AUSTRALIAN MEAT PROCESSOR CORPORATION

Guide for biogas capture, storage and combustion at abattoirs

Project code:	2013/9112 (A.ENV.0160)
Prepared by:	Johns Environmental Pty Ltd.
Date Published:	April 2015
Published by:	Australian Meat Processor Corporation

AMPC acknowledges the matching funds provided by the Australian Government to support the research and development detailed in this publication.

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Abbreviations

AIT	auto-ignition temperature
ALARP	as low as reasonably practicable
AMPC	Australian Meat Processor Corporation
AS	Assets
AT	methane analyser
AWL	above water level
CAL	covered anaerobic lagoon
CPU	central processing unit
EN	environment
ESV	EnergySafe Victoria
F	frequency (for risk calculation)
FCV	flow control valve
FA	flame arrestor
FMEA	Failure Modes and Effects Analysis
FT	flow meter
H_2S	hydrogen sulphide gas
HAZID	hazard identification
HAZOP	hazard and operability study
HDPE	high density polyethylene
MAOP	maximum allowable operating pressure
LEL	lower explosive limit
LFL, 1/2LFL	lower flammable limit, half the LFL.
LOC	Loss of Containment
OTTER	Office of the Tasmanian Economic Regulator
PE	people
PES	programmable electronic system

PL	plant
PLC	programmable logic controller
S	severity (for risk calculation)
SCADA	supervisory control and data acquisition
SMP	Safety Management Plan
TOW	top of (CAL) wall
WHS(NUL)	Work Health and Safety (National Uniform Legislation)

1 Introduction

1.1 Background

Biogas is the product of anaerobic biological breakdown of organic substances. Anaerobic ponds or lagoons (the terms are interchangeable) are a common treatment step of wastewater produced from the meat industry. The technology is simple and inexpensive to operate while significantly reducing the wastewater organic loading. The by product, biogas, is both a valuable fuel and a greenhouse gas. Captured biogas can be used to fuel a boiler or for co-generation. The burning of the biogas also significantly reduces methane emissions. Hence, the covering of the anaerobic ponds has recently become popular.

The collection and handling of biogas in a covered anaerobic lagoon (CAL) from the bacterial degradation of meat processing wastewater is accompanied by a number of hazards, the most significant of which include:

- Toxicity by hydrogen sulphide gas (H_2S) presence
- Flammability of biogas when mixed with air in the appropriate proportions
- Suffocation due to the exclusion of air, especially in confined spaces.

1.2 Aims

The aims of this guide are to:

- Inform the meat processing industry and associated regulatory bodies of the hazards and risks associated with the production, storage, transport and use of biogas produced in CAL systems treating industry wastewater
- Provide recommendations for the mitigation of these risks using ALARP principles
- Provide a consistent approach for the industry across Australia
- Provide technical material helpful for companies in preparing their risk management documentation.

1.3 Scope

Since 2007 there has been a rapid introduction of covered anaerobic lagoon technology (and its associated variants) into the red meat processing industry in Australia to replace traditional anaerobic ponds which were open to the atmosphere – albeit often through a relatively thick natural floating crust. Consequently, a need has arisen to provide informative and careful advice on the hazards of this new technology and how the risks associated with these hazards can be appropriately mitigated.

The guide is focused on the identification of hazards and mitigation of the risks associated with biogas capture from CAL technology treating meat processing wastewater and downstream storage and transport of the biogas for use in a range of gas appliances.

However the Guideline is also relevant for other biogas-producing anaerobic treatment technologies such as in-vessel reactors and where anaerobic solid digestion may be used.

The terms applying to biogas and biogas-fuelled devices can be complex. Appendix 1 contains a glossary of commonly used technical terms relevant to biogas and frequently used in regulatory material.

The Guideline does not seek to cover the design, installation or operation of biogas-fuelled gas devices such as flares, boilers or cogeneration equipment. These devices and their installation are regulated in most Australian States by regulations which reference Australian Standards. Appendix 3 reviews current legislation covering biogas in Australia.

Readers are also directed to the AMPC Biogas Manual which provides a more general introduction to biogas-producing technologies and highlights information of use to meat processing personnel.

An additional resource of interest is the AMPC publication "Waste Water Management in the Australian Red Meat Processing Industry" manual (2012). This contains a section describing the management of anaerobic ponds which is complementary to this Guideline.

1.4 Regulatory Approvals for CALs

In addition to the usual requirements for planning approvals often associated with general wastewater plant installations (such as development approvals and environmental licence amendments) which typically vary from State to State, there are specific regulations which apply to biogas and its production, storage, transport and use on a meat processing site.

In Australia, biogas falls under a regulatory framework which varies significantly from State to State. Biogas regulation tends to be viewed through State-idiosyncratic lenses including:

- Dangerous goods regulations, or
- Fuel gas regulations, especially in States with a history of coal mining incidents, or
- OH&S regulations with their emphasis on duty of care and ALARP (As low as reasonably practicable) approach to risk management.

For people new to managing biogas risks, this variance in approach and knowing which State authority regulates biogas can be very confusing and makes it challenging to find the appropriate advice. Table 1 summarises the applicable legislation and the State Authority responsible for its enforcement in each State or Territory. More detail including contact details for key safety regulatory personnel in each State can be found in Table 4, Appendix 3. Care needs to be taken to ensure that the regulatory situation has not changed since the publication of this Guideline.

There are various aspects of regulation involved with industrial biogas facilities. These can be sub-divided into three groups:

1. Regulations governing the manufacture and installation of gas equipment including flares, LPG flare pilot ignition systems, boilers and gas-fired cogeneration equipment. These are collectively termed Type B appliances. Typically the vendor of such equipment will have obtained the necessary approvals and require appropriately trained personnel to install the equipment.

2. Workplace health and safety or more specific, non OH&S regulations concerning hazards associated with biogas production, storage, transport and use at a specific site. Typically these will be the responsibility of the site and will apply during construction and normal operation.
3. Environmental regulations concerning emissions from gas fuel (e.g. biogas) burning. These will be site-specific and may involve exhaust emission quality parameters being applied to the site through the environmental licence.

Appendix 3 outlines the relevant legislation and its key aspects for each State and Territory in more detail.

Table 1: Relevant regulatory authority for each State

STATE	CURRENT REGULATION	RELEVANT AUTHORITY
Qld	Petroleum and Gas (Production and Safety) Regulations 2004	Petroleum & Gas Inspectorate, Safety & Health Division, Department of Natural Resources and Mines
NSW	Gas Supply (Gas Appliances) Regulation 2012	WorkCover NSW Department of Fair Trading
Vic	Gas safety (gas installation) regulations 2008	Energy Safe Victoria
Tas	Gas Act 2000 and Gas Safety Regulations	Workplace Standards, Department of Justice, Tasmania
SA	Gas Act 1997	Office of the Technical Regulator, Department for Manufacturing, Innovation, Trade, Resources and Energy, South Australia
WA	Gas Standards (gasfitting and consumer gas installation) regulations 2000 Dangerous Goods Safety (storage and handling of non explosive) regulations 2007	Energy Safety, Department of Commerce, Resource Safety Division, Department of Mines and Petroleum
NT	Dangerous Goods Regulations	NT Worksafe Department of Justice,

1.5 Disclaimer

The guideline is provided as an advisory document for meat processing personnel and their supporting services who are considering the design, construction, operation or decommissioning of biogas-producing anaerobic wastewater treatment technologies. The content is not intended to replace the need to adopt good engineering practice principles or to be aware of the changes in regulations subsequent to the date of the Guideline, which may require additional measures to be taken.

2 History of Anaerobic Technologies in the Meat Industry

Anaerobic bacterial processes have been integral to the treatment of strong but biodegradable industrial wastewater for many decades. The meat processing industry has utilised anaerobic systems widely due to the excellent anaerobic biodegradability of its wastewater and the highly robust and cost-effective nature of these processes. The main technology variants are briefly covered below. A more detailed discussion can be found in the Biogas Manual.

