



Safety and Process Engineering Consultancy
Hazard and Risk Assessments
Explosive Atmospheres (ATEX/DSEAR)
Process Incident Investigations
Engineering Expert Witness

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DSEAR Risk Assessment Results
Welsh Water Organic Energy
Cardiff Anaerobic Digestion Plant
Normal Operation

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Summary

A DSEAR risk assessment has been carried out for the Welsh Water Organic Energy Ltd Anaerobic Digestion facility in Tide Fields Road, Cardiff, which is required to meet the requirements of the UK Dangerous Substances and Explosive Atmospheres Regulations (DSEAR), as well as other UK regulations.

The DSEAR risk assessment identified several considerations for review before the Welsh Water Organic Energy Ltd Anaerobic Digestion facility can be considered to meet the requirements of DSEAR. Some of these recommendations are for plant installation, whereas others are for operations, to implement.

The considerations for review are listed as follows:

1. Ensure As Built process drawings (P&ID's & Schematics) are available and updated to show the Anaerobic Digestion Plant as it is installed. This should include the Pasteuriser plant, CHP unit, Odour Treatment Plant and Flare System.
2. Hazardous Area Classification (HAC) Zoning Diagrams in both plan and elevation views should be updated for the Anaerobic Digestion plant, as well as any ancillary equipment such as the CHP engine to identify any flammable ATEX zones.
3. Consider whether fire and gas detection systems are required for the food reception building.
4. Ensure that all chemical drums, containers, and IBC's used on site, are positioned above portable bunds designed to limit the potential for discharges to the environment.
5. Review whether external stored chemicals need to be protected against high solar radiation and temperatures.
6. Ensure all containers and pipes carrying gases, oils, water, exhaust gases and any other chemicals are labelled (narrative and/or colour code) with direction of flow indication. The site has labelled pipelines; however, this could be improved to include all pipes.
7. Ensure all hot surfaces have warnings and are insulated.
8. Ensure that all 'Ex' areas will be signed accordingly to identify any hazardous areas including all the main plant areas. The signs should be located on the entry to each plant area to warn any personnel before they enter each ATEX Zoned area.
9. Ensure that any equipment within the Hazardous Areas complies with the requirements for installation in that area. All installed ATEX equipment should be checked to ensure that it is suitable for the required Hazardous Area Classification / Zone.
10. All ATEX equipment should be checked to have been installed by competent personnel (i.e. Compex qualified).
11. Ensure that a zoned equipment audit of electrical and non-electrical equipment is available. This is a legal requirement under DSEAR Regulation 5(2)g.
12. Consider whether additional impact protection is required for the food reception building against impact from food delivery trucks.
13. Ensure that the local fire brigade is aware of the processes on site and the risks associated with flammable gases and chemicals.
14. Confirm whether the facility falls outside the Control of Major Accident Hazards (COMAH) Regulations 2015.

15. Review whether the facility should be assessed to ensure compliance with The Dangerous Substances (Notification and Marking of Sites) Regulations 1990, requiring notification to the relevant body if 25 tonnes of dangerous substance can be held on site.
16. Ensure that all equipment on site will have a start-up and shut-down procedure.
17. Consider whether activation of emergency shower should result in an alarm within the control room. This will warn the control room that an operator could be in danger and be exposed to a hazardous chemical.
18. A Site Legionella Risk Assessment will need to be undertaken to include all standing water systems including the emergency shower.
19. Confirm the integrity of the bund is maintained due a loss of containment situation.
20. The DSEAR Report should be reviewed and updated at least once every two to three years.

