/s	215 kg/s (first few seconds)

The distance from the source of the fire to the specified heat radiation for jet fire scenarios is listed in Table 14 below.

Table 14 – Heat Radiation from Jet Fires

Hole size	Distance to Heat radiation (metres)		
	$4.7kW/m^2$	**$12.5kW/m^2$**	**$23.5kW/m^2$**
Upstream of the Pressure Regulator			
Small leak (5mm)	7	4	3
Intermediate leak (25 mm)	40	25	15
Massive leak (100 mm)	145	90	65
Full bore (guillotine)	575	350	260
Downstream of the Pressure Regulator			
Small leak (5mm)	4	2	1.5
Intermediate leak (25 mm)	20	12	9
Massive leak (100 mm)	80	50	35

Hole size	Distance to Heat radiation (metres)		
	4.7kW/m^2	12.5kW/m^2	23.5kW/m^2
Full bore (guillotine)	350	215	155

The distance to 100% chance of fatality from a jet fire is shown in Table 15 below.

Table 15 – Distance to 100% Chance of Fatality

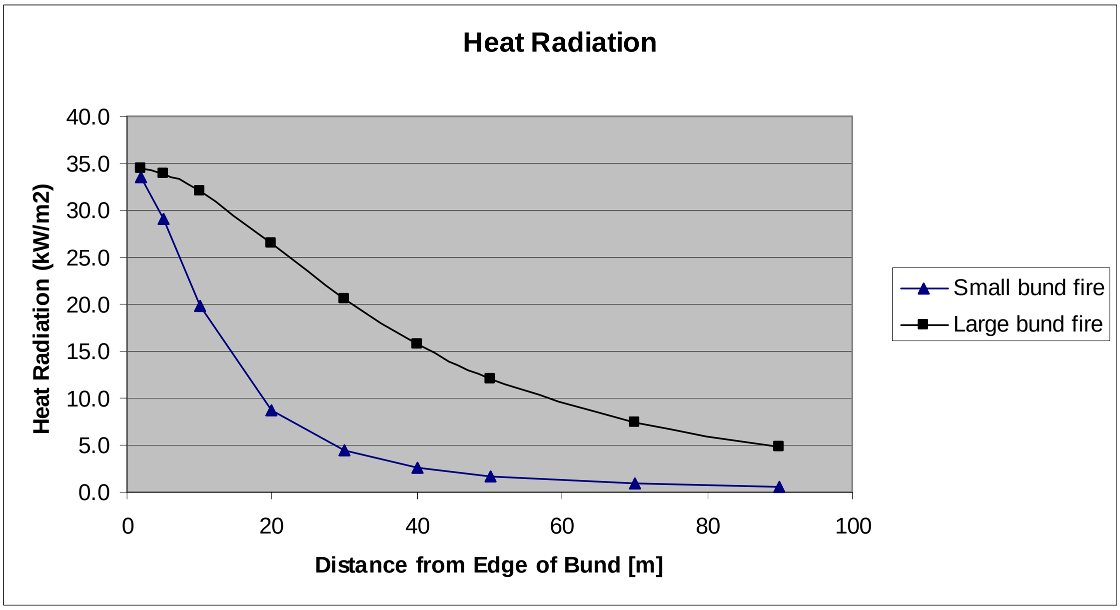
Hole size	Distance to 100% Fatality (metres)		
	Jet Fire	Flash Fire	Vapour Cloud Explosion
Upstream of the Pressure Regulator			
Small leak (5mm)	5	15	15
Intermediate leak (25 mm)	15	40	40
Massive leak (100 mm)	75	75	150
Full bore (guillotine)	150	220	250
Downstream of the Pressure Regulator			
Small leak (5mm)	2	10	10
Intermediate leak (25 mm)	10	25	25
Massive leak (100 mm)	30	60	75
Full bore (guillotine)	60	80	120

6.4 CONSEQUENCE CALCULATIONS – DISTILLATE FIRE

The consequences of a distillate fire, as calculated using the Point Source method, have been presented below (detailed calculation sheet is included in appendix 1). Two scenarios were investigated, namely a "small" and a "large" fire, covering 10% and 100% of the surface of the bund respectively[6].