2.1 Uncovered Anaerobic Ponds

Uncovered anaerobic ponds have long been used in the meat industry for wastewater treatment. These ponds treat the wastewater using the same biological activity as CALs, but are covered by a naturally formed crust consisting of floating fats and fine cellulosic particles, which may eventually host grass and reeds. These crusts can be quite thin where primary treatment is of a high standard, or may be over a metre thick where pre-treatment is cursory.

The biogas produced by these ponds escapes through fractures or vents in the crust. Consequently it is emitted into the atmosphere largely untreated, although the crust often deodorises it to a substantial extent. The loss of this biogas deprives the facility of a substantial source of energy-rich fuel. Uncovered anaerobic ponds can contribute 50% or more of the Scope 1 greenhouse emissions (according to NGER) from Australian meat processing plants.

It is worth noting that these ponds generate similar quantities of biogas to CALs and that there have been few instances of problems (such as fires, etc) with the release of biogas into the open despite numerous anaerobic ponds existing at many abattoirs in Australia.

2.2 Covered Anaerobic Lagoons

CALs are a variant of anaerobic pond technology in which the surface of the pond is covered with a synthetic geomembrane which traps the biogas for collection and use. The first CALs were installed in Australian red meat processing plants in the mid-1990s, for example at the Australia Meat Holdings Aberdeen facility and a trial CAL at Southern Meats Goulburn. Significant difficulties usually associated with crusts building up under the cover led to only a gradual implementation of this technology.

The introduction of the carbon pricing mechanism in 2012 provided an economic driver for the adoption of CALs since they provide a cost effective means for emissions abatement relative to other GHG abatement technologies. They offer other benefits including:

- Negligible offensive odour
- Potential to use the energy-rich biogas for boiler fuel and/or cogeneration to offset purchases of external forms of energy
- Improved visual amenity compared to natural ponds.

As of early 2013, at least 7 new CALs (totalling approximately 130 ML combined volume) had been commissioned at Australian red meat processing plants and/or rendering facilities since 2010, with a further 10 in the planning stage.

2.3 Vessel-based Anaerobic Reactors

High rate anaerobic reactors (digesters) have been popular for the treatment of highly soluble, biodegradable industrial wastewater since the 1980s. However, the high suspended solids and oil and grease content of meat processing wastewater and its particulate nature has meant that these reactor systems have typically performed poorly where applied to meat processing facilities.

Nevertheless, there are a few examples of successful low rate vessel reactor systems in Australia, usually at smaller plants. One example is the 3 ML reactor at BDC, Bunbury WA.

3 Description of Typical CAL in the Meat Industry

3.1 The Covered Anaerobic Lagoon

Figure 1 shows a typical covered anaerobic lagoon (CAL) in the meat industry.

The CAL typically consists of the following components:

- Impermeable liner - CALs typically have a high density polyethylene (HDPE) membrane overlain on a geotextile to prevent wastewater leakage into the subsoil. The liners are usually fixed into place with an anchor trench using the weight of earth or concrete fill to prevent movement.
- Cover - Typically HDPE is used for the construction of the CAL cover, although a variety of other plastic materials have also been used1. The cover is fixed in place by a variety of methods depending on the fabricator. An anchor trench approach is the most common rather than attachment of the cover to a concrete ring beam.
- Wastewater inlet and outlet pipes - The pipework is designed to allow the wastewater to enter and leave below the pond surface. The inlet pipework is designed to prevent short circuiting through the pond volume. The outlet pipework minimises floating solids carry-over.
- Biogas collection and discharge - A ring main around the lagoon perimeter and under the cover is often used to collect the biogas, although alternate concepts are used. A single discharge point in the ring main is common. This discharge exits the CAL either through the cover or liner.
- Biogas release valves - It is imperative that the CAL has biogas safety release mechanisms for instances where biogas is unable to exit through the conventional biogas take-off point. Examples include blockages or prolonged flare shutdown. A variety of safety release designs have been used. These range from simple pipe spears which lift out of the liquid as the cover expands, to more sophisticated mechanisms using water seals, or weighted flaps. Safety valves generally operate to allow biogas to escape to atmosphere when a preset pressure under the cover is exceeded.
- Inspection ports - Inspection ports allow access to the pond for visual inspection and instrument access during CAL operation.
- Weighting and stormwater removal system - These two systems work together to minimize stress to the pond cover. The weighting system performs two functions; it firstly minimizes wind forces on the cover by reducing the height of cover elevation exposed to the wind and secondly provides low spots for water accumulation. The stormwater removal system pumps the water away from where it accumulates. Excessive amounts of accumulated stormwater may displace large amounts of CAL treatment volume and may block pipes or biogas flow under the cover.

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[1] MLA (2009) *Anaerobic Cover Material Vulnerability*. Report A.ENV.0072. Prepared by Golder Associates, Perth.

- Sludge removal - Sludge removal systems may be installed to periodically remove accumulated sludge.

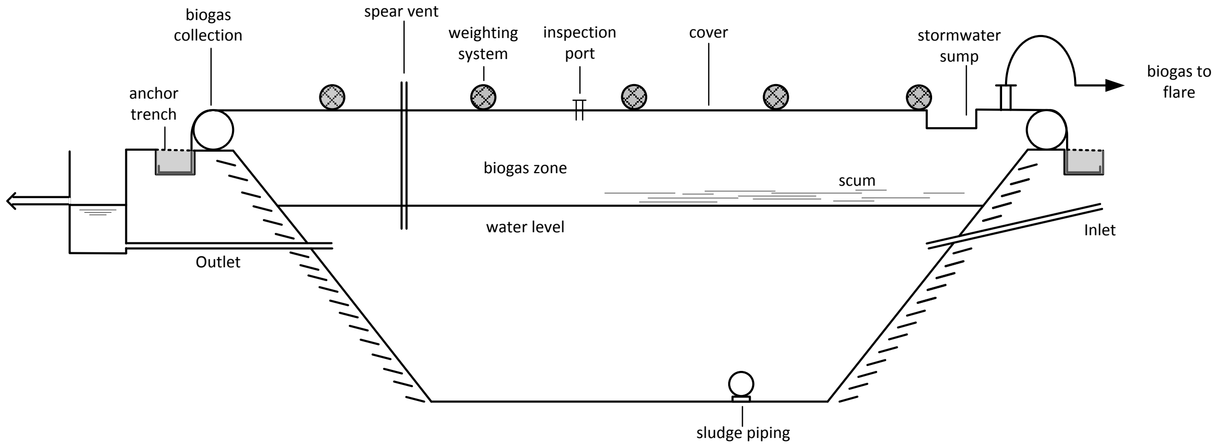

Figure 1: Schematic of typical Covered Anaerobic Lagoon.

3.2 The Biogas Capture System

The role of the biogas capture system is two-fold:

1. To capture and incinerate all biogas generated by the CAL to ensure the methane content of the biogas is converted by burning into carbon dioxide. Methane has a global warming potential of 21 times carbon dioxide. Consequently incinerating the biogas largely eliminates Scope 1 emissions from the CAL (especially since the carbon dioxide produced counts as a zero emission).

2. To ensure that all gaseous compounds with an offensive odour (H2S especially) are oxidised to odourless components.

The incineration of biogas can be accomplished several ways, but the most common methods in the Australian red meat processing industry are:

- Flaring, in which case the useful energy of the biogas is lost.

- Burning in a boiler. This method recovers the thermal energy of the biogas while simultaneously accomplishing the roles above. Emission abatement is increased in this method by the displacement of fossil fuels to equivalent energy content.

- Burning in a cogeneration engine. In this mode, biogas energy is converted into electrical energy (at about 35 – 40% efficiency). Significant heat recovery is also possible by use of heat exchangers to recover thermal energy either from the exhaust gases, or water jacket cooling or both. However, many meat processing plants are already hot water rich.

