Appendix J

Hazard Analysis

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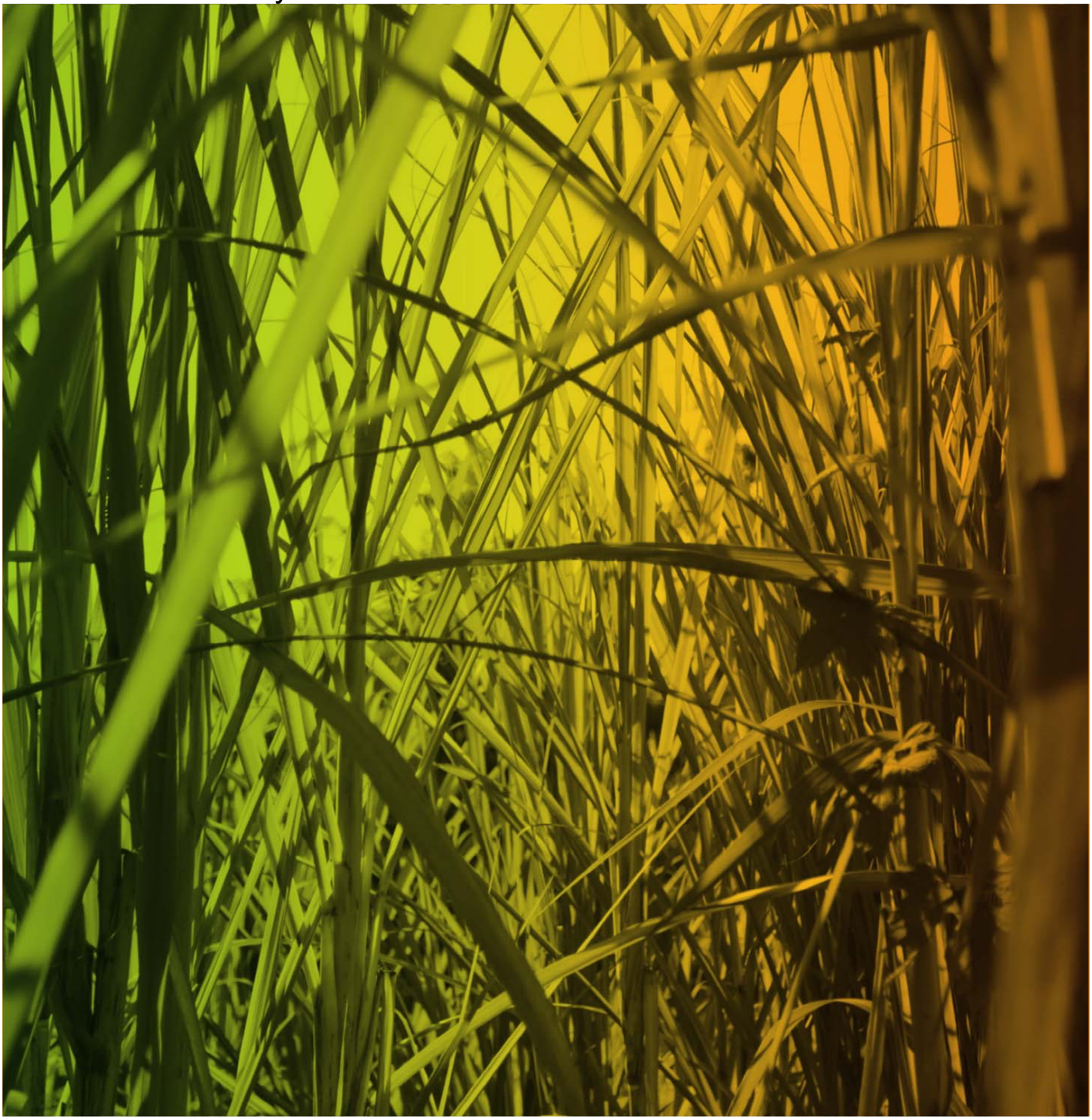
N6050103
National Ceramics Industries Australia Pty Ltd
3 March 2010

Expansion of an Existing Ceramic Tile Manufacturing Facility, Rutherford, NSW

Hazard Analysis



Expansion of an Existing Ceramic Tile Manufacturing Facility, Rutherford, NSW

Prepared for

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Executive Summary

Introduction

National Ceramic Industries Australia Pty Ltd (NCIA) proposes to undertake an expansion of its existing ceramic tile manufacturing facility (the Facility) at Rutherford, NSW. The proposal includes the construction and operation of a second factory building with four additional production lines on a parcel of land adjacent to (east of) the existing Facility. A number of Dangerous Goods (DGs) will be stored and handled within the new building, hence, it is necessary to review the hazards & risks associated with these goods and to determine whether they are effectively managed. NCIA has engaged AECOM to review the hazards and risks of the DG stored and handled at the site and to report on the findings of the assessment for inclusion in the Environmental Assessment.

Methodology

Initially, the quantities of DGs stored and handled at the proposed expansion were reviewed and it was identified that these did not exceed the threshold levels listed in State Environmental Planning Policy (SEPP) No.33 (Hazardous and Offensive Developments), hence, this SEPP does not apply to the site. Notwithstanding this, a hazard analysis was conducted to determine whether the Dangerous Goods proposed for storage and handling at the site posed a risk to the surrounding land uses. Under the guidance of the NSW Department of Planning documents (*Applying SEPP 33 (1994), "Hazardous and Offensive Development Application Guidelines", Department of Planning, NSW*), a predominantly qualitative assessment was conducted to identify the hazards and determine the risks to surrounding land uses.

Brief Description of Site Operations and Ha ard Analysis

The facility expansion would include the construction and operation of a second factory building with four additional production lines on a parcel of land adjacent to the existing tile manufacturing building. The proposed expansion would be located adjacent to the existing operation, on Lot 101 DP 1062820 Racecourse Rd, Rutherford, within the local government area of Maitland. The existing Facility is located within the Rutherford Industrial Estate where land use is predominantly industrial with a land zoning of 4(a). A former golf course is located on the southern and eastern boundaries of the Facility, known as Westside Golf Course and is the site for the proposed Heritage Green development. The northern and western boundaries are bordered by industrial developments.

The following DGs were identified to be stored and handled at the site:

- **Natural Gas** – fed by pipeline to the factory for use in the drying areas, kilns and shrink wrapping machines (natural gas will not be stored on site); and
- **Diesel Fuel** – stored in a 5,000 L above ground tank and used for fuelling the front end loader and forklift trucks.

A hazard analysis was conducted and a number of hazards were identified with the gas system and the diesel storage.

Gas releases may occur as a result of leaks from flanges and valves, leading to the potential accumulation of gas, delayed ignition and explosion. However, as natural gas is lighter than air, this scenario was not considered a risk as the gas would rise and dissipate into the open air and into the large building, escaping via the high level vents in the building. Gas explosions were therefore not considered a risk in the proposed expansion project. In the event of an immediate ignition of gas (from a leak) a jet fire may occur. The analysis conducted in the study identified that the magnitude of the gas jet fires were insufficient to impact offsite and therefore no further analysis was conducted.

Spill of diesel fuel was identified as a potential hazard to the environment. However, it was identified that the diesel tank would be bunded to prevent spills escaping beyond the immediate area of the tank storage. Notwithstanding this, it was identified that spills during transfer of fuel from tankers to the tank and during refuelling of vehicles could result in fuel escaping to the environment. In the unlikely event of an ignition of a spill it was identified that a pool fire could occur, resulting in heat radiation impact offsite. This incident was carried forward for further analysis.

Consequence Analysis

A review of the potential diesel release incidents that could result in fire identified that the worst case scenario was a diesel tank full bund fire. The analysis identified that a fire in the diesel tank bund would impact the site boundary at a heat radiation level less than 2 kW/m^2. The acceptable heat radiation impact level at the site boundary is 4.7 kW/m^2 (*Hazardous Industry Planning Advisory Paper No.4 (1992) – Risk Criteria for Land Use Safety Planning, NSW Department of Planning*). Hence, it was identified that there would be no impact beyond the site boundary, exceeding acceptable criteria, as a result of diesel fuel incidents at the site.

Conclusions and Recommendations

Based on the analysis conducted in the study, it was concluded that the proposed expansion of the NCIA Tile Factory would not result in hazards and risks at the adjacent land uses that would exceed the acceptable risk criteria (Ref.4).

Notwithstanding the above conclusion, two recommendations are made:

1. During the transfer of fuel from the road tanker to the diesel fuel tank and during the fuelling of vehicles, it was identified that fuel spills could escape beyond the immediate fuelling point, impacting the environment. It is therefore recommended that a spill containment “bund” be constructed for the area adjacent to the fuel tank consisting of a “speed-hump” type bund to contain any spills that may occur from fuel transfer operations.
2. It was identified that in the event of an incident, albeit a low probability, it will be necessary to provide emergency response to ensure the risks are maintained in the As Low As reasonably Practicable (ALARP) range. It is therefore recommended that the existing site emergency plan be updated to include potential incidents at the expanded facility, including gas releases/fires and diesel releases/fires.

1.0 Introduction

1.1 Background

National Ceramic Industries Australia Pty Ltd (NCIA) proposes to undertake an expansion of its existing ceramic tile manufacturing facility (the Facility) at Rutherford, NSW. The proposal includes the construction and operation of a second factory building with four additional production lines on a parcel of land adjacent to (east of) the existing Facility.

The facility will use a number of hazardous materials and dangerous goods as part of the tile manufacturing process, predominantly natural gas, with minor storage of fuels and oils. Hence, it is necessary to assess the hazards and risks associated with the tile manufacturing process to ensure that these do not impact adjacent land uses at levels exceeding the acceptable criteria.