[6] The bund has not been designed at the time of this PHA. This PHA assumed that the bund would be 35 m x 30 m (1050 m^2).

Figure 4 – Heat Radiation from Distillate Bund Fire



7 FREQUENCY ANALYSIS

7.1 GENERIC EQUIPMENT FAILURES

A summary of all incident scenarios that are incorporated into the PHA are listed in Appendix 4. The frequency of each postulated equipment failure was determined using the data in the table below.

The frequencies used for fixed plant and above ground piping are those that have been in use by Orica Engineering for over 15 years of risk assessments in Australia. These frequencies are based on Orica Engineering's interpretation of published and unpublished (internal ICI and Orica) data.

The frequencies used for all below ground gas piping and for all pipelines installed as per AS2885 (Ref 3) requirements are based on incident statistics between 1988 and 1992, gathered by the European Gas Pipeline Incident Data Group (EIGPIDG), Ref 13. This data source has been chosen based on the extensive statistical significance of the data available (1,470,000 kilometre-years)[7] and because of the similarities between the Australian Standard requirements and the requirements used in the European countries included in the incident statistics (Britain, Belgium, France, Netherlands, and Germany). These statistics provide details of leak rates for small and large holes but do not provide information on rupture frequencies. Rupture frequency data is therefore taken from the British Gas failure data as sourced by the British Gas Corporation Engineering Research Station (Ref 14) over 250,000 km-yrs.

Table 16 - Equipment Failures and Associated Frequencies

Type of Failure	Failure Rate (pmpy)
PIPELINES WITHIN FIXED PLANT (POWER PLANT)	
3 mm hole	9 / m
13 mm hole	3 / m
50 mm hole	0.3 / m
3 mm gasket (13 mm hole equivalent)	5 / joint
Guillotine fracture (full bore):	
< 50 mm	0.6 / m

[7] As a comparison, the available statistics in Australia are based on (only) 160,000 km-yrs. The available statistics from the US Dept of Transportation Office of Pipeline Safety is based on 970,000 km-yrs but the standards used in the US are understood to be further from the Australian standards than those in use in Europe (as included in the EGPIDG).

Type of Failure	Failure Rate (pmpy)
> 50 mm but < 100 mm	0.3 / m
> 100 mm	0.1 / m
VESSELS	
6 mm hole	24
13 mm hole	6
25 mm hole	3
50 mm hole	3
GAS SUPPLY PIPELINES (>100mm NB; 5.9 mm pipe thickness)	
<20 mm hole – steel pipeline	0.074/ m
<80 mm hole – steel pipeline	0.156 / m
Guillotine fracture (full bore) – steel pipeline	0.002 / m

The design of the power station has not been finalised and accurate P&IDs are not available at the time of this PHA. In such cases, conservative assumptions relating to the design need to be made, including the length of pipe, number of flanges required, operating pressures used etc.

Further, the article by Professor Michael Valenti for The American Society of Mechanical Engineers (Ref 15) provides an estimate of the complexity of the pipework and flange-systems inside the acoustic housing of the turbines: *For example, a 250-megawatt turbine's pipework may have more than 200 flanges and 90 flexible joints*.

The following assumptions were made – these assumptions are believed to be conservative.

Table 17 – QRA Assumptions

Feature	**Assumption(s)**
General – Overall Power Plant	
Percent operational	The Peaking Power Plant is expected to be operational for only a fraction of the time (less than 10% of the time). All data used in the present risk assessment are for a plant operating 100% of the time. The quantitative risk results are valid, though highly conservative, for the plant under the expected operating conditions. They are also valid for a plant operating 100% of the time.
Lateral Gas Supply Pipeline	
Length	One 10 kilometres long from the tie-off, through (but not including) the