Figure 2 illustrates a typical biogas train which usually contains the following elements:

- Biogas pipeline - This conveys biogas from the CAL cover to the flare.
- Knockout pot - This is generally a stainless steel vessel situated at the lowest point of the biogas pipeline to collect water condensing from the water-saturated biogas as it cools. The water can be safely drained at this point. This protects the downstream blower and instruments from damage.
- Gas Blower - The blower provides positive pressure to convey biogas to the flare for incineration.
- Measuring devices - Typically these include a biogas flowmeter (FT) and methane analyser (AT) with output logged to the facility SCADA system.
- Flow control valve (FCV) - A PLC system typically controls biogas flow to the flare through the automated flow control valve. In many cases, the valve is controlled according to the pressure under the CAL cover permitting the flare to operate at a number of biogas flow settings. Alternately, the blower operation can be modulated.
- Slam shut valve - A fast acting safety valve system which shuts off the biogas supply in the event the flare is not functioning or loses flame.
- Flame arrestor (FA) - This safety device prevents a flame front running back through the biogas supply line.
- Flare - The flare is a device which incinerates the biogas safely. There are two main types of flare available:
  - Fully enclosed - This flare type controls the air supply to the biogas burner to ensure a hot flame for maximum odour and methane destruction. The flare is completely enclosed in a refractory shield.
  - Candlestick - This flare is a simple Bunsen-burner type flare consisting of a vertical biogas tube with burner on top. The air supply is unlimited. This type of flare may have a metal shroud around the burner to prevent wind extinguishing the flame (which otherwise requires constant re-priming of the flare). This flare is less sensitive to biogas supply, but usually generates a cooler flame associated with less complete odour and methane destruction.

- Priming System - The priming system which usually consists of a LPG cylinder to feed the flare priming system in case of the need for flare reignition.

Where the biogas is used for cogeneration in a biogas engine, or diverted for boiler fuel, the flare exists as a contingency element of the system only. Prior to consumption of the biogas for boiler or cogeneration fuel, the biogas may require conditioning. This typically includes:

- Stripping of Hydrogen Sulphide - H2S is corrosive to motors and above a low threshold concentration, reducing the level of this contaminant is commonly required. The methods vary, but at the high biogas flows typical from meat industry CALs, some sort of stripping tower is used.

- Dehumidification - The biogas is saturated with water which is undesirable for cogeneration engines. It is common to chill the biogas to remove the excess moisture by condensation.

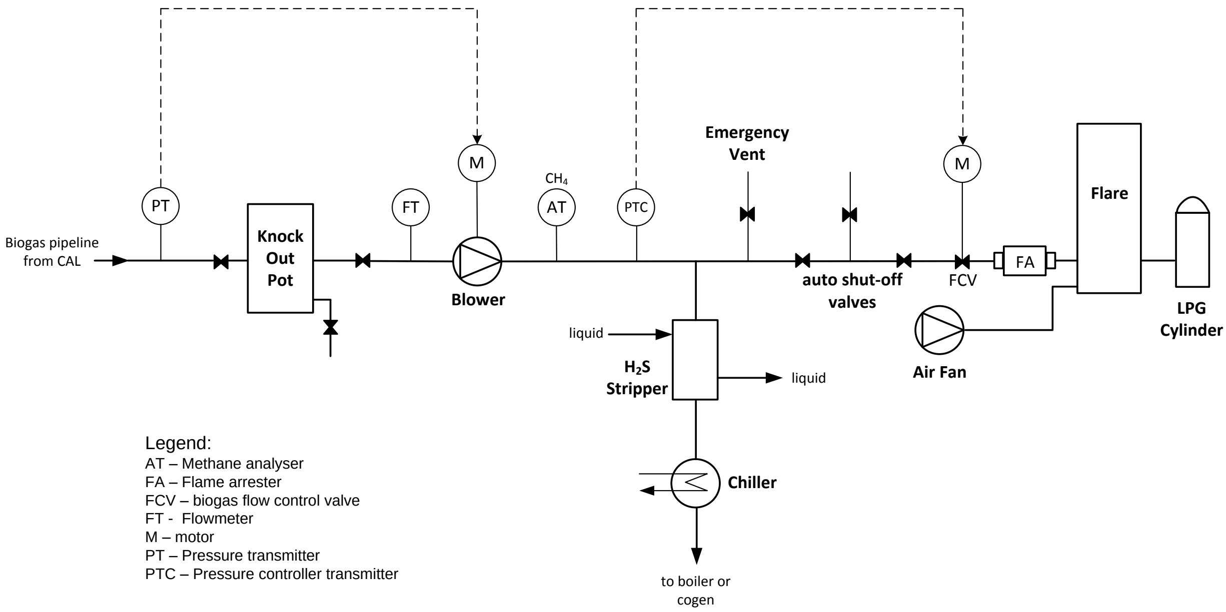

Figure 2. Schematic of typical biogas train and flare system

4 Risk Assessment

The Guidelines have been informed by a hazard and risk assessment study which considered a generic CAL biogas system. The study forms Appendix 2 of this document. The study looked at understanding the hazards and associated risks of the facility and was performed by Dr Ian Cameron of Daesim Technologies.

4.1 Approach

Standard hazard identification processes were used to elicit and document the hazards and their potential for harm to people, plant facilities and the environment. Due recognition was taken of detection methods and safeguards that are typically installed. The hazard identification (HAZID) was carried out using a combination of:

- Loss of containment (LoC)
- Failure Modes and Effects Analysis (FMEA), and
- Hazard and Operability (HAZOP) study techniques.

Risk was ranked on a qualitative 5x5 matrix combining potential impact with likelihood. This matrix is provided as Table 2; refer to Appendix 2 for the full explanation. An example of the outcome tables is provided as Table 3. The full table set is also contained in Appendix 2. These may be useful for meat processing sites in assessing risks at their facility.

The key hazards related to gas releases, possible fires and explosions. The significance of these events was considered by applying consequence analysis, where predictive models were used to estimate the impact of such events. Note was taken of past incidents both in Australia and overseas.

Table 2. Qualitative risk matrix.

CONSEQUENCE				FREQUENCY (yr^{-1})				
Increasing severity	People (PE)	Environment (EN)	Assets (AS)	A <0.001 or <1 in 1000 years	B 0.001-0.01 or between 1 in 100 to 1 in 1000 years	C 0.01-0.1 or between 1 in 10 to 1 in 100 years	D 0.1-1 or between 1 in 1 to 1 in 10 years	E >1 or >1 a year
1	Slight injury	Low pollution	Negligible damage	L	L	L	M	M
2	Minor injury	Minor pollution	Minor damage	L	L	M	M	H
3	Major injury	Moderate pollution	Moderate damage	L	M	M	H	VH
4	Fatality	Major pollution	Major damage	M	M	H	VH	VH
5	Multiple fatalities	Extreme event	Extreme damage	H	H	VH	VH	VH

Table 3. Risk table for covered anaerobic lagoons.

ITEM	HAZARD OR EVENT	POSSIBLE CAUSES	POSSIBLE CONSEQUENCES	DETECTION/PROTECTION MEASURES	RESIDUAL RISKS (S X F = R)		
					PE*	EN	AS
CAL1	Release of liquid contents from CAL	• Breach of lagoon containment wall and lining • Breach of lining and seepage to ground • Failure of tank wall (concrete systems) • Human failure on sludge recirculation system	• Release of effluent to environmentally sensitive areas • Major business interruption • Legal action by authorities or affected parties • Odour release	• Construction best practice standards for CALs • Inspection and leakage detection especially trench below liner pipe. • Isolation of spill • Spill control and recovery procedures • Emergency response procedures • Separation distances to vulnerable resources • Low probability of people in area, site layout planning • Strict control of ignition sources	1 x C = L (P_E = L)	3 x C = M	3 x C = M
CAL2	Large release of biogas from CAL	• Overpressure of CAL • Major failure of cover material • Large weld failure • Catastrophic failure of CAL fittings • Significant mechanical impact • Retaining cables cutting cover • De-anchoring of cover	• Dispersion of gas to atmosphere • Gas release and immediate ignition • Gas release and delayed ignition • Dispersion of hydrogen sulphide and possible human impacts	• Cover material standards • Inspection regimes esp. on cover seam welding • Suitable overpressure protection . • Separation distances to vulnerable resources • Low probability of people in area • Lightning protection • Strict control of ignition sources	4 x A = M (P_E =L; P_I =L)	1 x A = L	4 x A = M
CAL3	Small release of biogas from CAL	• Overpressure of CAL • Failure of cover material • Weld failure • Failure of CAL fittings • Mechanical impact	• Dispersion of gas to atmosphere • Gas release and immediate ignition • Gas release and delayed ignition • Air ingress to CAL and	• Construction standards • Inspection regimes • Pressure relief devices • Separation distances to vulnerable resources • Low probability of people in area • Open ports only when cover is flat on water,	2 x B = L (P_E =L; P_I =L)	1 x D = M	2 x D = M

		• Retaining cables cutting cover • Partial seam failure of cover with lagoon lining • Open ports in cover when inflated	potential partially confined explosion • Legal action by authorities or affected parties				

***People**: Considers the probability of a person present in the area (P_E). For gas releases, a probability of ignition (P_I) is also included. This was typically < 0.1

4.2 Summary of Findings

The findings of the study from the consequence estimates include:

1. There is little potential for major off-site impacts from fires and explosions, and hence the risks beyond the boundary are negligible. This is particularly the case given the general siting of anaerobic treatment systems and their ancillary equipment away from close proximity (e.g. more than 100 metres) to residential areas.