To assist with the assessment of risks, NCIA has commissioned AECOM to prepare a review of the hazards for inclusion in the Environmental Assessment (EA). This document details the results of the hazard review of the NCIA ceramic tile manufacturing facility expansion project at Rutherford, NSW.

1.2 Objectives

The objectives of the study are to:

- Prepare a hazard analysis (Hazan) for the proposed NCIA facility expansion at Rutherford, NSW, for inclusion in the EA documentation for submission to the NSW department of Planning (DoP);
- Review the Hazan results and determine any adverse impacts that may occur to the surrounding land uses, recommending hazard reduction measures where required; and
- Provide a report on the results of the Hazan study for inclusion in the Environmental Assessment for submission to the regulatory authority in support of the Development Application.

1.3 Scope of Work

The scope of work is for a Hazan study of the proposed expansion project at the NCIA ceramic tile manufacturing facility, Rutherford, NSW. The scope includes the assessment of hazard associated with the proposed facility, the analysis of hazard consequence and likelihood and the assessment of risks. The scope also includes a review of the potential risk impacts to the surrounding land uses and the recommendation of risk reduction measures where required.

The scope of work does not include the assessment of existing hazards and risks associated with the current operations, as these have been approved under separate DA conditions. However, where hazards associated with the current operations may impact the proposed facilities, and vice versa, these will be included in the assessment.

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2.0 Methodology

2.1 State Environmental Planning Policy No.33

State Environmental Planning Policy No.33, Hazardous and Offensive Developments (the Policy), has been issued by the DoP in relation to facilities storing and handling hazardous and offensive materials in order to ensure such facilities are located in the appropriate place.

The policy is supported by a guideline (Ref.1) to assist regulators and industry to determine whether facilities, that may be hazardous and/or offensive, are subject to the requirements of the policy. The guidelines provide threshold levels for the storage of Dangerous Goods and the number of Dangerous Goods transport operations, above which the policy applies.

The proposed NCIA facility will use a number of Dangerous Goods in the manufacture of tiles, predominantly natural gas and diesel fuel. The following goods will be stored and handled at the new facility:

- Natural Gas – natural gas will be fed to the site from a medium pressure gas main (1050kPa) running to the western side of the site. Natural gas will not be stored at the site.
- Diesel Fuel –will be stored at in the new facility, on site, in a 5,000 L above ground tank.

In addition to the above goods a number of drums of oil will be stored for lubrication, process and maintenance purposes.

A review of the SEPP33 application guidelines (Ref.1) indicates the following:

- Natural Gas – Table 1 (Ref.1) indicates that flammable gas (e.g. Natural gas) in quantities stored in excess of 5m^3 are subject to SEPP33. As there is no storage of Natural Gas at the site, SEPP33 does not apply in this case.
- Diesel Fuel – diesel fuel proposed for use at the facility is classified as a C1 combustible liquid. The guideline (Ref.1) indicates that C1 combustible liquids are not subject to SEPP33 (pg20, Ref.1). Hence, SEPP33 does not apply to the diesel at the site.
- Oils – the oils used at the proposed site are classified as C2 combustible liquids. The guideline (Ref.1) indicates that C2 combustible liquids are not subject to SEPP33 (pg20, Ref.1). Hence, SEPP33 does not apply to the oils at the site.

Based on the above analysis, SEPP33 does not apply to the proposed development. Notwithstanding this analysis, the Dangerous Goods handled at the site have the potential to explode or burn, resulting in hazards that may impact offsite if not effectively controlled. Hence, to demonstrate that the inherent and operational hazards associated with the handling of the Dangerous Goods at the NCIA site are effectively managed, a hazard analysis has been conducted.

To assist in determining the level of assessment required for the site, the SEPP33 guideline was consulted to identify a methodology and approach that could be used to demonstrate that the proposed safety systems associated with the natural gas and diesel fuel installations were commensurate with the site layout and location. The methodology used in the assessment is described in the following section.

2.2 Applying SEPP33 Guidelines

The “Applying SEPP 33” (Ref.1) guideline may be used to assist in the selection of the appropriate level of assessment for a facility handling Dangerous Goods. This guideline states the following:

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

- Where materials are relatively non-hazardous (for example corrosive substances and some classes of flammables).
- Where the quantity of materials used are relatively small.
- Where the technical and management safeguards are self-evident and readily implemented.
- Where the surrounding land uses are relatively non-sensitive.
    - *In these cases, it may be appropriate for a PHA to be relatively simple. Such a PHA should:*
- Identify the types and quantities of all DGs to be stored and used.
- Describe the storage/processing activities that will involve these materials.

- Identify accident scenarios and hazardous incidents that could occur (in some cases, it would also be appropriate to include consequence distances for hazardous events).
- Consider surrounding land uses (identify any nearby uses of particular sensitivity).
- Identify safeguards that can be adopted (including technical, operational and organisational), and assess their adequacy (having regards to the above matters).

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

A review of the hazardous materials proposed for use at the NCIA tile factory, indicates that only two goods are proposed for use, these are natural gas and diesel fuel. The natural gas will be piped to the facility from a medium pressure main running along the western boundary of the site. Natural gas will not be stored at the premises. The natural gas will operate at a pressure of 200kPa within the pipe work at the site, a relatively low pressure.

In addition to the natural gas, diesel fuel will be used for front end loaders and forklift trucks. The fuel will be stored in an above ground 5,000L tank located adjacent to the raw materials storage area.

Based on the type of hazardous materials stored and used at the site, and the fact that there will be minimal storage of flammable gas, a mixture of qualitative and quantitative assessment will be performed. Qualitative assessment will be performed for identified hazards to determine whether there will be an offsite impact. As detailed in the guidelines, qualitative analysis will be used to determine those incidents that have the potential to impact the adjacent facilities. Those incidents identified to have an offsite impact potential, will be subject to a consequence assessment and quantitative risk analysis (if required).

2.3 Detailed Ha ard Analysis

The detailed analysis of hazards and their impacts was performed to identify whether incidents that may occur, involving the Dangerous Goods (DGs), could impact offsite. The hazard analysis reviewed:

- type of DG;
- its characteristics;
- operating conditions of the equipment in which the DG is used;
- behaviour of the DG on release;
- postulated incident as a result of DG release (e.g. fire, explosion, etc.); and
- Safeguards installed to prevent, detect, protect and mitigate against incidents.

The assessment involved the development of a Hazard Identification Table to list those incidents that may occur and the prevention, detection, protection & mitigation systems used at the proposed facility. A detailed hazard identification assessment was then be conducted to determine the effectiveness of the proposed safeguards and whether these were considered to maintain the hazard within the As Low As Reasonably Practicable (ALARP) range.

Where an incident was identified to have the potential to impact offsite, a consequence analysis was performed to demonstrate that the protection/mitigation systems were effective in managing the hazard. Where additional hazard protection/mitigation was identified to be required, it was recommended as part of the study.

On completion of the study a draft report was developed for review by NCIA. Comments on the draft were then incorporated and a final report issued for inclusion in the EA.

3.0 Brief Description of the proposed Project

3.1 Background

National Ceramic Industries Australia Pty Ltd (NCIA) proposes to expand its existing ceramic tile manufacturing facility (the Facility) at Rutherford, NSW. This would include the construction and operation of a second factory building with four additional production lines on a parcel of land adjacent to the existing Facility.

The proposed expansion would be located adjacent to the existing operation, on Lot 101 DP 1062820 Racecourse Rd, Rutherford, within the local government area of Maitland. The existing Facility is located within the Rutherford Industrial Estate where land use is predominantly industrial with a land zoning of 4(a). An existing golf course is located on the southern and eastern boundaries of the Facility, known as Westside Golf Course. The northern and western boundaries are bordered by industrial developments. The regional location of the site is indicated in **Figure 3.1**.