Feature	Assumption(s)
	gas receiving station
Number of flanges	10 flanges
Pressure	10.2 MPa up to the entrance to the gas conditioning station
Temperature	25°C
Features	Gas receiving station (with emergency isolation valve station, pressure indication, flow indication and transmitter and non return valve) at the Central West Pipeline off-take points.
Design Standard	As per AS2885 requirements
Gas Pipelines Inside Peaking Power Plant Site, including Gas Receiving Station	
Length	10 metres up to the pressure regulator valve, then 280 metres after the pressure regulator, stretching from the gas conditioning area through to each turbine
Number of flanges	5 flanges up to the pressure regulator valve and 90 flanges after
Pressure	10.2 MPa up to the pressure regulator, then 2.5 MPa
Temperature	25°C
Features	Gas receiving area with pressure regulator, by-pass valves, non return valves, pressure indication, flow indication and transmitter
Design Standard	As per AS2885 requirements
Gas Piping to Gas Turbine Inside Enclosure	
Length	10 metres
Number of flanges	200 flanges inside each housing, 90 flexible joints (as flanges)
Pressure	2.5 MPa
Temperature	25°C

7.2 PROBABILITY OF OPERATION OF PLANT

The pipeline will be pressurised approximately 10% of the time. The peaking power plant itself however is expected to operate for about 10% of the time. Conservatively, this risk assessment has assumed that the peaking power plant will operate 100% of the time and that all parts of the plant will be pressurised, capable of releasing gas if damage occurs, 100% of the time.

7.3 FAILURE OF AUTOMATIC PROTECTION

Slam shut isolation valves will be positioned on either end of the supply pipelines. These valves will close automatically in case of a major leak at a pipeline. The following estimates of probabilities have been used as a guide for the purposes of determining the reliability of the automatic protection (Ref 16). While the design of the control system is not finalised, it is assumed that the protective systems will be designed to SIL 1 requirements.

Table 18 - Probability of Human Error

Safety Integrity Level (SIL)	Low Demand Mode of Operation (probability of failure to perform as intended on demand)
4	>=10^{-5} to < 10^{-4}
3	>=10^{-4} to < 10^{-3}
2	>=10^{-3} to < 10^{-2}
1	>=10^{-2} to < 10^{-1}

7.4 HUMAN ERROR

The following estimates of human error have been used as a guide for the purposes of determining human responses (Ref 17):

Table 19 - Probability of Human Error

ACTIVITY	Probability of error
Probability of failing to take correct action in high stress situations with one minute in which to act	0.9-1.0
Error in non-routine operation when other duties required	0.1
Error in routine operation where some care is needed	0.01
Error in routine simple operation	0.001

7.5 PROBABILITY OF FLAMMABLE OUTCOME

The probability of ignition if leak were based on the EGPIDG data (Ref18) as follows:

Table 20 – Ignition Probability

Leak size (mm)	Probability of ignition
<20mm	0.27
20 to 100 mm	0.019
>100 mm	0.235

The probability of a delayed ignition for the fixed plant is taken as 0.9M (in %), with M being the mass (in tonnes) of flammable vapour in the cloud (Ref 19). This equation was used to determine the probability of a flash fire.

The probability of an explosion in open plant is very low for a natural gas leak out in the open and is not considered a credible event for a release of gas outside of the enclosures of the gas turbine. This event is considered as a credible event for a flammable incident inside the gas turbine enclosure (see below).

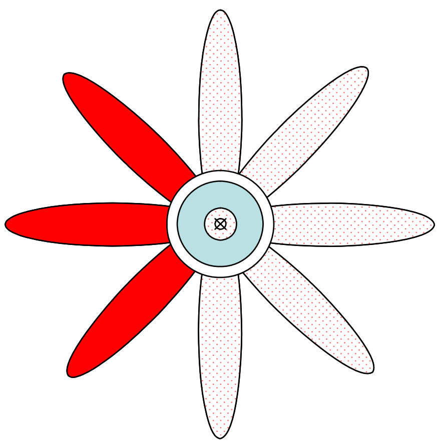
The probability of a jet fire was taken as:

$$P_{\text{jet fire}} = P_{\text{ignition}} - P_{\text{explosion}} - P_{\text{flash fire}}$$

The frequency of outcome of each individual incident scenario is listed in the spreadsheet in Appendix 4.