2. Impacts from small releases of biogas from openings in the cover of CALs (e.g. sample ports, over-pressure spears or small holes or tears) are considered low due to the low operating pressures under the cover. Modelling suggests that effect distances are typically highly localised and the biogas plume will rise rapidly and disperse.

3. Impacts from releases of biogas from biogas transmission lines between the CALs and gas users or flare systems are considered low due to the low operating pressures. Impacts can be more significant on the downstream side of the blowers where pressures are higher. The most likely issue is flame impingement on nearby equipment.

4. There are potentially more serious impacts on-site in the case of large releases of gas from CALs, and the possibility of explosion impacts from enclosed space ignition of biogas in generator set installations. Both situations have various levels of control and mitigation in place, particularly in relation to enclosed generator sets.

5. Loss of containment of biogas containing normal H2S levels (~ 0.2%v/v) is generally not problematic. However, at high H_2S concentrations (~ 5% v/v) large releases may have significant impact, especially at night.

6. Impacts from large biogas releases from CAL failures depend to a significant extent on the size of the aperture and its orientation to the ground.

   (i) Modelling suggests failures of substantial aperture such as 1m diameter disperse rapidly in the case of orientations above 20º above the horizontal and have little impact at ground level.

   (ii) Large gas releases from the cover which are near horizontal in orientation and have subsequent ground interaction can have significant distances to the LFL and ½LFL. These present a flash fire risk. This can necessitate an ignition exclusion zone around CALs of up to 40-50m in such an event.

(iii) The above outcomes from risk modelling are based on certain assumptions regarding weather conditions (wind speed and direction, etc) and site location. Local conditions may result in different outcomes. The flash fire at the Rivalea piggery CAL in January 2011 is an example where a cover tear (approx. 2-3 m in length) resulted in a large biogas plume being emitted on a very hot day. An ignition source approximately 30 – 40 m distant is thought to triggered the subsequent fire.

7. Explosion (blast) overpressures are caused by the shock wave resulting from confined biogas explosions (such as in an enclosed genset building). These can have significant on-site implications, and potential off-site impacts depending on location of the genset facility in relation to other land uses. Appropriate mitigation and control strategies are essential to ensuring that these events are prevented. Multiple failures can occur in gas detection and ventilation systems that permit explosive atmospheres to form rapidly within these facilities. Physical location of the facility on the site is important to mitigate possible impacts from explosions. Where appropriate, the use of open, covered areas to house equipment rather than fully enclosed buildings is an inherently safer design.

4.3 Conclusions

No quantitative consideration has been given to frequency of events that lead to potential impacts. Quantification is justified when the impacts can be significant and the designs are well defined. A qualitative assessment was made of hazard impacts which showed no high level risks. Human failures in operating the biogas system are a key determinant in risk control, centred on procedures and maintenance issues.

Application of inherently safer design practice can help bring risks to as low as reasonably practicable through complete elimination of hazards. That should be the aim of all designs and operations around biogas production and use.

5 Biogas Safety Guidelines

5.1 General Siting and Exclusion Zones

For many facilities the large size of the CAL and its association with wastewater treatment requires the CAL and associated equipment to be located distant from food processing operations and residents. This section outlines recommendations concerning the positioning of CALs and related equipment on the industrial site.

1. Where practicable CALs should be located on the site well away from other major ignition sources (boilers and byproducts facilities with hot surfaces), traffic and/or areas where people are working to safeguard infrastructure and personnel against the potential hazards arising from the nature of biogas. A minimum distance of 50 metres is recommended subject to site limitations.

2. As much as practicable, ignition sources should be minimised near the CAL and biogas train. These include:

   (i) Vehicles

   (ii) Electrical equipment

   (iii) Hot work (grinding and cutting operations)

   (iv) Open flames (cigarettes, matches, etc).

3. Where electrical equipment is required (for example stormwater removal, sludge or effluent pumps, motors and controls), it should be sited at least 3 metres from the edge of the cover. Electrical equipment should at minimum be suitable for operation in a Zone 2 (gases) area if within 3 m of a biogas source. Control panel enclosures should be rated IP55 minimum.

4. An exclusion zone of at least 3 metres is recommended around the CAL and associated inlet and outlet pits so as to prevent public and animal access. Animals, especially kangaroos and dingos have been known to severely damage CAL covers. The exclusion zone should be secured using a security fence. Security mesh is recommended and the fence should be at least 1800 mm in height. Exclusion of children is critical even though most CAL sites are usually remote from residences. All access points should be locked.

5. Safety signs should be erected near the main entry point to inform of the hazards and required safety measures within fenced area (See Photo 1). Recommended signage includes:

   (i) No entry – Authorised personnel only

   (ii) Exclusion of ignition sources (naked flames, smoking, etc)

   (iii) Biogas properties and hazards

   (iv) Deep tanks.

6. The biogas pipeline must be clearly identified with signage to prevent damage by third parties.

7. Tall objects such as light stands, power poles and trees should be positioned at a suitable

distance to eliminate the possiblity of their falling on the cover during storms or due to the failure of the supporting structure.

8. Vegetation should be controlled in the surrounding areas to reduce the fire risk to the cover in the case of bushfire or where a fire event occurs nearby. Where ember attack is a realistic possibility, consideration might be given to fire suppression systems to protect the CAL cover (e.g. sprinkler systems).

Photo 1: Suitable safety signs on exclusion zone.

5.2 Design for Cover Protection

The cover is the integral part of the CAL that captures the biogas. It is imperative that the cover is not compromised. Holes in the cover will not only allow loss of biogas to the atmosphere but also create a potentially hazardous environment. The cover design should include features that reduce the likelihood of damage.

1. The biogas collection system under the cover is employed to capture the biogas and transfer it to the biogas train. Meat processing CALs have a propensity to accumulate scum under the cover despite best practice pre-treatment. Biogas collection piping should be at least 500 mm above the maximum operating water level so that the risk of scum, foam or mousse entering the collection system is minimised. Gassy mousse resulting from incomplete breakdown of incoming organic load is particularly mobile and troublesome and can frequently occur during startup of CAL systems.

2. Overpressure release systems prevent cover over-inflation in the event that biogas cannot be withdrawn via the biogas train for any reason. Cover over-inflation may lead to it tearing from its fixings, or become subject to excessive wind forces. It is recommended to provide an overpressure release mechanism. Several options have been used in Australia including:

    (i) Safety spears (Photo 2). While these are simple, they are vulnerable to blockage by scum under the cover which may nullify their effectiveness and imposes additional stress on the cover. They are best placed well within the cover perimeter to avoid biogas release at angles near horizontal to the ground.

    (ii) Hydrostatic release valves (Photo 3) use a depth of liquid, typically water, to prevent biogas release below a set pressure. For most applications, 100 mm water head is sufficient to maintain less than 100 Pa.g pressure under the cover. The advantages of this device are simplicity, it is unlikely to be compromised by scums and gas release occurs remote from the CAL. The disadvantage is the requirement for constant topping up of the liquid and the small margin of error (especially on hot summer days), which can lead to excessive biogas release.

    (iii)Weighted flaps can be used instead of spears to avoid penetration below the cover. They are best placed well within the cover perimeter to avoid biogas release at angles near horizontal to the ground.