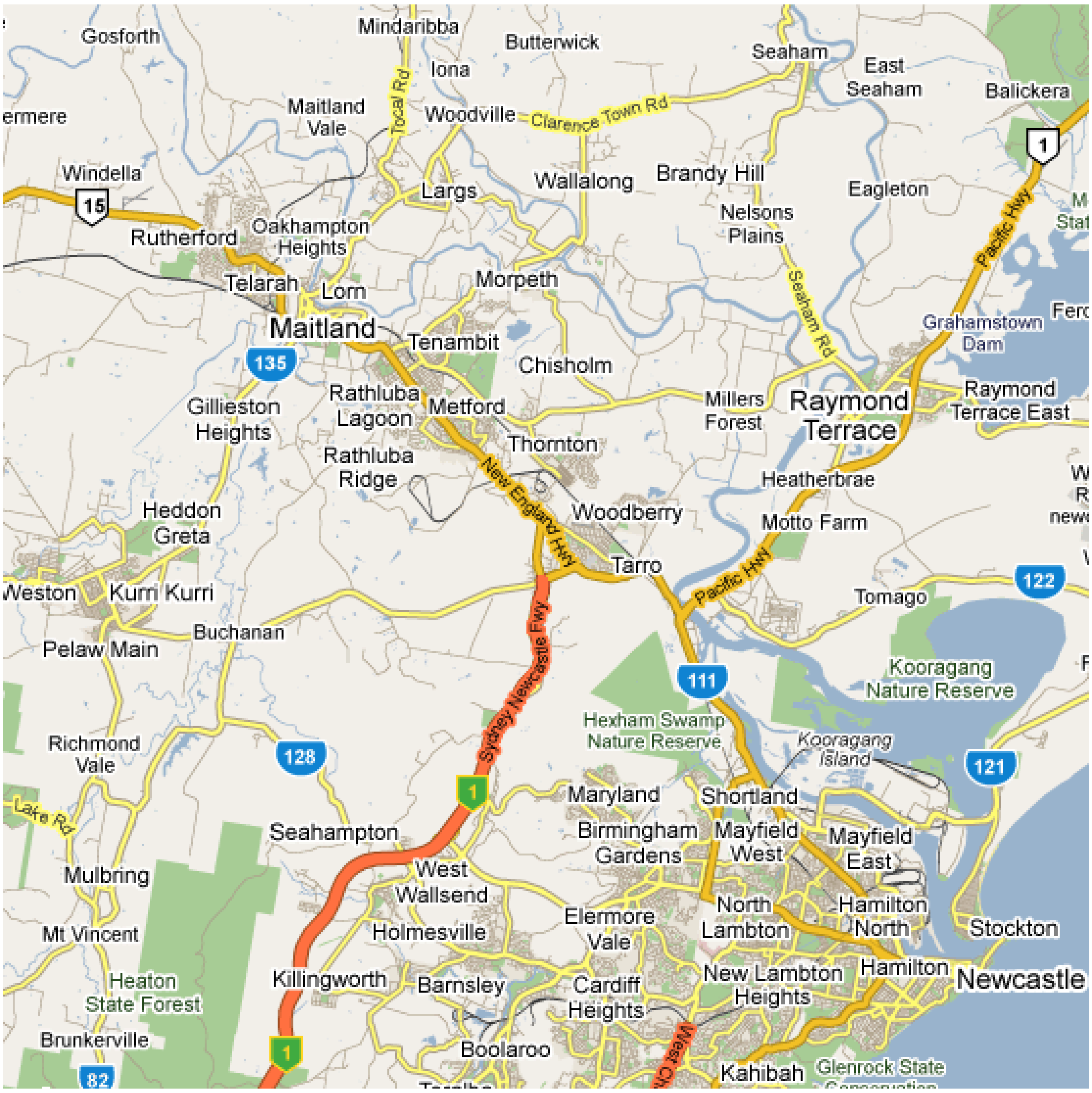

FIGURE 3.1

NCIA Tile factory – regional location

FIGURE 3.2

Site location and surrounding land uses

The proposed site layout, showing the location of the existing facility, is provided in **Figure 3.2**. The new building would be of similar scale and structure to that of the existing building and would be constructed close to the eastern boundary of the site. The building would be constructed in a north south orientation, with raw material (non-DG) storage and production beginning at the northern end and dispatch (tiles) occurring at the southern end.

Internal site traffic would travel on a two way road network along the western boundary and other traffic between the two buildings. Additional stormwater detention basins would be constructed to capture site run-off and the boundary areas would be landscaped

3.2 Dangerous Goods Stored and Used at the Site

The site uses only two materials that are classified as flammable or combustible, these are:

- Natural Gas; and
- Diesel Fuel.

The classification and description of each material are presented in **Table 3.1**.

Table 3.1 Dangerous goods description – natural gas and diesel fuel

Un No.	Proper Chemical Name	Class	Ha Chem	Quantity Stored
1971	Methane	2.1	2[S]E	Nil (supplied by pipeline)
-	Combustible Liquid	C1	-	5,000 Litres

3.3 Process Description

The manufacture of ceramic tiles involves numerous steps and a process flow diagram is provided in **Figure 3.3**. Due to technology improvements, the manufacturing process for the proposed expansion project would be slightly different to the manufacturing process used in existing operation. A brief description detailing the various steps in the proposed tile manufacture process is provided below.

3.3.1 Raw Materials

Raw materials that are used in the tile manufacturing process are predominantly clays and feldspars. These are naturally occurring products, which are typically sourced from quarries located in NSW and Western Australia. Clay is the main component of the tiles in the unfired state, providing both strength and body and contributing to the final properties of the tile. The feldspar is used to reduce water adsorption of the tile and adds to the tiles strength and whiteness.

A number of dry and wet glazes may also be used during the process, depending on the current demand for tile design and style. These typically comprise dry glazes, wet glazes and printing powders. Frit is a component of the glaze, which varies depending on the level of gloss required in the tile. Frit is made up of oxides and minerals such as feldspar and kaolin, and is typically imported from Italy or Spain.

3.3.2 Batching and Mill Feeding

The raw materials used in the initial phase of manufacture would be stored in a series of bunkers located at the northern end of the plant (see Bunker Store Area, **Figure 3.3**). The materials are collected from the storage bunkers using a Front End Loader and are placed into continuous weigh feeding hoppers.

The continuous weigh feeding hoppers ensure that the clay mill has a constant and consistent supply of raw materials. At the mill, water and de-flocculant are added to the milled material, also know as composite. De-flocculant is used to ensure that the composite does not combine during the milling process. The wet clay milling process described above for the proposed operation is identical to the existing manufacturing process. The de-flocculant is non-hazardous and non-dangerous goods.

3.3.3 Slip Preparation Drying and Pressing

Slip is the product of the wet clay milling process described above. Slip preparation involves adding water (40% volume) and de-flocculant to the composite to produce the composite solution, or slip. The slip is then gravity fed into a series of storage tanks. The slip is kept in suspension using stirrers within the tanks. From the tanks the slip is pumped out and sprayed through fine ceramic nozzles into the spray drier. The spray drier contains a gas fired burner that provides heat for the drying process. The burner is provided with natural gas from the main gas supply line running through the centre of the plant.

The granulated composite that remains after the spray drying process contains approximately six percent water. Water vapour and fine particulates would be emitted from an emissions stack off the spray drier. From the spray drier, all remaining lumps of clay are removed by screens and are returned to the clay mill for further processing. The granulated composite is then transferred via a conveyor belt to storage silos. The granulated composite is left within the silos for approximately 12 hours, which allows for interaction between water and clay to take place. The slip preparation and drying process described above for the proposed plant is identical to the existing manufacturing process.

The storage silos feed onto a conveyor belt where a dry glaze is applied. This material then passes through a roller press that compacts the dry glaze into the unfired granulated composite. Following the roller press additional dry glazing and tile decorating (printing) can occur as required. The continuous length is then cut into large sheets and is re-pressed. The sheets are then trimmed if necessary and cut to the required tile size. The tiles may undergo a final application of wet glaze as the style of tile requires and dried in a tile drier. The tile drier contains a number of gas fired burners that provide heat for the drying process. The burner is provided with natural gas from the main gas supply line running through the centre of the plant. Stack emissions from the tile driers include water vapour and fine particulates.

3.3.4 Gla ing

A dry glaze is applied prior to being roller pressed and again prior to being cut and dried as described above. There would be limited wet glazing undertaken in the proposed process, when compared to the existing manufacturing operation. It is not anticipated that dry glazing would have a negative impact on air quality. It is anticipated particulate emissions are likely to be reduced.

Storage of dry glazes would take place in a number of storage silos that would be located in the northern section of the new factory, prior to the beginning of the production line conveyors. Seven dry glaze colours are required to manufacture the full range of tiles, however up to twenty four storage silos may be installed.

Wet glaze application in proposed process would be significantly reduced when compared to the existing manufacturing process. Many tile varieties would not require wet glaze application in the proposed operation due to the use of dry glazes. Wet glaze preparation is undertaken as a batch process within the glaze preparation plant. Batches are prepared based on the particular glaze or effect that is required. The wet glazes are milled in batches, stored as a liquid and left to stand for 24 hours to allow for cooling and bubble removal.

Wet glazes are applied to the tile on the glazing line after the tiles are cut to size and dried in the tile dryer. The tile drier contains a number of gas fired burners that provide heat for the drying process. The burner is provided with natural gas from the main gas supply line running through the centre of the plant. Stack emissions from the tile driers include water vapour and fine particulates. Wet glazes are applied using an airpower applicator, which is a pump attached to rotating spraying nozzles that ensure a consistent finish over the tile. Wet glazes would be used to further enhance or decorate tiles in ways not possible during the dry glazing process.

3.3.5 Firing Gas Supply

Tiles are fed through a pre-kiln which removes the moisture from the applied wet glaze. The tiles then pass through the kiln at 1,300 degrees centigrade. The kiln contains a row of gas fired burners that provide heat for the firing process. The burners are provided with natural gas from the main gas supply line running through the centre of the plant. Each kiln would generate gaseous emissions from the combustion of natural gas. These emissions would be released via one scrubbed stack per kiln.

Figure 3.4 (a b) shows the isometric view of the gas supply line in the factory. The gas is supplied from the gas main, running along the western boundary via a gas reduction station. The gas supply main on the western boundary holds gas at 1050kPa, which is reduced via a reduction valve set to 200kPa (see **Figure 3.5** for gas reduction isometric and **Figure 3.2** for location of the gas reduction set). The gas is then fed (underground) to the factory in a 150mm nominal bore (NB) copper pipeline. The underground pipeline enters the factory on the western side and is run along the factory wall at a height of around 3m. The pipeline is installed to distribute gas to the various areas in a 150mm NB copper line (i.e. to the spray dryer, tile dryer and kilns). A 50mm NB copper pipeline is installed to the shrink-wrap machine, located in the southern section of the factory. Isolation valves (ball valves) are located along the length of the pipeline at each off-take (i.e. to equipment) and at selected points along the line.

The spray dryer, tile dryer and kilns are fitted with burners that provide flame/heat for the drying and curing processes. Each burner is fitted with a burner management system that continually monitors the flame condition (i.e. flame detection device) and isolates the gas supply via either one of two isolation valves in the event of flame loss (i.e. flame-out). The burner management systems are installed to comply with the relevant Australian Standards.

Once the tiles have cooled they are available for packaging and dispatch.

3.3.6 Packaging

Prior to packaging, the tiles are scanned for grading in line with NCIA's quality control procedures. Tiles are then boxed, palletised and shrink wrapped through an automated process. Once on the pallets, the tiles are stored, awaiting dispatch by road transport.