Jet fires are directional (as opposed to flash fires that are omni directional). While a jet fire can be directed towards any point in the sphere, about one third of all jet fires are assumed to be directed towards a boundary. This is based on the concept depicted in Figure 5 below, with the dark jets being those assumed to be directed towards the boundary and the light being assumed to be directed away from the boundary.

Figure 5 – Jet Fire Distribution



7.6 RELATIONSHIP BETWEEN EXPOSURE AND EFFECT

The relationship between exposure and effect was estimated based on the probit equation for heat radiation. In the case of flash fires, 100% fatality was assumed for anyone engulfed within the flaming cloud, and 0% probability outside it. In the case of a Vapour Cloud Explosion, the relationship between overpressure and probability of fatality defined in the Orica course material in Ref 12 is taken as defining the lethal zone.

8 RISK RESULTS AND COMPARISON WITH RISK CRITERIA

8.1 RISK CALCULATION – POWER STATION

8.1.1 Risk of a Confined Explosion Inside the Turbine Enclosure

The likelihood of a confined explosion inside the gas turbine enclosure was estimated taking into account that the basis of safety would include in the minimum (see Recommendations 5 and 6):

- Highly reliable ventilation fan system,
- Gas detection linked to automatic emergency shut down system,
- Prevention of ignition sources within the enclosure, and
- Separation distances to nearby gas turbines and pressure piping.

The frequency of explosion inside the turbine enclosure can be estimated as follows:

Explosion frequency = (Gas release frequency within enclosure) x (Ventilation fan failure probability) x (Gas detection and emergency shut down failure probability) x (Ignition probability of accumulated gas) x (Explosion if ignition probability).

With the following assumptions:

- Gas leak frequency = 1.4 x 10^{-3} t/yr (assuming equipment failure frequencies as per Table 16 and 290 flanges and flexible joints as per Table 17 above).
- Ventilation fan failure probability, allowing accumulation of gas = 0.01 (see recommendation 5).
- Gas detection failure and failure of the emergency shut down = 0.05 per gas detector, assume two independent detectors [and that both have to fail or fail to pick up the leak]. Also, taken into account is a 0.0025 probability of common mode failure for gas detectors (e.g. due to maintenance failure affecting detector system).
- Ignition probability of accumulated gas = 1. Even though all equipment and instrumented protective equipment used in the enclosure need to be designed for the hazardous zone requirements, a gas turbine could have hot surfaces above the auto ignition temperature of the fluids used even in normal circumstances (operation under fault conditions may increase surface temperatures).

- Explosion if ignition probability = 1 (i.e. assuming that all ignitions of flammable gases inside the enclosure would lead to an explosion. This is highly conservative).

Calculations show:

> Explosion frequency = $(1.45 \times 10^{-3}) \times (0.01) \times (0.05 \times 0.05 + 0.0025) \times (1) \times (1) = 7.2 \times 10^{-8}$ per year per enclosure.

With three enclosures, the total frequency of explosion inside gas turbine enclosure is:

F(explosion in gas turbine enclosure) = 2.2×10^{-7} per year.

This frequency is very low.

A confined explosion may generate high over pressures which could damage neighbouring equipment and gas turbines. It is however understood that the enclosures will be designed with explosions vents (/ panels) which would blow out in case of a pressure event, thereby reducing the effect of the confinement. Further, the turbines will be separated from each other by a 20 metres buffer zone.

With proper design it is unlikely that an explosion at one turbine would have serious effect at a neighbouring turbine.

Providing recommendations 5 and 6 are carried out, the risk from an explosion at turbine enclosure will be contained well within the site boundary.

8.1.2 Fire Risk – Distillate Storage

The likelihood of a distillate fire at the site, taking into account the properties of the material and its use within the site, is very low.

Hence, the risk of a diesel fire is minimal, provided the storage is designed in accordance with code requirements (in particular AS1940, Ref 10).