21. The following recommendations are for consideration as the Anaerobic Digestion Plant is operational:
 - a. Ensure operator training, skills and competency in the operation of the plant will be periodically reviewed.
 - b. Ensure Material Safety Data Sheets for all substances used are available on the company server with working copies kept on site for all employees to access.
 - c. Ensure COSHH risk assessments are available for all chemicals, raw materials and products on site and are available to all employees. These should be available on the company server, with working copies kept on site in the control room. COSHH Risk Assessments will need to be updated regularly by the site Health and Safety officer and audited by site management.
 - d. Ensure that suitable protective eyewear and clothing (overalls and gloves) will be worn by personnel when handling any chemicals on site. Any spills or leakages should be cleaned up using appropriate spill kits.
 - e. For any spillages or leakages during the handling and transfer of raw materials/chemicals, ensure that there is a company procedure in place to avoid any ignition sources and ensure that any spillages are cleaned up immediately.
 - f. Ensure maintenance records on the use of refrigerant R410A with the chiller plant are kept as required under EU Regulation No 517/2014 on fluorinated greenhouse gases. This should include:
 - The quantity and type of F-gas refrigerant in each system
 - Any quantities of refrigerant added
 - The quantity of refrigerant recovered during servicing, maintenance and final disposal.
 - Other relevant information including:
 - the identification of the company or technician who performed the servicing or maintenance
 - The dates and results of leak checks and leak detection system checks.
 - Information that specifically identifies stationary equipment containing 30 kg or more of refrigerant.

- g. Ensure that all maintenance contractors will be aware of the hazards on site and aware of the site Spillage & Clean Up procedure.
- h. Ensure that the Maintenance and Safety Policy will include the preventative maintenance scheme as identified in the Operating & Maintenance Manuals for this site. The site preventive maintenance policy should ensure that equipment is regularly inspected and maintained to reduce the likelihood of leaks and equipment failure.
- i. Ensure that before any maintenance work will be implemented, a risk assessment is undertaken via a permit to work system or via a safe systems of work procedure. The permit to work should include any dismantling of equipment.
- j. Ensure that any hot work inside the plant area will be subject to a Permit to Work and separate risk assessment.
- k. Ensure that before any maintenance work will be implemented, atmospheres are tested prior to commencement of any work and at intervals to ensure that no flammable atmospheres exist.
- l. Ensure that there will be a risk assessment for the use of portable tools and test equipment.
- m. Ensure that all portable equipment and all external contractor equipment will be certified and approved before use.
- n. Master copies of the maintenance records / procedures will need to be available on the company server, with records kept on site in the control room or offices. Site management will need to maintain and keeps maintenance records / procedures up to date.
- o. Ensure that persons on site will not carry sources of ignition such as open flames and any operations which require hot work and/or the ability to create sources of ignition are controlled by a risk assessment. Any personnel entering any hazardous areas should not carry any sources of ignition including mobile phones, cameras and other electrical equipment unless it is suitable for the required zone.
- p. Ensure that the Site Emergency Plan is developed for the plant to cover fire and emergency procedures for evacuation and includes liaison with the local fire brigade. In addition, the site emergency plan should include emergency procedures for any nearby residents that maybe affected.
- q. Ensure operators will receive regular training in the use of fire extinguishers.
- r. Ensure that the local fire brigade is contacted to acquaint them with the details of the operation and risks associated with the AD plant.
- s. Ensure that a written site Traffic management policy and suitable risk assessment are in place for normal operation of the AD plant, to ensure that site vehicle incidents are prevented by the effective management of transport operations.
- t. Briefing paper for the emergency services giving brief details of the process and risks on site including flammable gas & CHP engine oil, should be developed.
- u. Ensure that all gas cylinders, when used on site will be stored in line with guidance provided by British Compressed Gases Association guidance note GN2 - *Guidance for the Storage of Gas Cylinders in the Workplace*. Gas cylinders should be stored in a dedicated storage area.

- v. Ensure that chemicals stored on site will be stored in line with guidance provided by HSE Guidance document HSG71 - Chemical Warehousing: The storage of packaged dangerous substances. All chemicals were stored in dedicated bunded storage areas.
- w. The pasteurised waste odour could contain high levels of ammonia. Review whether Work Instruction or SOP should include opening of doors to dissipate odour and a check of ammonia levels is undertaken before operator enters the building.
- x. Review whether operator has to check and confirm odour abatement system (bio-filter) is operational prior to pasteurisation proceeding. If not, then Work Instruction (SOP), should require the operator to open odour line vent valve to atmosphere.

1.0 Introduction

Welsh Water Organic Energy (WWOE) operate an Anaerobic Digestion (AD) facility at their site in Cardiff, Wales. The facility uses household food waste to produce biogas which is utilised in the CHP engine to generate electricity and heat.

The Welsh Water Organic Energy Anaerobic Digestion facility is required to meet the requirements of the UK Dangerous Substances and Explosive Atmospheres Regulations¹ (DSEAR), as well as other UK regulations.