3. Cover seam welds should use split head wedge and/or extrusion welding techniques to join HDPE sheets to permit non-destructive weld testing to ensure gas tightness during construction.

4. Penetrations through either the CAL liner or cover should be reinforced to minimise the risk of tearing. This is particularly true of penetrations such as inlets, outlets and safety spears where the protuding element under the cover may become bound into undercover scum and crust leading to excessive stress on the supporting welds due to differential movement of the cover and crust.


Photo 2: Safety spears. **Photo 3: Hydrostatic release valves.**

5. Stormwater removal systems should be designed to remove large volumes of accumulated stormwater on the cover surface, which can potentially strain cover fixings and stretch the cover. In some instances excess stormwater can depress the cover to block inlets, outlets or access of biogas to the undercover biogas collection system.
6. It is recommended to avoid installing electrical items on covers such as stormwater pumps unless fitted with temperature cutouts.

Photo 4: Typical stormwater removal system.

7. Partitions fixed to the underside of the cover (such as hanging curtains or baffles) are not advised. These have a tendency over time to fold and lift up under the cover where they may block access by biogas to overpressure devices or the collection system.
8. A hazardous area analysis consistent with AS/NZ 60079.10.1:2009 Explosive aatmospheres – Classification of areas is recommended to assess the extent of suitable zones of separation of potential biogas release points from identified hazards. Where possible and appropriate, larger exclusion distances should be provided for potential ignition sources to minimise the possibility of flash fires in the event of major releases from covers.

5.3 Biogas Train Design

The biogas train includes biogas piping, blower, instrumentation, gas conditioning equipment and all biogas combustion units as shown in Figure 2.

Biogas pressures are typically low for meat processing industry CALs. Biogas pressure upstream of the blower and under the CAL cover is usually less than 0.1 kPa. In some cases it may be under negative pressure for some covers. Upstream of the blower, a typical biogas delivery pressure to the flare using centrifugal blowers is still low at less than 5 kPa. Higher pressures may be used for delivery to gas boilers and cogeneration gensets.

A hazardous area analysis is recommended for the biogas train as per item 8 of Section 5.2.

5.3.1 Biogas system: CAL to Blower

1. A manual isolation valve is recommended in the biogas pipeline adjacent to the CAL to permit isolation of the biogas train from the CAL.

2. In laying out pipe runs and equipment, due recognition should be given to potential gas releases and ignition that could lead to damage by flame on nearby objects. Typical lateral impact distances due to thermal radiation from a small jet fire (ignition of biogas leak from pipeline) are small (of the order of 3 metres or less).

3. Consideration should be given in design to isolation strategies, particularly where long biogas pipe runs are planned.

4. Consideration should be given to fire escalation if flames cause grass fires and these propagate. Open areas should have hazards minimized to reduce escalation.

5. Stainless steel pipeline construction is recommended for above ground biogas piping as it has good corrosion resistance and fire protection properties. Australian Standard AS 4645.2:2008 Steel pipe systems provides guidance for design and construction of gas piping systems, although in the context of higher gas pressures (up to 1,050 MAOP).

6. PVC and HDPE may be considered for biogas piping, but generally it is required to be underground as protection against fire risk (from external fires). Australian Standard AS 4645.3:2008 Gas Distribution Network: Plastics pipe systems provides guidance for design and construction of gas piping systems, although in the context of higher gas pressures (up to 700 kPa).

Table 4: Comparison of HDPE and Stainless Steel for Biogas Piping

CONSIDERATION	HDPE	STAINLESS STEEL
Cost	Cheaper	
Maximum operating temp (°C)	65°C. Some grades lower.	Not an issue
Corrosion resistance	Excellent	Excellent
Insulation properties	Excellent	Poor – increases biogas condensation in pipeline
Fire vulnerability	High. Some States prohibit above ground use.	Low
Field fabrication	Straightforward	Difficult

7. With plastic piping care is needed regarding the impact of high biogas temperatures. Under Australian conditions, biogas temperatures may be higher than the permitted temperature tolerance. For most HDPE pipes the operating temperature tolerance is up to 65oC, but AS 4645.3:2008 limits PE80B and PE100 pipes to operating temperatures of less than 40oC. Any biogas recirculation system must take into account heat added through the recirculation blower.

8. When working with plastic piping, there is a need to beware of static electricity discharges especially when working on the pipeline. Ensure good earthing practice (see AS 5601.1-2010).

9. Consideration must be given to handling significant amounts of condensate drainage in the pipeline due to the high degree of humidification of the biogas, which is often at elevated temperature under the cover. Condensate volume may increase substantially during periods of flare outage due to biogas cooling in above ground stainless steel piping. The pipe should grade back to the CAL or a knock out pot at a constant minimum slope of 2% to prevent accumulation.

10. A suitably designed knockout pot must be installed at low points in the biogas pipeline to remove condensate and to ensure hazards such as mousse (due to CAL biological dysfunction) or scum captured by the biogas collection system under the cover does not enter the blower. These units must be manufactured from non-combustible material.

Photo 5: Above ground stainless steel biogas pipe.

Photo 6: Knockout pot in biogas train.

5.3.2 Biogas system: Blower to the Flare

1. The biogas system downstream of the blower should be designed and installed in accordance with AS 3814-2009 (industrial & commercial gas-fired appliances) and must comply with the safety requirements of AS 1375-1985 (SAA Industrial fuel-fired appliances code). The mechanical installation must be certified by a licensed gas fitter.

2. Aspects of the design of this part of the biogas system depend in the relevant Australian Standards on the anticipated biogas fuel load – for example for the nature of the safety shut off valves. For lighter-than-air (biogas) gas rates, large meat processing plants and independent renderers treating a high proportion (>80%) of their raw wastewater through CALs, the biogas rate can be expected to fall into the range 5 – 20 GJ/h. Smaller abattoirs will typically be less than 5 GJ/hour.

3. Biogas combustion units, such as flares, boilers and cogeneration units, are classified as a Type B appliance. The design of the flare-burner management system is required to comply with AS 3814-2009 (industrial & commercial gas-fired appliances). Imported flares must obtain Australian approval for use.

4. Electrical services at the biogas train to comply with AS 3000 Electrical installations and be certified by a registered electrician. Electrical equipment should be either located outside any hazardous area (e.g. Zones 1 or 2), or be compatible with operation in the designated hazardous zone.

5. Stainless steel pipeline construction is recommended for biogas piping downstream of the blower.

6. All components of the biogas system especially safety shut off valves, blowers, meters and burner management system items should be rated for operation with moist biogas, hydrogen sulphide, ammonia and other components likely to be present unless downstream of biogas conditioning equipment.

7. Monitoring of biogas methane content and flow is recommended. Typical methane levels for biogas generated by meat processing CALs are 65 – 75% v/v. Independent render plants may generate biogas of lower quality (usually 60 – 65% v/v). Biogas with methane content less than 20%v/v is non-flammable. The biogas blower should be designed to alarm at 30% v/v and trip at 25% v/v to prevent flare flame-out.

8. The following components must be supplied in the flare system:

   (i) An appropriate flame arrestor must be provided at the flare inlet and between points of use (gas engines, boilers, etc) and the blower

   (ii) A suitable safety shut off system for the biogas appropriate to the expected biogas rate

   (iii) Interlocking of methane content to trip the biogas flare if methane content falls too low (see 7 above)

   (iv) Automatic ignition system

   (v) A blower management system which avoids drawing a negative pressure on the CAL cover (which risks drawing in oxygen into the biogas). Where a single blower operates more than one CAL, care is needed to ensure the management system maintains positive pressure under all covers.

9. The biogas flare should be installed to handle the entire design flow of biogas anticipated from the CALs to ensure that it is safely incinerated in the event of problems disrupting its use in boiler or genset systems. This avoids the necessity to hold excessive biogas volumes under the CAL cover and/or vent large volumes through over-pressure devices.

10. Care should be taken siting the biogas flare relative to the CAL. The biogas flare must be sited at separation distances from ignition sources that comply with AS/NZ 60079.10.1:2009 Explosive atmospheres – Classification of areas. A minimum distance of 6 metres is generally recommended. Special consideration is required where the CAL is built with a significant height

above natural ground level, to prevent the heat plume from the flare affecting the cover in wind conditions which might push the plume towards the CAL.

