

## Session 3: Avoiding electrical equipment in hazardous areas

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### Abstract

In minerals processing and mining industries people are not generally familiar with the requirements for electrical equipment in hazardous areas. It can be hard to achieve and maintain compliance to the standards.

This paper presents the results of a recent review of hazardous areas at an iron ore mine site in the Pilbara region.

The review demonstrated that the extent of the hazardous areas at the mine site could be reduced dramatically by eliminating hazards through pre-emptive design.

### Introduction

**Safety in Design** is:

*‘a process defined as the integration of hazard identification and risk assessment methods early in the design process to eliminate or minimise the risks of injury throughout the life of a structure being designed. It encompasses all design including facilities, hardware, systems, equipment, products, layout and configuration.’<sup>1</sup>*

The handbook ‘*Principles of Good Work Design*’ published by Safe Work Australia explains that:

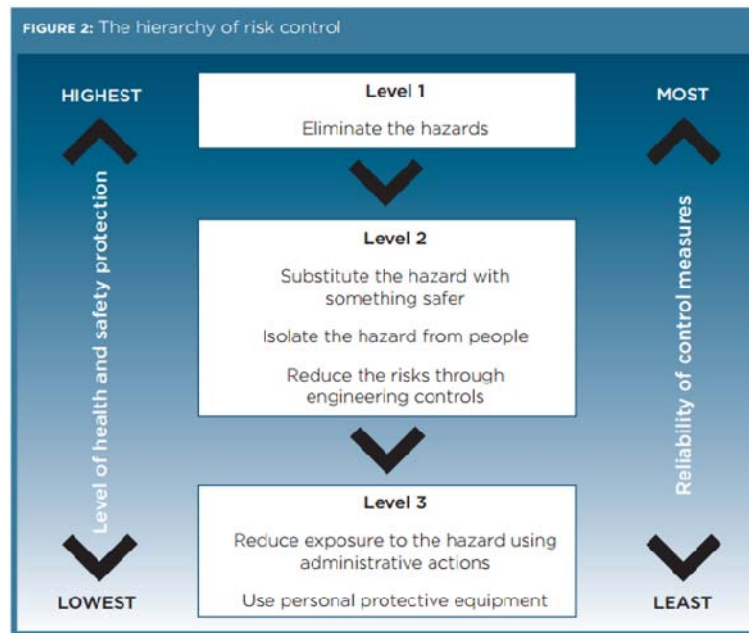
*‘Good work design gives the highest level of protection so far as is reasonably practicable [...in...] prevention of workplace injury and illness.’<sup>2</sup>*

Some people prefer to ‘err on the safe side’ by being conservative in classifying areas as hazardous with respect to explosive atmospheres. Applying unnecessary area classification does not improve safety. It is not consistent with the Safety in Design process.

In practice it can be difficult to maintain compliance of electrical equipment in hazardous areas (EEHA). This is particularly true at facilities such as iron ore mines. People outside of the hydrocarbons industries are not usually familiar with EEHA requirements.

The Australian standards for classification of areas for explosive atmospheres make it clear that **the first priority should be to eliminate hazards.**<sup>8</sup>

This principle is fully consistent both with Safety in Design and with the ‘hierarchy of risk control’ promoted by Safe Work Australia.<sup>3</sup>



Where it is not practicable to eliminate the risk of explosive atmospheres the next priority should be to **reduce the extent of hazardous areas as far as practicable**.

Reducing risks through **engineering controls** is the next best option, though it will be less reliable and generally more expensive. Electrical equipment in hazardous areas requires strict controls on design, installation, inspection and maintenance. It is always difficult and expensive to maintain electrical equipment in hazardous areas.

Reducing risks through **administrative controls** should be seen as a last resort. Electrical equipment in hazardous areas depends heavily on administrative controls to ensure continuing integrity.