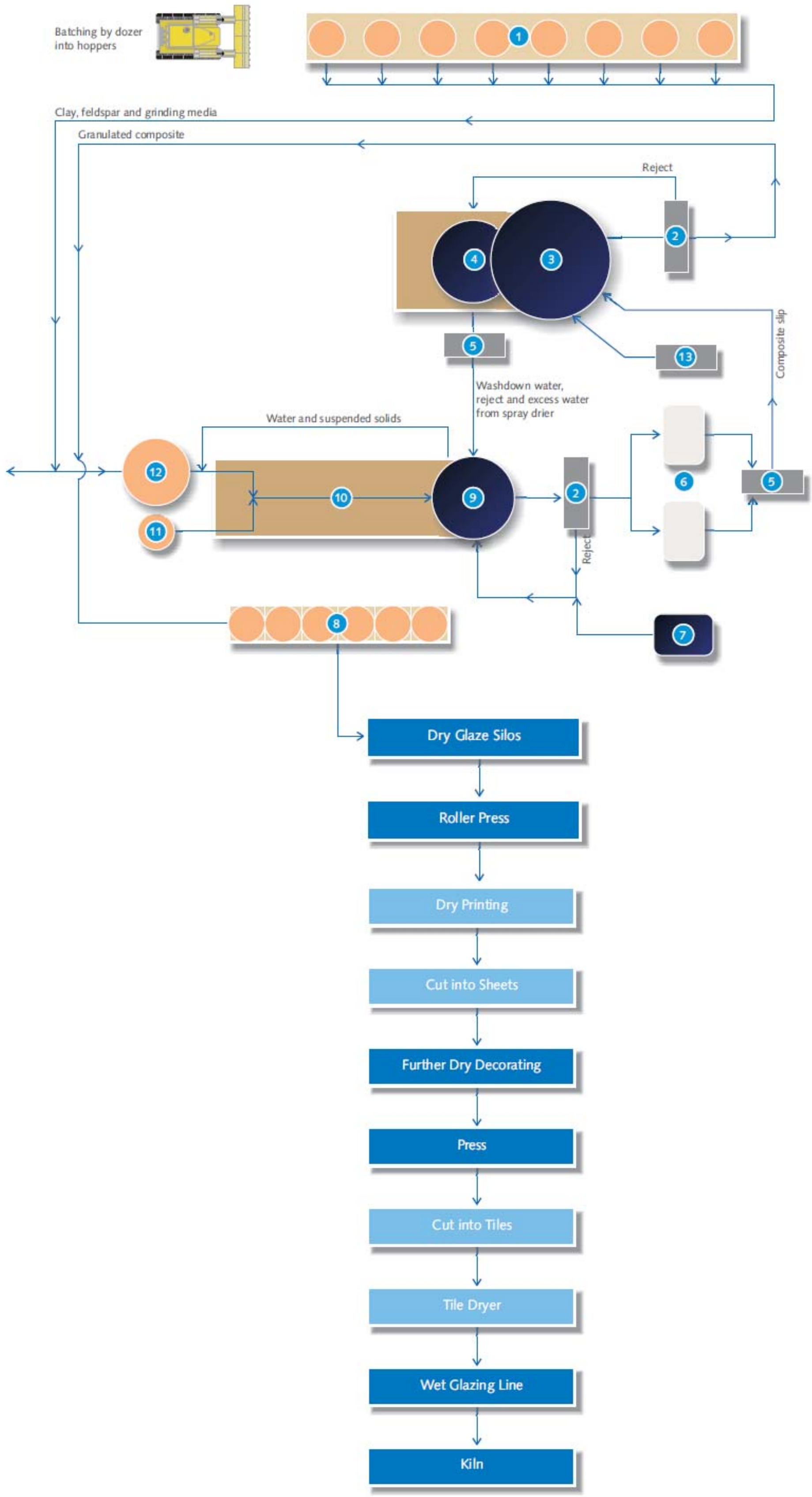

Figure 3.3
Process flow diagram – NCIA Tile manufacturing

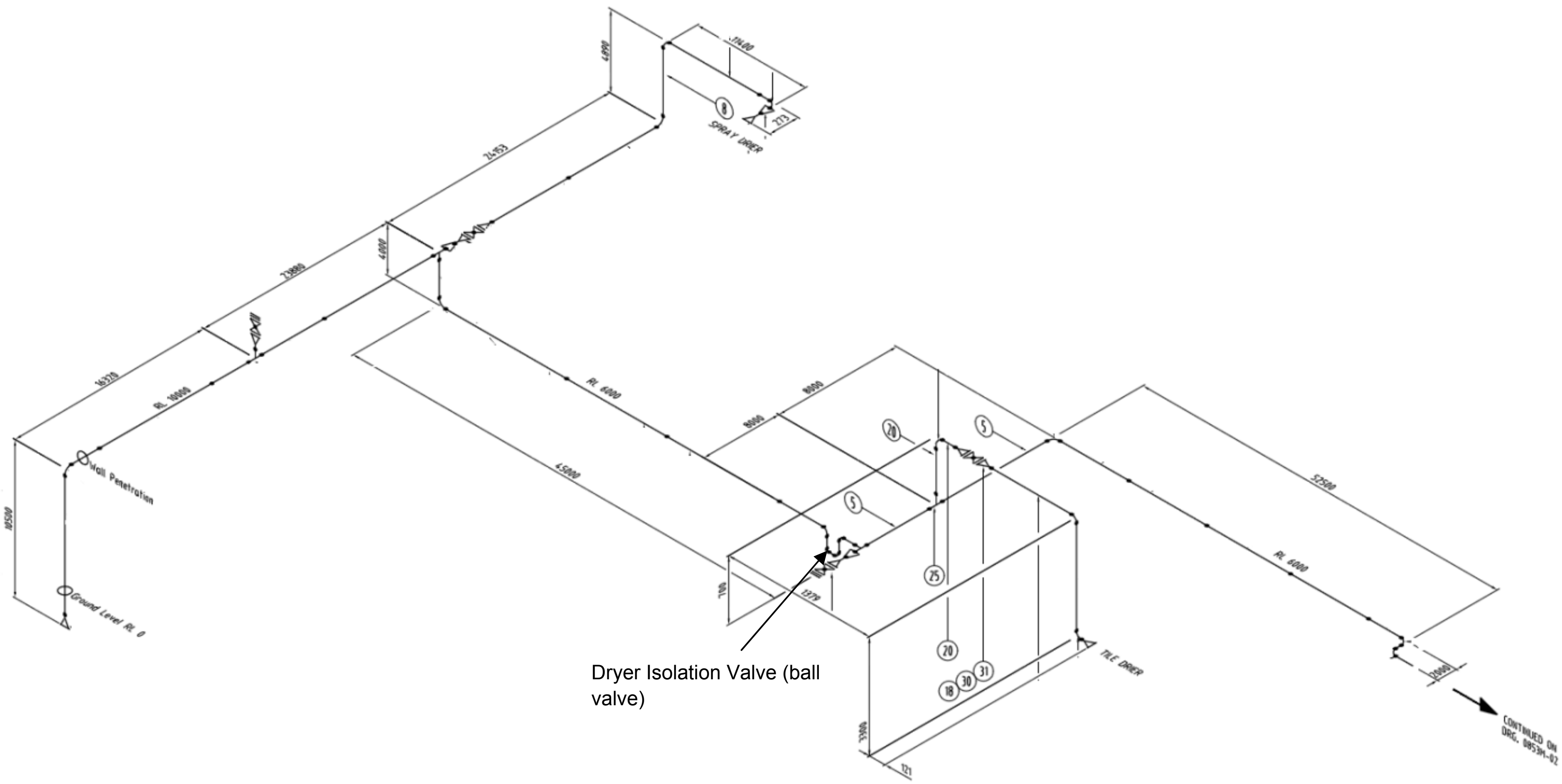

Figure 3.4a
Gas supply pipeline isometric

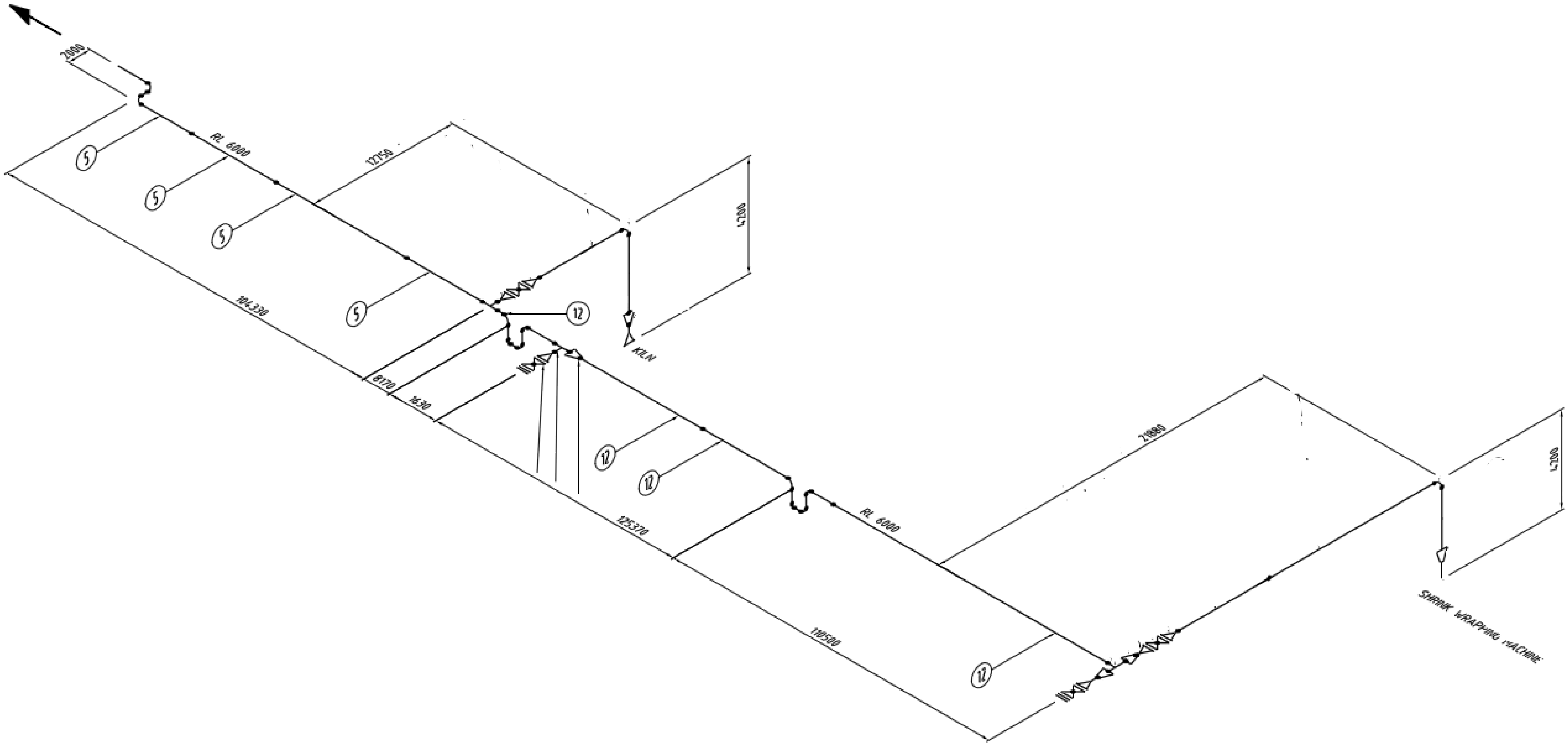

Figure 3.4b
Gas pipeline isometric

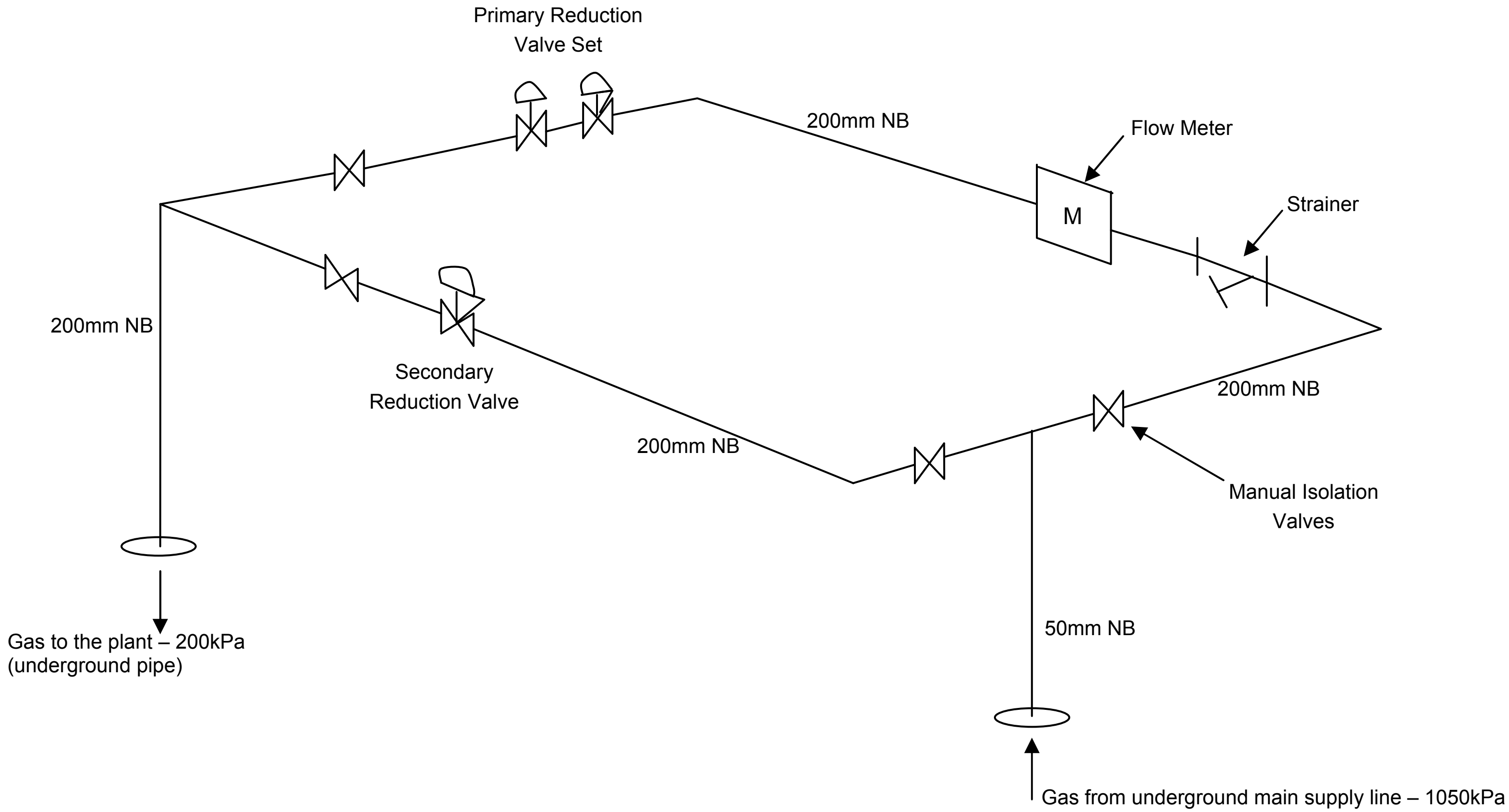

Figure 3.5
Isometric view of the gas let down station

3.3.7 Gas System Safeguards

The gas systems are installed with a number inherent and installed safeguards, which include:

- Back up pressure reduction valves in the main let down station;
- Low operating pressure in the factory (200 kPa) and low pressure at the equipment (50 kPa);
- Pipe work located in elevated position, preventing potential vehicle collision incidents;
- Burner Management Systems (BMS) installed on all firing systems at the factory;
- Flame detectors installed on all burners; and
- Gas isolation valves installed at all burners, activated by flame loss.

3.3.8 Diesel Systems

- Minor quantity of diesel stored (<5,000 L)
- Diesel fuel only stored (diesel is a combustible liquid and is not classified as flammable);
- Fuel is stored in accordance with the Occupational Health and Safety (Dangerous Goods Amendment) Regulation - 2005;
- Bunding is provided for the diesel storage to contain spills; and
- Tank refuelling will be performed by an experienced fuel supplier who will be in attendance during the full refuelling operation (i.e. at each tank refuelling).

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4.0 Hazard Analysis

4.1 General Ha ard Identification

A hazard identification table has been developed and is presented at **Appendix A**. Those hazards identified to have a potential impact offsite are assessed in detail in the following section of this document.

Section 3.2 lists the type of Dangerous Goods (DGs) proposed for storage and handling at the NCIA facility. It is noted that all hazardous and dangerous goods listed in this section will be stored and handled in accordance with the applicable Australian Standard specific to the particular DG listed. **Table 4.1** lists the characteristics of the DGs proposed for storage and handling at the NCIA facility.