As of 1st June 2015, there have been changes in the way DSEAR classifies dangerous substances and now under DSEAR all dangerous substances have to be classified as according to the CLP system as defined by the classification, labelling and packaging Regulation (2008).

Before DSEAR was amended, a dangerous substance was defined as a substance or preparation which could be classified as *Explosive, Oxidising, Extremely flammable, Highly flammable or Flammable*, whether or not that substance or preparation was classified under the CHIP Regulation (Chemicals (Hazard Information and Packaging for Supply) Regulation 2009).

Under DSEAR dangerous substances are now classified as “any substance classified within a physical hazard class in the CLP Regulation.” This includes the following Hazard Classes.

- Explosive
- Flammable gases
- Flammable aerosols and aerosols
- Gases under pressure
- Flammable liquids
- Flammable solids
- Self-reactive substance/mixture
- Pyrophoric liquids
- Pyrophoric solids
- Self-heating substance/mixture
- Water-reactive — emits flammable gases
- Oxidising liquids
- Oxidising solids
- Organic peroxides
- Corrosive to metals

These changes bring two new and different Hazard classes — *Gases under pressure and Corrosive to metals* — into the definition of a dangerous substance under DSEAR.

¹ DSEAR brings together various obligations on employers to protect workers from danger, due to the presence of ‘dangerous substances’ The HSE has issued a DSEAR Approved Code of Practice (“ACoP”) L138). A brief overview of the key elements of the legislation is provided in Appendix 6.

The other major difference is in the classification of Flammable liquids. Under the CHIP Flammable category, the upper flash point limit of a flammable liquid is 55°C, whereas for the corresponding CLP category it is less than 60°C.

DSEAR brings together various obligations on employers to protect workers from danger, due to a number of circumstances, including fire, explosives (including dust) and chemical agents. A brief overview of the key elements of the legislation is provided in Appendix 6.

The Welsh Water Organic Energy Anaerobic Digestion facility is a workplace² and DSEAR Regulation 5 requires a risk assessment of the work processes³. As part of the risk assessment, it must be assessed whether an explosive atmosphere⁴ is likely to form and for how long it is likely to remain.

This DSEAR Risk Assessment is in line with HSE ACoP L138, identifying the hazards and risk associated with the dangerous substances present within the Anaerobic Digestion Plant only.

2 “workplace” means any premises or part of premises used for or in connection with work, and includes –
(a) any place within the premises to which an employee has access while at work; and
(b) any room, lobby, corridor, staircase, road or other place –

(i) used as a means of access to or egress from that place of work; or,
(ii) where facilities are provided for use in connection with that place of work;

3 work processes” means all technical aspects of work involving dangerous substances

4 “explosive atmosphere” means a mixture, under atmospheric conditions, of air and one or more dangerous substances in the form of gases, vapours, mists or dusts in which, after ignition has occurred, combustion spreads to the entire unburned mixture.

2.0 Description of the Process

Welsh Water Organic Energy, part of the Glas Cymru group which includes Dŵr Cymru Welsh Water, has acquired an Anaerobic Digestion Plant from Kelda Water Services.

The Welsh Water Organic Energy anaerobic digestion plant is located next to Welsh Waters Cardiff East Wastewater Treatment Works on Tide Fields Road in Cardiff and receives various types of solid food waste from household waste collections by Cardiff Council and the Vale of Glamorgan Council. The facility can process up to 35,000 tonnes per year of food waste.

In all cases, food waste is delivered to the site by delivery trucks, pre-treated and fed into the anaerobic digesters. Biogas composed of mainly methane and carbon dioxide with small amounts of hydrogen sulphide is produced from the anaerobic digestion of food waste within the digesters. The digesters are located close together and are all constructed of concrete walls, fitted with external insulation.

Digestate is stored in a digestate storage tank fitted with an inflatable plastic membrane roof which collects and stores biogas from the digesters and feed reception tank.

The digesters, the feed reception tank and the digestate storage tank are each fitted with two identical resealable liquid relief valves for over and under pressure protection. The digesters are normally controlled at a pressure of 4 mbarg, with the relief valves set to operate at a slightly higher pressure of 5 mbarg.