## Electrical Equipment in Hazardous Areas

Electrical equipment for hazardous areas achieves risk reduction through 'engineering controls'. The electrical equipment is designed to limit the probability of ignition of flammable vapours or dusts through limiting these possible causes of ignition:

- Surface temperature
- Spark ignition energy
- Risk of loose connections
- Risk of overheating due to leakage currents
- Radiated energy emission.

The effectiveness of these ignition protection techniques depends heavily on administrative controls:

- Certification of equipment
- Inspection and maintenance procedures
- Competency management for designers, maintainers, inspectors
- Documentation dossiers
- Records of inspection and maintenance.

In practice many operators find that it is difficult to maintain a good level of compliance. This is particularly true in industries such as minerals extraction where most people are not familiar with hazardous area requirements.

## The scope of the review

In 2002 a hazardous area classification was prepared for a mine site in the Pilbara region. The classification identified numerous hazardous areas in and around the mine site.

In 2014 the operator of the mine site identified that remedial work was necessary for some of the electrical equipment in the hazardous areas.

The hazardous area information dossier was incomplete and needed to be updated. Inspection and maintenance plans needed to be prepared. Inspection and maintenance records needed to be completed and stored in the dossier.

The electrical engineers at the mine site suspected that the 2002 hazardous area classification may have been overly conservative. In 2015 they engaged I&E Systems to review the area classification and the state of the equipment and the information dossier.

## Materials

The review considered the extent of hazardous area zoning with respect to a number of different materials:

- Ammonium nitrate dust
- Ammonium nitrate emulsion
- Biogas (methane, hydrogen sulphide)
- Diesel fuel
- Flammable liquids storage (solvents, paints)
- Gas bottle storage (LPG, acetylene)

## Review results

### Ammonium nitrate

The author of the 2002 classification study admitted to a lack of knowledge with regard to the flammability of ammonium nitrate. The area zone classification for ammonium nitrate was left on hold in that study.

Material safety data sheets and standard industry references make it clear that ammonium nitrate is not flammable. It cannot give rise to explosive vapour or dust. The melting point of ammonium nitrate is 170 °C. Ammonium nitrate begins to decompose above 170 °C

The CSBP MSDS IF1875 states that:

*Ammonium nitrate is not flammable under normal applications and is not considered a fire risk, but will support combustion in an existing fire by liberating oxygen – even if smothered. It is for this reason that fires involving ammonium nitrate cannot be extinguished by the prevention or air ingress (for example, smouldering with steam) because of the in situ provision of oxygen from the ammonium nitrate itself.*

*Thermal decomposition may result in toxic gases, such as oxides of nitrogen and ammonia, being produced.*<sup>10</sup>

Ammonium nitrate becomes dangerous when exposed to fire. It supports combustion because on decomposition it produces nitrous oxides which are powerful oxidizing agents.

The BIA Report 13/97 from the IFA (Institut für Arbeitsschutz, a German institute for work safety) records that ammonium nitrate has an ignition temperature of 520 °C. When heated above 520 °C it will decompose explosively.<sup>5</sup>

The explosion at the West Fertilizer Company in Texas resulted from a fire. The initial decomposition of ammonium nitrate exacerbated the fire. Subsequent explosive decomposition of ammonium nitrate caused the explosion.

Explosion may result when road trains transporting ammonium nitrate are involved in a traffic accident. If a fire starts with spilt fuel combustion may be accelerated by the ammonium nitrate. Explosion occurs subsequently if the fire heats the ammonium nitrate to above 520 °C.

Ammonium nitrate becomes explosive when it is mixed with combustible chemicals such as diesel fuel. Explosion requires either detonation or fire.

EEHA techniques would not provide any protection against the risk of fire or explosion of ammonium nitrate.

The first priority must be to keep ammonium nitrate separate from any potentially combustible materials and protected from fire. There is no benefit in applying area classification.