Table 4.1 Characteristics of ha ardous and dangerous goods stored and handled at the NCIA

Material Name (Ref.2)	Class	Ha ardous Properties
Methane, Compressed or Natural Gas Compressed with a high Methane content.	2.1	Gas is flammable and if released could ignite. Ignited leak at the release source would result in a jet fire. Un-ignited releases could form a gas cloud, which may ignite after a delay and explode. Gas is lighter than air, rises and dissipates on release. Minimal environmental damage as gas rises with little or no impact to surroundings.
Diesel (Liquid)	C1	Liquid is combustible and will burn if ignited, resulting in pool fire in the area under the release point. Flash point of the liquid is >90°C, hence, ignition likelihood is very low as the material does not readily vaporise at ambient temperature. Potential impact to the bio-physical environment depending on spill quantity and containment.
Oil	C2	Oil is not classified as a dangerous good in NSW. Oil is combustible and will burn if heated and ignited, however, oil flash point exceeds 150°C and ignition is highly unlikely unless the oil is heated above 150°C. Potential impact to the bio-physical environment depending on spill quantity and containment. Note: based on the fact that oil is not classified as DG in NSW, no further assessment has been conducted in this study.

4.2 Detailed Ha ard Identification

4.2.1 Ha ard Analysis

A hazard analysis table (see **Appendix A**) was developed to determine the potential hazards, their impact and proposed safeguards at the NCIA facility. The study identified a number of potential incidents that could lead to impact to people, plant and the environment. A summary list of hazards is presented below:

- Gas leak, ignition and fire at the let down station.
- Gas leak ignition and flash fire or explosion at the gas let down station.
- Gas leak, ignition and fire in the factory.
- Gas leak ignition and flash fire or explosion in the factory.
- Diesel spill during refuelling of tanks or fuelling of vehicles, ignition and fire in the vicinity of the refuelling tanker.

- Diesel spill into the tank bund, ignition and pool fire in the bund.

Each identified hazardous incident has been assessed in detail below.