8.1.3 Overall Individual Risk of Fatality Risk – Peaking Power Plant

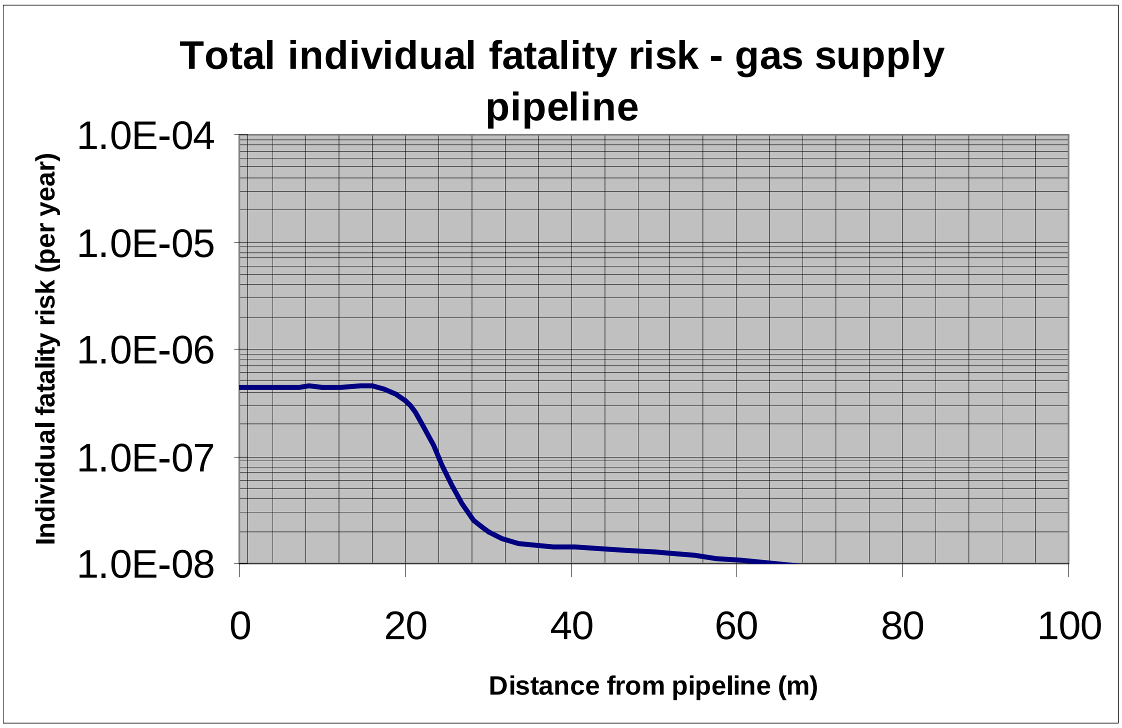
For the present development, the risk of fatality of 1 pmpy does not extend beyond the site boundaries and is therefore well away from the residential areas.

Note that all data used in this risk assessment are for a plant operating 100% of the time. The quantitative risk results are valid, though highly conservative, for the plant under the expected operating conditions, which are for a plant operating at a maximum 10% of the time.

8.1.4 Overall Individual Risk of Fatality Risk – Lateral Supply Pipeline

Figure 6 shows the risk-transect for individual fatality at the natural gas supply pipelines. Again, the risk criteria which is relevant for residential development (1 pmpy) is never reached. The pipeline does not travel next to any sensitive development (such as schools, hospitals etc.) where lower risk criteria would be relevant.

Figure 6 – Individual Risk Transects for the Lateral Gas Supply Pipeline



8.1.5 Overall Societal Risk of Fatality

The above criteria for individual risk do not necessarily reflect the overall risk associated with any proposal. In some cases for instance, where the 1 pmpy contour approaches closely to residential areas or sensitive land uses, the potential may exist for multiple fatalities as the result of a single accident. One attempt to make comparative assessments of such cases involves the calculation of societal risk. As the risk of fatality of 1 pmpy does not extend beyond the site boundaries the concept of societal risk is not applicable for the proposed development.

8.2 TRANSPORT RISK

The review of road transport risks concludes that the risk associated with the transport of dangerous goods and potentially hazardous material to the site is very low.