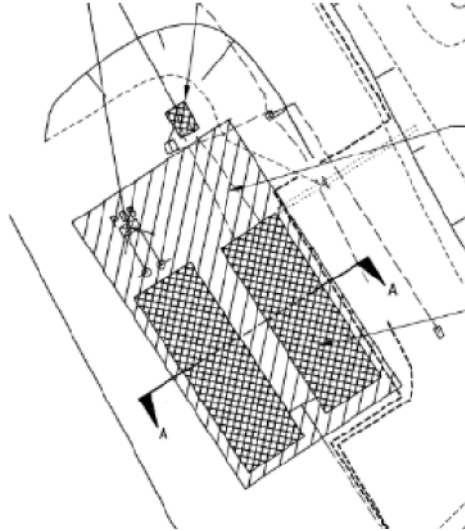
## **AMMONIUM NITRATE STORAGE**



## Biogas

The 2002 classification study identified that sewage might give rise to 'biogas', which is a mixture of methane, carbon dioxide and hydrogen sulphide. The study applied a blanket zoning around the waste water treatment plant.

### BLANKET AREA ZONING AROUND A WASTE WATER TREATMENT PLANT



In practice sewage only gives rise to biogas under anaerobic ('septic') conditions. The treatment plant at this mine site uses an aerobic process.

Biogas might be given off if the treatment plant were to fail and the process turned septic.

However the toxicity of hydrogen sulphide makes the biogas lethal at levels far below the concentration at which it would be flammable. It is more appropriate to eliminate the toxicity hazard than to design the equipment for an explosive atmosphere.

The first priority must be to prevent the generation and accumulation of hydrogen sulphide and methane.

At this mine site the treatment plant is completely open and well ventilated. Even in the event of equipment failure flammable or toxic atmospheres will not accumulate.

The entire area can be declassified.

## AEROBIC WASTE WATER TREATMENT PACKAGE



### Other examples of toxicity over flammability

Similar examples where toxicity has to take precedence over flammability can be found in other applications on mine sites.

On decomposition xanthates give rise to carbon disulphide. Although carbon disulphide is flammable it is extremely toxic at levels far below its flammable limit.

Ammonia gas is another example of a flammable gas that can be found in industrial applications such as refrigeration. Again, the toxicity of ammonia is of much greater concern than its flammability.

The priorities in a hierarchy of risk controls should be to:

- Eliminate the use of toxic or flammable materials
- Prevent the release of toxic or flammable materials
- Prevent the accumulation of toxic or flammable materials, or ensure safe dispersal.

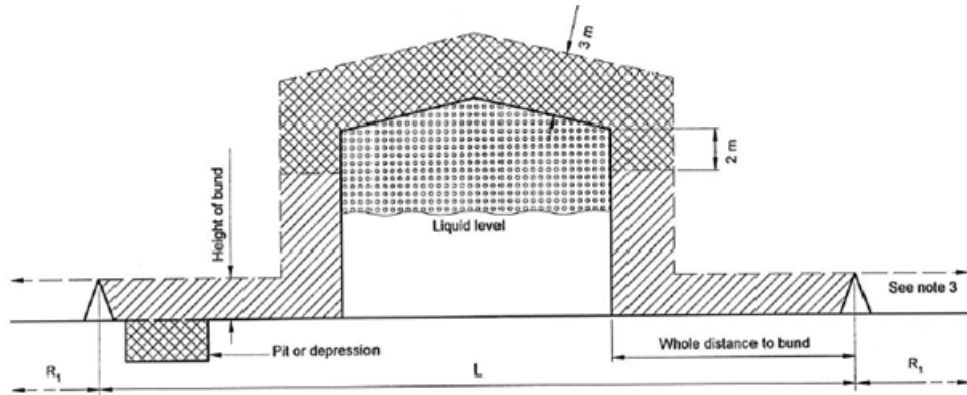
Applying EEHA standards for electrical equipment in these situations is of little value in reducing the risk to personnel because it does not mitigate the toxicity hazard.



## Diesel fuel

The 2002 classification study stipulated extensive hazardous areas around all of the diesel storage and handling facilities at the mine site.