4.2.2 Gas Let Down Station - Ha ardous Incidents

The gas let down station is installed to reduce the gas pressure from 1050 kPa to 200 kPa for feed to the factory. The let down station consists of a primary let down valve set and secondary let down valve. The primary let down valve set is used for the normal let down operations and consists of two pressure control valves installed in series. In the event the main let down valve in the primary set fails (i.e. allows full pressure to the supply main), the on-line stand-by valve will automatically control the pressure. In the event the primary reduction valve set requires maintenance, a secondary pressure control valve is installed for use when the primary set is offline.

The let down station pipe work is fully welded with the minimum number of flanges, located only at valves and meter components. All high pressure flanges are fitted with spiral wound gaskets (SWG), which are fitted with a backing ring to prevent gasket blowout. Based on this design the likelihood of pipe work leak is minimal as all bends are fully welded. The potential for catastrophic failure of the flanged joints is also minimal as the SWG prevents gasket blowout. The most likely incident is a “wire-cut” leak across the face of a flange or a seal leak in the stem of a valve. The leaks are minimal resulting in hole equivalent diameters of around 5mm.

In the event of a release of gas from a flange or valve leak, the gas would not accumulate or form a cloud, as the let-down station is located in the open and natural gas is buoyant, being lighter than air (i.e. molecular weight of methane – 16, molecular weight of air = 28). As a gas cloud will not form, there is a negligible risk of ignition and explosion. Hence, this incident has not been reviewed further.

Notwithstanding the above assessment, there is a potential for the release to ignite immediately, causing a gas jet fire at the release point. Whilst this is feasible, the likelihood is extremely low as there are no ignition sources in the vicinity of the let-down station and the let-down station is located within a locked chainmesh enclosure, preventing access to the station components.

A rough estimate of jet fire length (Ref.3) can be estimated from the formula:

L = 300d, where L = jet fire length and d = equivalent diameter of the hole

Hence, for a jet fire at the let-down station (flange/valve leak), the length of the flame would be 300 x 0.005 = 1.5m. A review of the let down station installation indicates that the components in the station are over 5m from the site boundary, hence, there would be no flame impact beyond the site boundary as a result of the postulated jet fire at the let-down station. Further, there are no structures or facilities at the adjacent site that would be impacted by the heat radiation from such a fire. Based on this analysis, no further assessment of fire incidents at the let down station have been conducted as there are no offsite impacts from this incident.

4.2.3 Gas Supply System (Factory) – Ha ardous Incidents

Once the gas is let down into the main factory pipework, it is reduced to 200kPa. This is a relatively low pressure and would not subject the pipework to overstress of potential failure from overpressure. Notwithstanding this, minor leaks may occur at joints in the system resulting in the accumulation of gas, ignition and explosion. However, as noted in **Section 4.2.2**, methane gas is buoyant and does not readily accumulate or form gas clouds unless confined. As the gas rises, there is a potential for it to be contained within the factory roof, however, the roof is designed with high level vents where the roof and wall joint. This permits the gas to escape, preventing accumulation and gas cloud formation. Based on this there is a negligible risk of flash fire and/or explosion in the factory building.

In the event of immediate ignition of a gas leak, a gas fire would occur. However, unlike the high pressure gas (1050 kPa), a gas jet fire would not occur. The ignited gas would result in a diffuse flame without the intensity of a full gas jet fire. The diffuse flame would be short in length and localised around the leak point. Review of the proposed location of the gas main throughout the factory indicates that it is elevated and located well clear of equipment and components until it connects to the equipment to which the gas is supplied.

Prior to the connection of gas to the equipment, a further gas reduction is provided to let the gas down to pressures in the order of 50 kPa. Gas pipework and systems operating at 50kPa are highly unlikely to leak and should leaks occur at low pressures (i.e. ≈50 kPa) the diffuse flame would be very localised around the leak point and would not impact equipment adjacent to the gas connections. Based on this analysis, there would be little if any impact from ignited leaks of gas within the factory, hence, no further analysis has been conducted for these incidents.

Natural gas is used within the various tile curing and drying systems to provide heat in the form of gas flames (burners). The gas is supplied to a burner element where it is fed to the burner, with air, and ignited by a pilot flame. The burner systems are all installed in accordance with the relevant Australian Standard, incorporating burner management systems (BMS). The BMS includes a flame detector that constantly monitors the flame on each burner. Should the flame fail (i.e. flame-out), then the detector will initiate a gas supply shut down at the burner, preventing the potential for continued gas supply to the burner space which could result in delayed ignition and explosion. The effectiveness of BMS systems is well understood and is incorporated into the furnace firing codes and standards. Historically there are few, if any, firing incidents where code installed burners are used and the risks associated with these systems are negligible. As the NCIA heating and drying systems will all be installed in accordance with the relevant codes, standards and regulations (including BMS), the risks associated with this part of the factory are considered to be low and certainly within the ALARP range, hence, no further analysis has been conducted on these systems.

One incident that could occur at the factory is a collision between vehicles in the factory (e.g. forklifts) and the gas main. This could result in catastrophic failure of the gas line and large release of gas into the factory building. Externally, the gas main is installed underground, hence, there will be no collision impacts. However, in the building there is a potential for forklifts to strike the gas main during operations. To prevent this, the main will be installed above 3m height within the factory and located along with main pipe racks and cable trays in areas where forklifts cannot access. This prevents the potential for collision between vehicles and the gas main. Based on the proposed gas main location, it is considered that impacts risks are negligible and no further assessment is conducted.

4.2.4 Diesel Tank Incidents

The diesel tank at the proposed site will be a 5,000 L elevated horizontal tank, located over a tank bund. In the event of a tank leak, the bund will contain any spills, preventing impact to the environment. Hence, there will be a negligible risk to the environment from diesel tank spills.

In the event a diesel fuel spill is ignited, there is a potential for a pool fire in the bund. The pool fire could radiate heat beyond the site boundary, as the proposed diesel storage is on the eastern side of the factory building. Hence, this incident has been carried forward for further analysis.

4.2.5 Diesel Tank Refuelling or Vehicle Fuelling Incidents

Diesel fuel will be delivered to site by a tanker truck. The tanker truck will park adjacent to the diesel tank and transfer the fuel using a flexible hose. A tanker mounted pump will be used to transfer the fuel under the continuous monitoring of the tanker driver. In the event of a hose failure (leak or rupture), the tanker driver will immediate initiate the emergency shut-down button on the tanker truck. This will isolate the fuel supply and prevent further spill. As the truck will be located outside the tank bund, there is a potential for the fuel to escape from the transfer area and into the environment. Hence, **it is recommended that a speed-hump type bund be located around the area where the tanker truck transfers fuel**. This will reduce the risk of spill to the environment and maintain the risk within the ALARP range.

Vehicles (front end loader and forklift truck) will also be refuelled adjacent to the diesel tank. These vehicles will park alongside the tank and the driver will fill the vehicle fuel tank using a bowser type filling nozzle (i.e. similar to refuelling in a service station). During filling of vehicles, there is a potential for a spill to occur, resulting in release to the environment. However, based on the recommendation made above, spills would be retained within the "speed-hump' type bund and would not escape offsite. Hence, there would be no impact to the environment.

In the unlikely event a spill of fuel is ignited, there is a potential for a fuel fire in the containment area around the fuel transfer point (i.e. tank filling and vehicle refuelling area). A pool fire would then occur in this area, causing heat radiation that could impact offsite. Hence, this incident has been carried forward for further analysis.

4.3 Summary of Ha ardous Incident Analysis

Based on the above analysis, the risks associated with the gas system operations are considered to be low and within the ALARP range, hence, no further analysis is considered necessary for the gas components and equipment.

It was identified that diesel spills could be ignited, resulting in pool fires that could radiate heat offsite above levels permissible in the accepted criteria documents (Ref.4). Two incidents were considered for further analysis, these have been carried forward into the consequence assessment section of the study.

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5.0 Consequence Analysis

5.1 Incidents Carried Forward for Consequence Analysis

The following incidents were carried forward for consequence analysis:

- Diesel spill during refuelling of tanks, ignition and fire in the vicinity of the refuelling tanker; and
- Diesel spill into the tank bund, ignition and pool fire in the bund.

Each incident is assessed in detail in the following sections.

5.2 Postulated fire incidents

There are two potential fire incidents associated with the diesel storage; tank bund fire and fuel transfer fire.

In the event of a release of diesel into the tank bund, the bund may fill with the full tank contents (5,000 L) resulting in a full bund fire. The diesel bund will be about 4m equivalent diameter, the recommended diesel refuelling point bund (speed-hump) would be 3m x 2m = 6m^2 (or equivalent pool diameter of 2.8m). Hence, the largest fire at the diesel storage would be the diesel tank bund fire. As the two fires would be within close proximity of one another, only the largest fire has been assessed, as this will provide the worst case scenario.

5.3 Diesel Bund Fire

A detailed assessment of the diesel bund fire has been provided in **Appendix B**. The analysis conducted in this appendix indicates that heat radiation at the site boundary would occur at a level of less than 2 kW/m^2. The acceptable heat radiation criteria at the site boundary is 4.7kW/m^2 (Ref.4). Hence, there would be no impact at the site boundary that would exceed the acceptable heat radiation criteria. **Table 5.1** shows the heat radiation impact from a diesel tank bund fire at selected distances from the bund.

Based on this analysis, the proposed fuel storage facilities would not exceed the acceptable risk criteria published by the DoP (Ref.4) and, therefore, no further analysis has been performed for this scenario.

Table 5.1 – Distance to selected heat radiation impact levels diesel storage area bund fire

Heat Radiation Level (kW/m^2)	Distance (m) from Diesel Storage Bund
35	6.2
23	7.1
15	8.3
12.5	8.9
8	10.5
6	11.8
4.7	13
2	18.7

Notwithstanding the analysis conducted above, to ensure the risks are maintain within the ALARP range, it is recommended that the existing site emergency plan be updated to include response to potential emergencies that may occur in the new facility.