8.3 ADHERENCE TO RISK CRITERIA

The quantitative analysis showed that:

Individual Risk of Fatality: The risk of fatality at the nearest residential area is well below the criterion for new installations of one chance in a million per year (1×10^{-6}/yr). The 1×10^{-6}/yr individual fatality risk for the power station for the lateral natural gas supply pipeline is contained well within the site boundaries.

It follows that the risk of fatality at the nearest open space and the nearest industrial area are also well below the criterion of ten and fifty chances per million years respectively (10×10^{-6}/yr and 50×10^{-6}/yr) and contained within side boundaries.

Injury Risk: The risk of injury at the nearest residential area is well below the criterion for new installations of fifty chances per million years (50×10^{-6}/yr).

Propagation Risk: The risk of propagation of an incident at the power station or at the lateral natural gas supply pipeline does not encroach into any other industrial areas.

Societal Risk: The risk of fatality does not extend anywhere close to any residential and is well within the criteria for business / industrial areas. It is therefore considered that the current installation does not have a significant impact on societal risk.

9 CONCLUSION AND RECOMMENDATIONS

9.1 OVERVIEW OF RISK

The main hazard associated with the proposed project is associated with the handling of natural gas (predominantly composed of methane gas), which is a flammable gas held under pressure. Other, less significant hazards, are associated with the handling of combustible liquids (distillate).

Hazards may arise in fixed plant, storage, and pipelines. The predominant mode in which a hazardous incident may be generated is associated with a leak. This would generally only have the potential to cause injury or damage if there was ignition, which resulted in a fire or explosion incident. The factors involved are:

- Failure must occur causing a release. There are several possible causes of failure, with the main ones being corrosion and damage to the equipment by external agencies;

- The released material must come into contact with a source of ignition. In some cases this may be heat or sparks generated by mechanical damage while in others, the possible ignition source could include non-flame proof equipment, vehicles, or flames some distance from the release;

- Depending on the release conditions, including the mass of material involved and how rapidly it is ignited, the results may be a localised fire (for example a so called jet fire), a flash fire or an explosion of the vapour cloud formed through the release.

- Finally, for there to be a risk, people must be present within the harmful range (consequence distance) of the fire or explosion. How close the people are will determine whether any injuries or fatalities result.

9.2 SUMMARY OF RISK RESULTS

The detailed design has not been completed as yet for this development. A set of very conservative assumptions as to the design and operation of the plant have been made, including a 100% on-line operation of the plant (despite the fact that it is expected that the plant will be operational for 10% of the time only, with appropriate fire proof isolation valves separating the plant from pressurised gas supplies).

Even though many of the assumptions in this PHA are highly conservative, the results show that the risk associated with this development is very low. The most stringent risk criteria, as required by the Department of Planning, are adhered to.

9.3 RECOMMENDATIONS

The risk assessment carried out in this study assumed that the facility will be operated with appropriate consideration to safety and safety management at all stages.

The following recommendations emphasise the assumptions made in this risk assessment:

Recommendation 1: It is recommended that an assessment is carried out of the safety management system implemented and used at the site, specifically as it applies to the proposed hazardous materials handling, pipelining and storages within the first year of operation.

Recommendation 2: Any issues relating to temperature cycling to be taken into account during detailed design in order to avoid stress corrosion cracking.

Recommendation 3: High and low pressures of the natural gas supply to be associated with an automatic trip / emergency isolation of gas flow.

Recommendation 4: The use of leak detection in high risk natural gas piping to be investigated.

Recommendation 5: The detailed design of the gas turbine enclosure and associated equipment should clearly outline the basis of safety used to ensure that explosive situations do not arise (/the risk is rendered negligible). Reference should be made to European ATEX Directive (Ref 7) and the UK HSE PM84 (Ref 8) or other guidance / regulation of equivalent safety.

Recommendation 6: Fire protection inside the gas turbine enclosure to be determined, including use of explosion panels and use of fire retardant material.

Recommendation 7: A system should be put in place to ensure that any removal of critical safety function (e.g. for repair or exchange) is subject to careful scrutiny by plant management (decisions on whether to shut down plant or a gas turbine if a critical safety function is removed need to be canvassed).