### HAZARDOUS AREA ZONING AROUND DIESEL STORAGE



### TYPICAL MINE SITE DIESEL STORAGE TANK



## TYPICAL MINE SITE DIESEL FILLING STATION



The zoned areas affected a large quantity of electrical equipment.

Compliance to the EEHA standards for this equipment requires a significant amount of work in design and installation as well as in ongoing inspection and maintenance.

In many of the situations that we inspected we found that certified equipment had been installed, but it had not been installed and maintained in accordance with the standards.

The example in the photograph below shows several non-compliances. The stop button is not certified. The junction box is certified to US standards rather than IEC or Australian standards. One of the bolts securing the lid of the junction box is loose.

It would be an expensive exercise to upgrade the installation to achieve compliance.



## NON-COMPLIANT EX-RATED DIESEL PUMP INSTALLATION



### The case for de-classifying diesel fuel storage facilities

The IDC Technologies 'Hazardous Areas WA' Conference in Perth, March 2015 included a presentation titled '*A Case Study: Hazardous Area Considerations for Diesel Storage in a Hot Climate*' by D. Bianchini, J. Van Staden and H Cox.<sup>4</sup>

The paper established that diesel fuel cannot usually give rise to flammable atmospheres under normal storage and handling.

The specifications for diesel fuel used in Australia stipulate a flash point of at least of 61.5 °C.

The flashpoint is defined as the temperature at which a compound gives off sufficient vapour to ignite in air. Below this temperature the vapour will not ignite. The EEHA standards suggest a margin of 5 °C for safety, so below about 56 °C we can be confident that diesel fuel vapour will not ignite.

Bianchini, Van Staden and Cox reviewed the temperatures that are likely to occur within diesel storage tanks exposed to sunlight in the Pilbara region. They concluded that diesel with a flashpoint below 60 °C might give rise to flammable mixtures in the vapour space of storage tanks when the ambient temperature exceeds 43 °C. Outside the tank vapour space vents flammable mixtures might extend for only a few centimetres. Natural ventilation provides effective dispersion and dilution.

In practice there can be wide variations in flashpoint. Australian refiners and importers typically specify a minimum flash point of 64 °C. Automotive diesel is blended to suit the requirements of regional climates and the seasons of the year. Winter grade diesel supplied to Tasmania will have a lower flashpoint than fuel supplied to the Pilbara in summer.

A Discussion Paper on Operability Fuel Parameters (Petrol and Diesel) published in 2001 by Department of Industry, Science and Resources noted that:

*Flash point of diesel is not specified in Australian standard AS357-1998 but is controlled by each of the Australian refiners and importers through their own standards or specifications which typically specify a minimum flash point of 64°C when measured in accordance with ASTM D93.*<sup>6</sup>

The discussion paper quoted 1999 statistics from an Australian Institute of Petroleum (AIP) report with flashpoint levels for diesel as:

Maximum: 104 °C

Minimum: 62 °C

Average: 80 °C

In our review we suggested two possible paths:

- If the fuel might be supplied with a flashpoint of 61.5 °C or lower in summer a zoned area would be necessary only within the tank vapour space and not outside the tank. The zoned area would only affect the level sensors in the tanks, about a dozen devices in total across the whole mine site.
- If the fuel could be guaranteed to have a flashpoint of 68 °C in summer the hazard could be eliminated.

A mining operator that buys fuel in shipments that are worth well over \$1M should be able to specify fuel quality standards to its suppliers. The fuel suppliers have similar issues in hazardous area zoning and are likely to be sympathetic.

The priorities in a hierarchy of risk controls should be to:

- Eliminate the risk of flammable atmosphere by sourcing fuel with a flashpoint appropriate for the ambient conditions
- Reduce the risk of flammable atmosphere by providing shading, insulation or reflective coatings.

The alternative approach is to apply a conservative hazardous area zoning. Not only is it much more expensive but it is less effective. It relies on engineering controls and on administrative controls.