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6.0 References

Table 6.1: References

Reference Number	Reference
Ref 1	*Applying SEPP 33 (1994), "Hazardous and Offensive Development Application Guidelines", Department of Planning, NSW*
Ref 2	*The Australian Code for the Transport of Dangerous Goods by Road and rail (known as the Australian Dangerous Goods Code of ADG), 7th ed. 2007, Federal Office of Road Safety (Canberra, ACT)*
Ref 3	*Tweeddale, H.M. (1993), "Hazard Analysis and Reduction", University of Sydney, School of Chemical Engineering*
Ref 4	*Hazardous Industry Planning Advisory Paper No.4 (1992) – Risk Criteria for Land Use Safety Planning, NSW Department of Planning*
Ref 5	*Lees, F.P.(2005), Loss Prevention in the Process Industries, Butterworth-Heinemann, London*

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Appendix A

Hazard Identification Table

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NCIA TILE FACTOR – HA ARD IDENTIFICATION TABLE			
Area	**Identified Ha ard**	**Consequence**	**Safeguard**
Gas let-down and metering station	Gas leak and immediate ignition	Jet fire, heat radiation offsite to adjacent properties	• spiral wound gaskets used in flanges (prevents blow out) • system pressure test at commissioning • regular maintenance and inspection • remote system pressure monitoring (Jemina Gas) • Remote & open air location of the station • External corrosion protection provided for underground pipelines (yellow jacket)
	Gas leak and delayed ignition	Gas cloud explosion or flash fire	• spiral wound gaskets used in flanges (prevents blow out) • system pressure test at commissioning • regular maintenance and inspection • remote system pressure monitoring (Jemina Gas) • Remote & open air location of the station • External corrosion protection provided for underground pipelines (yellow jacket)
Main gas supply pipeline to the tile manufacturing equipment	Gas leak, immediate ignition	Jet fire, heat radiation offsite to adjacent properties	• Low pressure pipeline (<200kPa) • System pressure test at commissioning • Pipeline installed in pipe-rack within the factory (clear of potential vehicle impact) • Fully welded pipeline along the full length of the line • Large building with no confinement • Odorised gas used (i.e. readily detectable leak)
	Gas leak, delayed ignition and explosion	Gas cloud explosion or flash fire	• Low pressure pipeline (<200kPa) • System pressure test at commissioning • Pipeline installed in pipe-rack within the factory at a height of ≈3m (clear of potential vehicle impact) • Fully welded pipeline along the full length of the line • Large building with no confinement • Odorised gas used (i.e. readily detectable leak) • Gas is buoyant (lighter than air), low potential to form gas cloud
Spray drier burners	Gas leak and immediate ignition	Jet fire in valves and metering equipment adjacent to the spray drier	• Low pressure pipeline (<200kPa) • System pressure test at commissioning • Valves and metering equipment installed well clear of traffic zones at a

NCIA TILE FACTOR – HA ARD IDENTIFICATION TABLE			
Area	**Identified Ha ard**	**Consequence**	**Safeguard**
			height of ≈2.5m (no impact damage potential) • Odorised gas used (i.e. readily detectable leak) • Regular checks and inspections of gas equipment
	Gas leak, delayed ignition and explosion	Gas cloud ignites and explodes within the factory	• Low pressure pipeline (<200kPa) • System pressure test at commissioning • Valves and metering equipment installed well clear of traffic zones at a height of ≈2.5m (no impact damage potential) • Large building with no confinement • Odorised gas used (i.e. readily detectable leak) • Regular checks and inspections of gas equipment
	Flame out in drier	Gas continued to feed to the drier, delayed ignition and explosion	• Burner management system installed, incorporating: - Flame detectors (x2) - Automated gas isolation valves (x2) - Manual isolation valves • Odorised gas (leak readily detected by smell) • Low pressure pipelines (<200kPa) & low leak rate
Glazing drier burners	Gas leak and immediate ignition	Jet fire in valves and metering equipment adjacent to the spray drier	• Low pressure pipeline (<200kPa) • System pressure test at commissioning • Valves and metering equipment installed well clear of traffic zones at a height of ≈2.5m (no impact damage potential) • Odorised gas used (i.e. readily detectable leak) • Regular checks and inspections of gas equipment
	Gas leak and delayed ignition	Gas cloud ignites and explodes within the factory	• Low pressure pipeline (<200kPa) • System pressure test at commissioning • Valves and metering equipment installed well clear of traffic zones at a height of ≈2.5m (no impact damage potential) • Large building with no confinement • Odorised gas used (i.e. readily detectable leak) • Regular checks and inspections of gas equipment

NCIA TILE FACTOR – HA ARD IDENTIFICATION TABLE			
Area	**Identified Ha ard**	**Consequence**	**Safeguard**
	Flame out in drier	Gas continued to feed to the drier, delayed ignition and explosion	• Burner management system installed, incorporating: - Flame detectors (x2) - Automated gas isolation valves (x2) - Manual isolation valves • Odorised gas (leak readily detected by smell) • Low pressure pipelines (<200kPa) & low leak rate
Kiln burners	Gas leak and immediate ignition	Jet fire in valves and metering equipment adjacent to the spray drier	• Low pressure pipeline (<200kPa) • System pressure test at commissioning • Valves and metering equipment installed well clear of traffic zones at a height of ≈2m (no impact damage potential) • Odorised gas used (i.e. readily detectable leak) • Regular checks and inspections of gas equipment
	Gas leak and delayed ignition	Gas cloud ignites and explodes within the factory	• Low pressure pipeline (<200kPa) • System pressure test at commissioning • Valves and metering equipment installed well clear of traffic zones at a height of ≈2m (no impact damage potential) • Large building with no confinement • Odorised gas used (i.e. readily detectable leak) • Regular checks and inspections of gas equipment
	Flame out in drier	Gas continued to feed to the drier, delayed ignition and explosion	• Burner management system installed, incorporating: • Flame detectors (x2) • Automated gas isolation valves (x2) • Manual isolation valves • Odorised gas (leak readily detected by smell) • Low pressure pipelines (<200kPa) & low leak rate
Diesel fuel tank	Tank leak into the bund, diesel ignition	Pool fire in the bund radiating heat to the surrounding area (potential offsite heat radiation impact	• Diesel fuel tank is bunded, limiting fire spread • Fire hydrants, hose reels and extinguishers installed throughout the site • Limited fuel quantity (5,000L) minimising fire duration • Site is staffed 24 hours, with staff in

NCIA TILE FACTOR – HA ARD IDENTIFICATION TABLE			
Area	**Identified Ha ard**	**Consequence**	**Safeguard**
			attendance in the fuel storage area for the majority of the time
Diesel refuelling	Refuelling line leak, diesel pool and ignition and fire	Pool fire in the refuelling area, radiating heat to the surrounding area (potential offsite heat radiation impact	• Refuelling area is bunded to limit the spread of spills • Operator is present during refuelling and tank filling operations • Fire hydrants, hose reels and extinguishers installed throughout the site • Limited fuel quantity (3,500L) minimising fire duration

Appendix B

Consequence Analysis

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B.1 Fire Modelling

Figure B1 shows an illustration of a typical pool fire in a fuel transfer location. It can be seen from this illustration that the flame tilts with the wind directions.

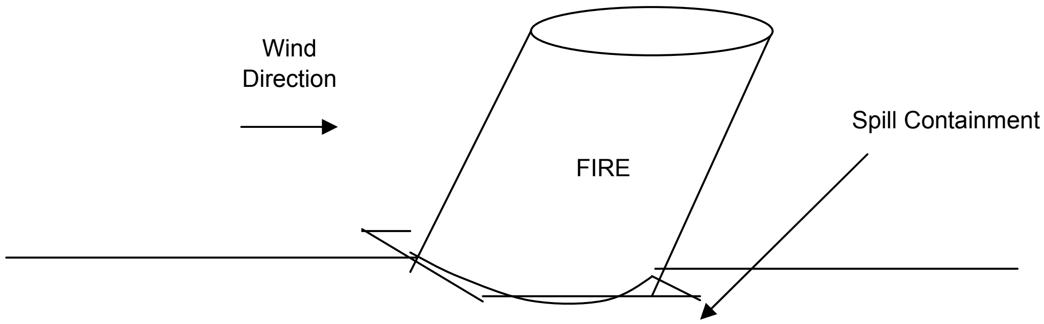

Figure B1
Example of typical fire in a bund

Whilst the spill containment may be rectangle shape, the fire will act as a cylinder within the rectangular spill containment, the flames being drawn into a cylindrical shape as a result of the updraft within the fire. Heat from the cylindrical flame radiates to the surrounding area. A number of mathematical models may be used for estimating the heat radiation impacts at various distances from the fire. The point source method is adequate for assessing impacts in the far field, however, a more effective approach is the view factor method, which uses the flame shape to determine the fraction of heat radiated from the flame to a target. The radiated heat is also reduced by the presence of water vapour and carbon dioxide in the air. The formula for estimating the heat radiation impact at a set distance is:

$Q = E\,F\,\tau$

Where: Q = incident heat flux at the receiver (kW/m^2)
E = surface emissive power of the flame (kW/m^2)
F = view factor between the flame and the receiver
τ = atmospheric transmissivity

Figure B2 shows the heat radiation path for the fire. It can be seen from this figure that flame tilt and height above ground level will have impacts on the amount of heat flux received by the target.