11. It is preferred to site blowers and compressors in open environments to minimise risk of biogas accumulation. Where these items are in an enclosed room, electrical equipment should at minimum be suitable for operation in a Zone 2 (gases) area. The room should be equipped with a methane gas detection system designed to alarm at 20% LEL and a suitable device to alarm at an appropriate level for H_2S per local regulations. Automatic shutdown of equipment should occur at 40% LEL. See Section 5.5 for more recommendations for enclosures.

5.3.3 Biogas system: Genset Buildings

The use of biogas for generation of electricity on-site has led to the installation of generator sets, usually installed in enclosed structures for the purpose of noise control and security reasons. This poses a unique risk of explosion of released gas within the enclosure, and amplification of blast pressure in comparison to open structures.

1. Consideration should be given to the appropriate siting of gen-set facilities, both for on-site impacts and for off-site impacts in the event of an explosion.
2. If practicable, where noise control and other factors permit, at least 2 sides of any genset enclosure should be open to allow dispersion of any gas releases. This will minimize any explosive effects and would generate a low pressure flash fire rather than an explosion.
3. Strict controls on ignition sources and personnel access within any enclosure is essential, as is the reliability of ventilation systems.
4. The use of ventilation systems, interlocks and gas detection are critical to ensure that initial biogas release events cannot propagate to an explosive situation.
5. Ventilation systems must be designed such that they effectively disperse any gas releases. It is likely that any ventilation system will not be able to handle a large, instantaneous release of gas. Using simple enclosed volume turn-overs can deal with fugitive emissions but would not be truly effective on acute events such as a line rupture.
6. See Section 5.5 for more recommendations for enclosed buildings.

5.4 Operation

The risk associated with biogas hazards is reduced by safe operating practices, which can be formulated in the Safety Management Plan for the facility (See Section 5.9).

5.4.1 General Safe Operating Practices: Infrastructure Protection

The following safe operating practices are recommended to protect the infrastructure associated with the CAL from damage:

1. Cover inflation. Covers should not be inflated more than 2 metres above top of wall (TOW) during normal operation. Excessive inflation increases the risk of damage and/or hazardous biogas releases. Inflation of more than 2 metres above TOW should be regarded as abnormal operation and risks significant cover stress in moderate wind conditions, weighting pipe dislocation and may increase the severity of any biogas release in the event of damage. This

was a contributing cause to the Rivalea incident in 2011. If significant storage of biogas is desired (for example to carry biogas over a weekend), purpose built gas storage systems are available and are a safer option.

2. Operating a CAL under vacuum (negative pressure) should be avoided unless specifically designed to do so. Negative pressures under the cover risk oxygen and nitrogen ingress.
3. Regular inspection of the overpressure relief system for blockages and other issues. The regularity should reflect the likelihood of problems occurring. For example, where pre-treatment of effluent is rudimentary and/or scum is observed accumulating under the cover, the inspection should be at least weekly.
4. Regular inspection of the CAL cover, the anchor perimeter and the biogas line should be conducted at least weekly to check for:

   (i) biogas leaks

   (ii) physical damage to the cover (for example animal damage, tears around spears or stormwater removal sumps, etc) or piping

   (iii) excessive foam or crust in outlet weirs

   (iv) structural deterioration of the cover

   (v) excessive stormwater sitting on the cover

   (vi) unusual movement or dislocation of weighting pipes or system.

   Any damage must be reported to the appropriate company official immediately to ensure the problems are rectified promptly.
5. Accumulated stormwater should be removed as quickly as possible to reduce the risk of cover damage and interference with overpressure relief systems, inlets and outlets. This is particularly a concern in areas of very high rainfall intensity (mm/hr), such as Queensland.
6. Condensate accumulation in the biogas train should be regularly removed, preferably by automatic devices, to prevent blockages and corrosion.
7. Sharp or heavy objects on the cover should be avoided to minimise the risk of accidental rupture or holing of the cover.
8. Human traffic on the cover should be minimised. Double thickness walkways, preferably using textured HDPE or similar material, can be helpful to permit access to critical areas.
9. Vehicular traffic in the area should be minimised and the speed strictly controlled to avoid loss of the vehicle and occupants into the deep tanks and/or damage to the CAL components from collision with the vehicle (for example the vehicle hitting the biogas piping).
10. During total fire ban days it is recommended not to operate the flare except when the flare is a totally enclosed type.

5.4.2 General Safe Operating Practices: Working on the CAL Cover

From time to time, personnel need to access the floating CAL cover for maintenance or monitoring reasons. While the likelihood of cover failure (e.g. splitting) is very low, the severity associated with a person falling through the cover is high. For this reason, access onto the cover should be minimised and any access treated with due care. An appropriate hazard analysis is recommended prior to entry.

The following list of safe operating practices is recommended as a minimum to protect personnel working on the cover and reduce the risk to human health and safety. They can be organised as Work Instructions as required. This list is not intended to remove the need for a facility to perform its own safety analysis.

1. Access to the CAL and biogas train area must be limited to authorized persons only.
2. Authorised persons must be trained to understand the potential hazards existing in, on and near the CAL and associated infrastructure, the correct procedures to adopt when working on the CAL cover and the appropriate procedures in the event of an emergency.
3. Footwear and clothing must not contain sharp components that might damage the cover.
4. Access to the cover should only proceed after careful inspection of the cover to ensure that it is structurally sound and contains no areas of deep water on the cover (since the water may flow rapidly towards persons on the cover as they depress the cover).
5. Access to the cover should be avoided when inflation is substantial (for example more than 2 metres above TOW).
6. Any equipment carried on to the cover must not be excessively heavy or possess surfaces, protrusions or edges likely to damage the cover.
7. Heavy equipment or packages should not be dropped from standing height on to the cover surface since the impact may damage the plastic.
8. A personal gas detector capable of detecting methane and H2S should be worn by personnel working on the cover of a CAL.
9. The possession of mobile phones, laptops and other electronic equipment on the cover must be carefully considered for its potential as an ignition source.
10. Opening a sample/inspection port on the cover should only be performed when the surrounding cover area is at the water level to avoid excessive biogas release. If the cover is inflated above water level near the port, the biogas train should be activated to reduce the biogas inflation before opening the port (this may require several hours).
11. A spotter located off the cover and equipped with communication equipment to contact emergency contacts should be present when persons are working on the cover.
12. Care should be taken near wet areas to avoid slippage injury.
13. Care should be taken to avoid heat stress if working on the cover for long periods of time. In Australian conditions, the cover temperature can be very hot and radiate a substantial heat load

to the person.

14. It is essential that any 'Hot' work carried out on the CAL cover be strictly controlled and consideration given to the likelihood of ignition of biogas releases.

5.4.3 General Safe Operating Practices: Working near the CAL

Under normal operation, biogas concentrations beyond 5 metres from the edge of the CAL cover are likely to be negligible since the system is tightly sealed. Extensive experience with open surface anaerobic ponds used by the industry for decades has found them relatively safe even with vehicular traffic on the pond walls.

Nevertheless, the confinement of the biogas under the cover and in biogas piping means that there is the possibility of local release in the event of a problem. The following safe operating practises will reduce the risk to human health and safety for personnel working near the CAL. They can be organised as Work Instructions as required. This list is not intended to remove the need for a facility to perform its own safety analysis.

1. Access to the CAL and biogas train area must be limited to authorized persons only.
2. Authorised persons should be trained to understand the potential hazards existing in the CAL and associated infrastructure, the correct procedures to adopt when working in the CAL zone and the appropriate procedures in the event of an emergency.
3. A personal gas detector capable of detecting methane and H2S should be worn by personnel working near a CAL.
4. The possession of mobile phones, laptops and other electronic equipment near the CAL must be carefully considered for its potential as an ignition source.
5. Inlet and outlet pits must be designated a confined space and covered to prevent unauthorised access. Appropriate safety precautions must be implemented prior to access.
6. Opening any valve or piping accessing the contents of the CAL must be performed with extreme caution. These may include:

   (i) Emergency biogas venting mechanisms

   (ii) Sludge removal piping valves

   (iii) Biogas condensate drain valves.