The fuel supplier for the mine site in question confirmed that the fuel is usually supplied with flash point in the range 70 °C to 80 °C. The fuel supplier provided examples of fuel quality test certificates which showed that in winter the actual flash point was 68 °C.

## Flammable liquids storage (solvents, paints)

Flammable liquids such as solvents and paints are commonly stored in workshops on mine sites.

AS 1940-2004 covers the storage and handling of flammable and combustible liquids. It gives requirements for storage cabinets for minor storage of aerosol pressure packs and unpressurised containers. <sup>7</sup>

### TYPICAL FLAMMABLE LIQUID STORAGE CABINET



The hazardous area classification standard AS/NZS 60079.10.1:2009 includes an informative annex that has recommendations for area classification for storage cabinets as defined by AS 1940.

Containing the flammable material within appropriate storage cabinets is usually sufficient to manage the risk, provided that the ventilation is adequate.

According to AS 1940 storage of quantities up to 250 L is classed as 'minor storage'. For minor storage AS/NZS 60079.10.1 recommends a Zone 2 area that extends just 300 mm from the cabinet.

The cabinets should be positioned well clear of any electrical equipment and should be in a reasonably well ventilated area.

## FLAMMABLE LIQUID STORAGE CABINETS IN A TYPICAL WORKSHOP



The cabinets seen in this photograph are in a well ventilated situation. The total volume of material stored is small compared to the volume of the space around the cabinets.

If the cabinets are installed in confined space any vapour arising from a damaged container might accumulate to form a flammable mixture. In that situation the entire volume of the confined space would have to be treated as a zoned hazardous area.

During our inspection at the mine site we found a pair of minor storage cabinets containing flammable liquids inside a shipping container.

The shipping container had been adapted as a semi-permanent storage and had been equipped with electrical lighting.

The ventilation was limited and the lighting was not suitable for use in a hazardous area.



## FLAMMABLE LIQUIDS STORAGE INSIDE A SHIPPING CONTAINER



The priorities in a hierarchy of risk controls should be to eliminate the risk of flammable atmosphere where practicable.

Positioning the storage cabinets in a well ventilated area rather than in a confined space would reduce the hazard.

It is not appropriate to apply hazardous area zoning because it is difficult and expensive to maintain effective protection.



## Gas bottle storage

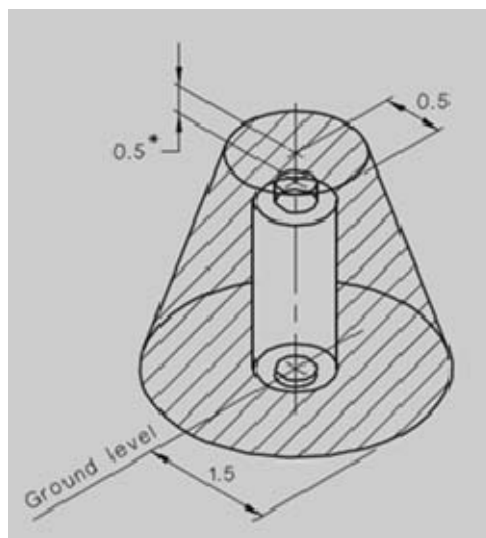
It is common practice to store large quantities of flammable gases such as propane and acetylene near workshops.

### TYPICAL STORAGE FOR BOTTLED FLAMMABLE GASES



Guidance for hazardous area zoning of gas bottle storage is given in the hazardous area classification standard AS/NZS 60079.10.1.

For the LPG cylinders a standard zoning of Zone 2 IIA T2 can be applied within the space 0.5 m above and 0.5 m laterally from any cylinder valve, extending to a distance of 1.5 m laterally at the base of the cylinder.



LPG gas is heavier than air so the zoned area extends further out at ground level than at the top of the cylinders.

Acetylene gas is slightly lighter than air, so for acetylene the zoned area extends above the bottles.

A standard zoning of Zone 2 IIC T2 can be applied for 2 m in all directions around the acetylene gas bottles.