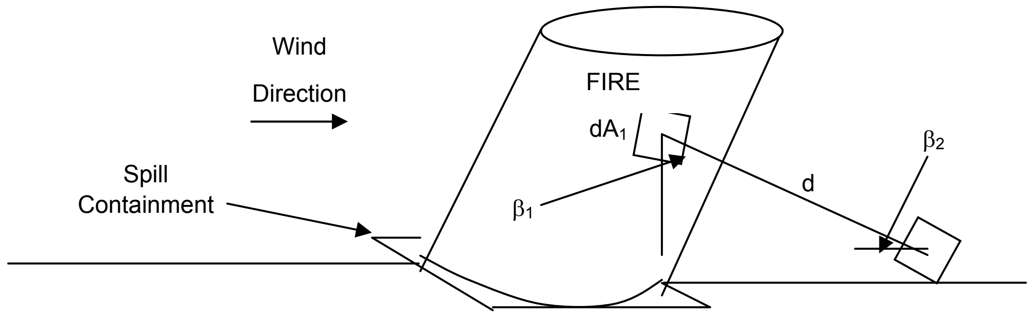

Figure B2
Heat Radiation Impact On A Target From A Cylindrical Flame

The calculation of the view factor (F) for the scenario depicted in **Figure B2** depends upon the shape of the flame and the location of the flame to the receiver. F is calculated using an integral over the surface of the flame, S. The formula can be shown as:

$$F = \iint_S \frac{\cos\beta_1 \cos\beta_2}{\pi d^2}$$

The above formula may be solved using the double integral or using a numerical integration method in spread sheet form. This is explained in **Section B2**.

B.2 Development of the Numerical Integration Model

B2.1 Introduction

The spreadsheet calculator (SSC) determines the radiation flux experienced at a “target” originating from a cylindrical fire. It is intended typically for fires of flammable liquids (Class 3) though it can be used with any material so long as the “emissivity” of the flame is known. This is the heat flux at the surface of the flame and is given in kilo Watts per square metre (kW/m^2). The other parameters needed are: diameter of the fire, height of the fire walls, distance to target, height of flame, tilt of flame caused by wind. It is assumed that the walls have some height although there is no reason not to use the calculator for pool fires at ground level by entering a zero height.

B2.2 Design Basis

The SSC is designed on the basis of finite elements. The fire is assumed to be in the shape of a cylinder of the same diameter as the equivalent pool diameter. The height of the fire can be calculated using the following formula:

$$L = 42D\left(\frac{m}{\rho_o (gD)^{0.5}}\right)^{0.61}$$

Formula B1 (Ref.5)

where: L= mean flame height (m)
D= pool diameter (m)
ρ_o= ambient air density (typically 1.2 kg/m^3)
m= mass burning rate (kg/m^{2}s) = 0.0667, based on 5mm/min burn down rate (Ref.3)
g= acceleration due to gravity (9.81 m/s^2)

Once the flame height is known, the surface of the cylinder can be divided into many separate plane surfaces. To do this, a plan view of the fire was drawn and the relevant distances and angles allocated. The plan view is for the target and the base of the fire in the same horizontal plane.

The angle “theta” is varied from zero to 90 degrees in intervals of 2.5 degrees. Zero deg. represents the straight line joining the centre of the tank to the target (x0, x1, x2) while 90 deg. is the point at the extreme left hand side of the fire base. In this way the fire surface is divided up into elements of the same angular displacement. Note the tangent to the circle in plan. This tangent lies at an angle, gamma, with the line joining the target to where the tangent touches the circle (x4). This angle varies from 90 deg at the closest distance between the tank and the target (x0) and gets progressively smaller as theta increases. As theta increases, the line x4 subtends an angle phi with x0. By similar triangles we see that the angle gamma is equal to 90-theta-phi. This angle is important because the sine of the angle give us the proportion of the projected area of the plane. When gamma is 90 deg, sin(gamma) is 1.0, meaning that the projected area is 100% of the actual area.

Before the value of theta reaches 90 degrees the line x4 becomes tangential to the circle. The fire cannot be seen from the rear and negative values appear in the view factors to reflect this. The SSC filters out all negative contributions.

For the simple case, where the fire is of unit height, the view factor of an element is simply given by the expression:

VF = ∆A. sin(gamma)/(π. x4. x4) .... Eq 1

where ∆A is the area of an individual element at ground level.

Note the denominator (π. x4. x4) is a term that describes the inverse square law for radiation assumed to be distributed evenly over the surface of a sphere.

Applying the above approach, we see the value of x4 increase as theta increase, and the value of sin(gamma) decreases as theta increase. This means that the contribution of the radiation from the edge of the circular fire drops off quite suddenly compared to a view normal to the fire. Note that the SSC adds up the separate contributions of Eq 1 for values of theta between zero until x4 makes a tangent to the circle.

It is now necessary to do two things: (i) to regard the actual fire as occurring on top of a fire wall (store) and (ii) to calculate and sum all of the view factors over the surface of the fire from its base to its top. The overall height of the flame is divided into 10 equal segments. The same geometric technique is used. The value of x4 is used as the base of the triangle and the height of the flame plus the tank, as the height. The hypotenuse is the distance from target to the face of the flame (called X4'). The angle of elevation to the element of the fire (alpha) is the arctangent of the height over the ground distance. From the cos(alpha) we get the projected area for radiation. Thus there is a new combined distance and an overall equation becomes:

VF = ∆A. sin(gamma).cos(alpha)/(π. x4'. x4') .... Eq 2

The SCC now turns three dimensional. The vertical axis represents the variation in theta from 0 to 90 deg representing half a projected circle. The horizontal axis represents increasing values of flame height in increments of 10%. The average of the extremes is used (e.g. if the fire were 10 m high then the first point would be the average of 0 and 1 i.e. 0.5 m), the next point would be 1.5 m and so on).

Thus the surface of the flame is divided into 360 equal area increments per half cylinder making 720 increments for the whole cylinder. Some of these go negative as described above and are not counted because they are not visible. Negative values are removed automatically.

The sum is taken of the View Factors in Eq.2. Actually the sum is taken without the ∆A term. This sum is then multiplied by ∆A which is constant. The value is then multiplied by 2 to give both sides of the cylinder. This is now the integral of the incremental view factors. It is dimensionless so when we multiply by the emissivity at the "face" of the flame, which occurs at the same diameter as the fire base (o pool), we get the radiation flux at the target.

B2.3 Analysis Results

Prior to the development of the model, parameters were developed (e.g. pool equivalent diameter, flame height, SEP, wind tilt, etc.). Pool equivalent diameter has been estimated as 14.3m (see **Section B2.1**).

Flame Height:

$$L = 42D\left(\frac{m}{\rho_0 (gD)^{0.5}}\right)^{0.61}$$

where:
- L= mean flame height (m)
- D= pool diameter (m)
- ρ_o= ambient air density (typically 1.2 kg/m^3)
- m= mass burning rate (kg/m^{2}s) = 0.0667, based on 5mm/min burn down rate (Ref.3)
- g= acceleration due to gravity (9.81 m/s^2)

Using a diameter of 3m, the flame height is 7.7m.

Wind Tilt has been estimated to be 30^{o}C.

Surface Emissive Power (SEP)

SEP is a function of the fire magnitude (i.e. diameter and height), which governs the amount of heat at the surface of the fire. Larger fires tend to generate larger quantities of soot or smoke, which shields the more luminous components of the flame. Large diameter pool fires average an SEP of about 20kW/m2. The average SEP of an 80m kerosene fire is about 10kW/m^2, suggesting the correlation is conservative (Ref.3).

From the correlation of Mudan (Ref.5) the following formula may be developed for calculating the SEP of a flame:

SEP = SEPm exp(-sD) + Es (1-exp(-sD))

Where:	SEP =	the total surface emissive power of the flame
	SEPm =	the maximum surface emissive power of luminous spots on a large hydrocarbon fuel flame (140kW/m^2)
	SEPs =	the surface emissive power of a smokey flame (20kW/m^2)
	S =	0.12m-1 (an experimentally determined parameter)
	D =	diameter of the pool

Based on the above formula, the calculated SEP for the diesel fire is 103.7kW/m^2.

Transmissivity

Transmissivity is the reduction in heat radiation due to the presence of water vapour and carbon dioxide in the atmosphere between the radiation source and the target. This can be calculated using the following formula:

Transmissivity = $1.006 - 0.01171(\log10X(H_2O) - 0.02368(\log_{10}X(H_2O)))^2 - 0.03188(\log_{10}X(CO_2) + 0.001164(\log_{10}X(CO_2)))^2$

Where:	$X(H_2O)$ =	(RH x L x Smm x 2.88651 x 102)/T
	$X(CO_2)$ =	L x 273/T
	RH =	relative humidity
	L =	path length in metres
	Smm =	saturated water vapour pressure in mm mercury (= 17.535 @ 293K)
	T =	temperature in degrees Kelvin (293K)

The distance the diesel bund is about 25mm, relative humidity is selected as 70% (0.7). Using these values and the values listed above, the transmissivity parameter is calculated to be 0.8.

Summary of Inputs to the SCC Model

Using the methodology presented in **Section B2** the following inputs have been developed for the heat radiation model.

Fire Diameter	3m
Fire height7.7m	
Flame tilt	30 degrees
SEP	103.7 kW/m^2
Transmissivity	0.8 (at 25m)

B.3 Consequence Analysis (SCC Model Results)

The SCC model was entered into a Microsoft Excel spread sheet and the data above input to the model. A heat radiation level of 4.7kW/m^2 was selected and the distance to this level of heat radiation was estimated to be 30.1m. **Table B1** shows the distances to selected values of heat radiation.

Table B1 – Distance to selected heat radiation impact levels diesel storage area bund fire

Heat Radiation Level (kW/m^2)	Isotainer Storage Distance (m)
35	6.2
23	7.1
15	8.3
12.5	8.9
8	10.5
6	11.8
4.7	13
2	18.7

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