   There is a significant risk of the rapid release of biogas in these situations with the release potentially rising towards the head of the person working the release mechanism. Under these circumstances, there is a heightened risk of asphyxiation and injury.
7. It is essential that any 'Hot' work carried out near CALs be strictly controlled and consideration given to the likelihood of ignition of biogas releases.

5.5 Unodourised Biogas Risks

Biogas produced from anaerobic breakdown of meat processing wastewater is typically offensively odorous since the bacteria are degrading sulphur-containing meat proteins. Hydrogen sulphide levels are typically between 200 – 2,000 ppm and sometimes higher. The lowest level measured to date in meat processing biogas has been 70 ppm.

It is a legal requirement to odorise gases supplied to users so that gas releases (leaks) are immediately detectable. The requirements of the odorant under the Gas Safety (Gas Quality) Regulations are that the odorised gas must:

- have an odour which is distinctive and unpleasant, and
- have an odour level that is discernable at one-fifth of the LEL of the gas.

Typically an odorant mixture comprising for example tetrahydrothiophene (commonly “thiolane”) and tert-butyl mercaptan is added to the gas at level between 7 – 14 ppm. In Queensland the Petroleum & Gas Regulation 2004 prescribes the addition of ethyl mercaptan at 25 g/tonne of liquid LPG. These odorants typically have an odour threshold of less than 1 ppb with a recognition threshold of about 1 ppb.

Hydrogen sulphide has very similar human odour recognition thresholds to these commonly used odorants with a recognition threshold of 4.7 ppb2. It meets both requirements of an odorant as described by the Gas Safety Regulations. Consequently the detection of biogas releases by humans is as certain as if typical odorants had been added.

Where biogas is to be used rather than simply flared, the relevant State regulations should be checked in regard to any need for odourisation. Since H2S is not a recognised odorant, and is not added to the biogas, State authorities will consider biogas “unodorised”.

In most cases, the use of unodourised biogas within an enclosure on the industrial site is permissible subject to State guidelines. For example in Queensland[3], these include:

1. The enclosure containing the equipment must be protected by interlocked forced ventilation and equipment shutdown systems which are adequately designed, installed, commissioned and operational prior to initiation of the unodourised biogas feed to the equipment. Ventilation must comply with AS 5601:2010 Sections 5:13 and 6.4.
2. Gas detection and shutdown systems must be adequately designed, installed, commissioned and operational prior to initiation of the unodourised biogas feed to the equipment.
3. Gas alarm must be activated at any level exceeding 20% of the LEL level (~1%v/v methane). Automatic equipment shutdown and evacuation procedures must be initiated at 40% LEL.
4. Induction and orientation of relevant staff shall ensure they are fully cognisant of the dangers of unodourised gas.

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[2] ISU (2004) *The Science of Smell Part 1: Odor perception and physiological response*. Report PM1963a.
[3] DME (2009) *Guidelines for use of unodourised gas under the Petroleum & Gas (production and Safety) Act 2004*. Version 2.

5. Safety warning signs must be placed at appropriate locations on site, including on pipe work, to warn of the possible presence of unodourised gas.

6. Written procedures for commissioning, maintenance and ongoing operation of the gas supply system must reflect the unodourised nature of the gas and be made available to the relevant staff.

7. The installer, commissioner and/or maintenance personnel shall have suitable equipment and the necessary training to ensure safety in dealing with the unodourised nature of the gas during the construction, commissioning, operational and maintenance phase of the project.

8. Maintenance, testing and recording procedures are established to ensure the functional integrity of the gas detection system.

9. A scheduled system and record of manual leak surveys is to be followed, requiring discovered leaks to be repaired immediately and a 'close-out' audit process implemented.

Clearly many of these guidelines can be considered redundant for biogas from meat processing plants since hydrogen sulphide is an equally effective odorant and is always present at levels readily detectable by the human olfactory system at levels of dilution at the 20% LEL.

5.6 Construction Phase

The risks from biogas during construction are negligible where:

- the pond is filled with clean water (from clean stormwater, bore or well treated effluent) to enable the fitting of the pond cover
- Other established CALs or anaerobic systems are not present in the vicinity.

Often the quantity of clean water required to fill the pond for cover fitting exceeds supply and wastewater must be used. In this instance, the organic concentration in the water should be minimized to limit anaerobic action and biogas release. Experience has shown that methanogenic activity is slow to occur in the first 3 – 4 weeks, by which time the cover is usually complete.

The biogas train and flare and all cover overpressure devices should be installed within 2 weeks of wastewater being put into a new CAL. This ensures that suitable protection against odour emissions and biogas discharge to the open environment are minimised.

The commissioning of the biogas train and flare may require longer operation of the CAL since it usually requires at least 4 – 6 weeks for sufficient quantities of biogas to be generated.

The initial biogas should be vented since it may contain a high proportion of oxygen and nitrogen due to air trapped under the cover during installation.

5.7 Decommissioning Phase

Significant biogas production in an established anaerobic system to which effluent supply has ended will cease rapidly. While significant volumes of biogas are being produced, it will be necessary to continue operating the biogas train to ensure its safe destruction.

After this time, some small quantities of biogas may continue to be produced due to sludge and scum or crust digestion. These quantities should be sufficiently low as to allow their safe dispersion through the overpressure relief systems in the cover.

Access to the area should be limited to only authorised personnel in view of the risks posed by the deep water-filled tank.

5.8 Emergency Situations

The generic risk assessment performed as part of this guideline found that the key hazards in regard to biogas are related to biogas releases, possible fires and explosions. The most serious impacts are related to:

1. Large releases of biogas from CALs, for example by a significant rupture of the cover when over-inflated
2. Explosion impacts from enclosed space ignition of biogas in generator set installations.

These are covered below. The impact of biogas releases from small leaks in the cover, or from releases from biogas transmission pipelines between the CAL and flare are considered low due to the low operating pressures in the system.

5.8.1 Large Releases from CALs

In a large biogas release, a significant quantity of methane and carbon dioxide escapes the cover as a plume, whose shape depends on many factors including the orientation of the release point in reference to the ground plane and the pressure under the cover.

The most probable releases are likely to be due to:

- over-pressure in the CAL leading to large release via the overpressure protection system
- a significant rupture or tear in the CAL cover
- a significant failure of gas tightness in the cover anchoring system.

The larger the rupture and the higher the pressure under the cover, the larger the release rate will be. Release modelling suggests that large-scale releases in the case of orientations above 20 ˚C above the horizontal are buoyant and disperse rapidly with little impact at the ground level.

In contrast, large gas releases from the cover that are near horizontal in orientation (for example from a puncture in the cover near the cover anchorage point in an over-inflated CAL exhibiting "whale-back" form) can have significant ground interaction and travel substantial distance at ground level. This form of release poses:

- a suffocation and H_2S toxicity hazard to personnel and animals
- a flash fire risk with sufficient energy to seriously injure or kill personnel nearby.

In the event of a large release with a near horizontal orientation:

1. An immediate exclusion zone of at least 50 metres should be declared around the CAL
2. All personnel and animals should be evacuated from an area within at least 100 metres of the

release point

3. All potential ignition sources within 50 metres of the release point including vehicles, mobile phones, electronic controls, stormwater removal pumps, biogas flare etc should be deactivated

4. The exclusion zone should be maintained until the gas release has reduced the pressure under the cover to less than 50 Pa

5. Access to the damaged CAL (once the cover pressure has fallen to less than 50 Pa) should be only by authorised persons equipped with suitable gas monitoring and other personal safety equipment to assess repair

6. Wastewater flow to the damaged CAL should be minimised until repairs are affected to the extent that this is practicable.

5.8.2 Enclosed Space Ignition

The impacts of an explosion of biogas in an enclosed building are sufficiently severe to warrant careful attention to ensuring that the risk is mitigated through the use of well-designed ventilation systems, interlocks and gas detection so that the initial biogas release event is unable to propagate to an explosive situation.