If there are light fittings are within 2 m of acetylene bottles the electrical installation should be suitable for Zone 2 IIC T2. That would be an expensive solution and it would be difficult to maintain its integrity.

#### **UNCERTIFIED LIGHTING ABOVE ACETYLENE GAS STORAGE**



A much simpler solution might be to remove the lighting or to remove the gas bottles from the area directly under the light fittings.

If the light fittings are retained the area would need to be clearly placarded prohibiting storage of acetylene.

Regular inspections should be scheduled to ensure that the restrictions are effective.

The priority should be to reduce the hazard by providing good ventilation and by keeping electrical equipment away from sources of flammable gases and vapours.

### **Other examples of minimising hazards**

There are many other examples in industry relating to the storage and handling of potentially flammable vapours and dusts.

Over the years we have been asked to advise on area classification for materials such as:

- Flour or starch
- Coal
- Biomass (woodchips)

- Ammonia
- Xanthates
- Frothing agents

One approach is to apply equipment designed and certified to reduce dust and vapour ignition hazards.

A better approach is to eliminate the accumulation of dust or vapour and to reduce the possibility of dense clouds of dust.

With potentially flammable dusts it is better to concentrate on:

- Hygiene and housekeeping
- Dust extraction
- Dust suppression.

Electrical equipment should not be installed where clouds of flammable dust cannot be avoided.

Safety by design should be applied as the first priority in hydrocarbons and petrochemicals industries too:

- Minimise vents and drains discharging to atmosphere
- Improve ventilation
- Position air intakes in safe areas
- Eliminate Zone 1 as far as practicable
- Accept Zone 2 where it cannot be avoided, but minimise the extent
- Position electrical equipment outside Zone 1 as far as is practicable.

## Conclusions

In our review of hazardous areas at an iron ore mine site we found that some areas could be completely declassified:

- Ammonium nitrate storage
- Biogas in wastewater treatment

We found that it is inevitable that some minimal areas need to be zoned as hazardous with respect to flammable vapours. In most cases it is practicable to eliminate electrical equipment entirely from those areas.

- Flammable liquids storage (solvents, paints)
- Gas bottle storage (LPG, acetylene).

In the case of diesel fuel storage and handling we found that a case could be made for completely declassifying the areas. It may be possible to eliminate the vapour explosion hazard by sourcing fuel with a sufficiently high flashpoint.

If the flashpoint cannot be guaranteed the hazardous areas can be minimised, as described in the paper by Bianchini, Van Staden and Cox.

The choice of strategy depends on the individual situation:

- Are electrical tradesmen with EEHA competence readily available?
- Can the fuel supplier guarantee a flash point sufficiently high?
- Are test certificates available?
- Has the temperature of the tanks been measured at the maximum ambient temperatures?
- Can the storage tanks be shaded or insulated?

**Whatever strategies are chosen appropriate records must be kept to demonstrate that the risk management is appropriate and effective.**

## Safety in Design and the Hierarchy of Risk Controls

Hazardous area zoning should be carried out as part of the process design by people with expertise in the materials and processes.

As a first principle hazardous areas should be eliminated by preventing flammable vapours or dust clouds accumulating.

The safe design approach is to design the fuel to be non-flammable (as distinct from combustible) and to specify a flash point that is appropriate for the environment.

Processes should be designed to prevent accumulation of flammable vapours. For instance aerobic sewage treatment is inherently safer than septic sewage treatment.

Where hazardous areas cannot be eliminated the extent of the zoned areas should be actively minimised by design. The probability of release and the rate of release can be reduced while ventilation and dilution can be increased.

Storage facilities for flammable materials should be designed to control the quantity of possible release and to promote dispersion of vapour or gas.

Finally, as far as is practicable electrical equipment should be eliminated from areas in which flammable gas, vapour or dust hazards might occur.

This approach is consistent with the hierarchy of risk controls:

- Eliminate
- Substitute
- Isolate the hazards
- Engineering controls
- Administrative controls
- PPE

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