5.9 Safety Management Plan

A site specific safety management plan (SMP) should be developed covering the risks and management associated with the biogas system. Some States, such as Queensland and WA have prescriptive safety management plan requirements with clear guidelines as to the content of the SMP.

All meat processing plants have formal workplace health & safety management systems in place and as much as practicable, the biogas SMP should be consistent and integrated within this system.

This guideline recommends the following minimum inclusions in a biogas system SMP:

1. A description of the biogas system including plant layout, a process flow diagram, a scaled map indicating distance to nearest receptors and location of critical isolation equipment

2. The organisational structure and safety appointees and responsibilities. Some States have specific requirements regarding responsibilities pertaining to biogas installations

3. Operator(s) of the system

4. A formal safety or risk assessment of the biogas system. This should include hazard identification, assessment of possible risks and associated control measures to eliminate or minimise the risk as low as reasonably practicable. This can be informed by the risk assessment performed as part of this guideline (See Section 4)

5. Documented standard operating and maintenance procedures. All meat processing sites operate formal OH&S systems which can be expanded to include the CAL and biogas train. This should include interactions with external contractors who may need to work on or near the system so that all work is performed in a controlled and safe manner

6. Description of control systems. These should be clearly identified and the personnel responsible

trained in their use

7. Emergency response procedures. These identify the response required for given events, allocate responsibilities and identify equipment, evacuation areas and training required.

Anaerobic wastewater systems and the ancillary biogas train and flare are complex systems coupling a complex microbiological biogas production system with in most cases complex biogas flaring systems. Day to day operation of wastewater treatment plants at many meat processing plants is often a part responsibility allocated to staff positions vulnerable to high turnover.

The effect of human failures can be significant, as key contributors to loss of containment, either at the design phase of the system, or through poor training and poor procedural practice. It is vital that these human factors be expressly considered and managed within a facility to minimize the hazard potential.

Appendices

Appendix 1 - Definitions

The following commonly used definitions may be of use. Many are selected from Australian Standard 3814-2009.

TYPE B APPLIANCE	An appliance, with gas consumption in excess of 10MJ/h, for which a certification scheme does not exist. *NOTE: A Type A appliance when used in an industrial/commercial application for which it was not intended is considered to be part of a Type B appliance. An example of this is a certified direct-fired space heater used as the heating/ventilating device in a spray/bake paint booth.*
AUTO-IGNITION TEMPERATURE (AIT)	The lowest temperature at which the rate of self-heating of a gas-air mixture exceeds the rate of heat loss to the surroundings, thus causing the mixture to ignite.
ATMOSPHERIC BURNER	A system where all of the air for combustion is produced by the inspirating effect of the gas or the natural draught in the combustion chamber or the combination of the two without mechanical assistance.
AUTOMATIC BURNER	A burner system that, on starting, follows a self-acting sequence that has been manually or automatically initiated, to provide gas and ignition to the burner without any intermediate manual operation.
BIOGAS	The gas resulting from anaerobic bacterial breakdown of organic material.
BIOGAS TRAIN	The equipment associated with the carriage, conditioning and preparation of biogas for burning in flares or other uses.
BURNER OFF CYCLE	A normal cessation of operation occurring when a pre-determined operation condition is reached and the operation of the burner to provide the application of heat is no longer required. The equipment is placed into a safe stand-by condition ready to restart on demand *Or* A shut down to a safe stand-by condition in response to an incorrect condition signal resulting from a fault that is unlikely to be hazardous or is likely to be self-rectifying so that normal restarting is permissible when the fault has cleared.
CERTIFIED/CERTIFICATION	Assessed by a certifying body and having a certificate number to demonstrate compliance with a relevant Standard and/or other acceptable safety criteria.
CERTIFYING BODY	A body acceptable to the technical regulator that provides assurance of compliance of appliances and components with relevant Standards and other accepted safety criteria.
CHP	Combined heat and power plant which through the combustion of biogas generates heat and electrical energy.
DAMPER	An adjustable device for controlling: (a) Air flow in a forced or induced draught air system (b) The flow of flue products in a flue system (c) The recirculation of air, flue gases or process gases, or (d) The flow of any other fluids.
FAIL-SAFE	A feature that ensures absence or malfunction of any critical control or safety component, system, signal or function will not result in an unsafe condition.

FLAME ABNORMALITY	A flame condition that results in flame lift, floating, light back, appreciable yellow tipping, carbon deposition or objectionable odour.
FLAME DETECTOR	A device that is sensitive to flame properties and initiates a signal when flame is detected.
FLAME ESTABLISHMENT PERIOD	The period that begins when the fuel valve is energised and ends when the flame safeguard system is first required to supervise that flame.
FLAME FAILURE RESPONSE TIME	The time taken for the flame safeguard to detect loss of flame and de-energize the safety shut-off valve.
FLAME PROVING PERIOD	The supervised period immediately following the flame establishment period and before any further operation other than shutdown is permitted.
FLAME SAFEGUARD	A safety device that automatically cuts off the gas supply if the actuating flame is extinguished.
FLAME SAFEGUARD SYSTEM	A system consisting of a flame detector (s) plus associated circuitry, integral components, valves and interlocks, the function of which is to shut off the fuel supply to the burner(s) in the event of ignition failure or flame failure.
FLARE	An engineered unit which safely combusts biogas and air mixtures to destroy its methane content and odorous components.
GAS CONSUMPTION	The rate of energy consumed by an appliance under specific conditions and expressed in multiples of joules per hour, for example, megajoules per hour (MJ/h) or gigajoules per hour (GJ/h).
IGNITION TEMPERATURE	The lowest temperature at which heat is generated by combustion faster than heat is lost to the surroundings, and combustion thus becomes self-propagating.
INTERMITTENT PILOT	A pilot that is automatically ignited each time the burner is started, and which is automatically extinguished with the main burner.
INTERRUPTED PILOT	A pilot that is automatically ignited each time the burner is started, and which is automatically extinguished at the end of the main flame establishment period.
LOWER EXPLOSIVE LIMIT (LEL)	The lowest percentage of gas in a mixture of gas and air in which the combustion can be self-sustaining at standard temperature (15˚C) and pressure (101.325 kPa absolute) conditions.
PERMANENT PILOT	A pilot that is intended to be permanently alight while the appliance is in service and that is controlled independently of the main burner.
PILOT	A permanently located burner independent of the main burner, small in relation to it, and arranged to provide ignition for the main burner.
POSITION-PROVING SYSTEM	A means of checking that the safety shut-off valves and vent valves of a double block and vent safety shut-off system are in the correct position.
PROGRAMMABLE ELECTRONIC SYSTEM (PES)	A system based on one or more central processing units (CPUs) connected to sensors and/or actuators, for the purpose of control, protection or monitoring.
PURGE (OR PURGING)	With respect to an appliance means the removal of combustibles.
SAFETY SHUT OFF SYSTEM	An arrangement of valves and associated control systems that shuts off the supply of gas, when required, using a device that senses an unsafe condition
SAFETY SHUT OFF SYSTEM, DOUBLE BLOCK AND VENT	A safety shut off system that incorporates two safety shut off valves in series, with the space between the two valves automatically vented. These valves are interlocked so that when the safety shut off valves are closed, the vent valve is open and vice versa.
SAFETY SHUT OFF VALVE	An automatic shut off valve that meets the requirements of AS 4629 and is used to shut off gas supply to an appliance when a signal is generated indicating the approach of an unsafe condition.

STANDARD GAS CONDITIONS	The temperature and pressure values at which biogas volumes are calculated. Typically for biogas, standard gas conditions are 15^{o}C, and a pressure of 1 atmosphere (101.3 kPa).
VENT LINE	A pipe that is connected to a gas pressure regulator, relief valve or a double block and vent safety shut off system and will convey gas to a safe location
VENT VALVE, DOUBLE BLOCK AND VENT SAFETY SHUT OFF SYSTEM	A valve in the vent line of a double block and vent safety shut off system that automatically opens when de-energised and automatically closes when energised.
ZONES	Potentially explosive areas are classified on the basis of zones according to the probability of the presence of a potentially explosive area. In Australia, the appropriate standard is AS/NZ 60079.10:2009 *Explosive atmospheres – Classification of areas*.