Biogas from the digesters is routed to a CHP engine and a biogas boiler via the biogas main. The biogas main is fitted with condensate collection vessels to collect water/condensate from biogas.

A pasteurisation plant is used to treat spent digestate before the solids and liquor from the spent digestate are separated. The liquor from the solids separation plant is pumped to the digestate storage tank. The solids are collected and stored for offsite disposal.

This DSEAR risk assessment reviews the existing Welsh Water Organic Energy Anaerobic Digestion (AD) plant only.

3.0 Record of DSEAR Risk Assessment

DSEAR Risk Assessment Results	
Subject (Building/Area/Equipment)	<p>This Risk Assessment is for the normal operation of the Anaerobic Digestion Plant at</p> <p style="text-align: center;">Welsh Water Organic Energy Ltd Tidefields Rd, East Moors, Cardiff, CF24 5SB.</p> <p>The Welsh Water Organic Energy Ltd facility consists of an Anaerobic Digestion Plant where food waste is used to produce biogas which is utilised in a CHP engine to generate electricity and heat.</p> <p>Solid food waste from household waste collections by Cardiff Council and the Vale of Glamorgan Council is delivered to site and fed to the anaerobic digesters. Biogas composed of mainly methane and carbon dioxide is generated in the digesters and routed to a CHP engine and/or biogas boiler.</p> <p>Biogas is combusted in a 2 MW CHP engine to generate electricity and heat. Excess gas not used in the gas engine or boiler is disposed of via the emergency flare.</p> <p>Spent digestate from the digesters is pasteurised, before the solids and liquor from the spent digestate are separated. The liquor from the solids separation plant is returned to the digestate storage tank. The solids are collected and stored for offsite disposal.</p> <p>The Cardiff facility is a large site and the Anaerobic Digestion plant is located at one end of the site. The Anaerobic Digestion plant includes:</p> <ul style="list-style-type: none"> - Food Waste Reception Building (including reception hall and pasteurised solids separation room). - Plant Room - AD plant area (including feed reception tank, digesters, digestate storage tank and Technology Building) - CHP area (including boiler, chiller & flare) - Pasteurisation Plant area (including 3 tanks) - Chemical IBC storage area - Offsite site offices and weighbridge

	<p>The equipment for the Anaerobic Digestion plant is located outdoors within a bunded area. This includes the Technology Building which houses the Pump Room, site air compressor and air desulphurisation system. The Technology Building is between the Digester and Post Digester Tank.</p> <p>The CHP engine is located at one end of the site, within its own containerised enclosure. Next to the CHP engine enclosure, there is a biogas boiler, a biogas chiller and the flare system.</p> <p>The plant room is adjacent to the main food waste reception building and positioned next to the chiller plant area, which is used to monitor and control plant operation. The plant is operated via a SCADA system with a 24 hr alarm function. There is also local HMI control.</p> <p>The site also has an office building with a meeting room and welfare facilities as well as a car park area. These are located outside the main plant area at the entrance of the site.</p> <p><i>The site P&IDs were available for review, however, no 'AS Built' process drawings were seen for the Pasteuriser plant, CHP unit, Odour Treatment Plant and Flare System during the site visit. Welsh Water Organic Energy Ltd should ensure that all process drawings (P&ID's & Schematics) of the 'As Built' plant as it is installed are available.</i></p>
Date of Risk Assessment	This Risk assessment was developed over the period of 2 nd September 2020 to 20 th November 2020.
Carried Out By (List all)	<p>Zaffer Khan, SPE Consultants Limited and Jonathan Coker, Stephen Hutchings and Rhodri Williams, Dŵr Cymru Welsh Water.</p>
Hazardous Substances (or attach list)	There are several hazardous substances associated with the Anaerobic Digestion process at the Cardiff facility. These include: Biogas, thermal oils and diesel.

	<p>There are additional hazards from the exhaust gases generated from the combustion process, the dosing chemicals used for the process, refrigerant gas R410a used in the chillers and lubrication oils used for the CHP engine and hydraulic power packs.</p> <p>The anaerobic digestion process will use various types of organic feed sources to generate digester biogas. At present, solid food waste is used as a feed material, however, there are plans to use liquid waste in the future.</p> <p>Biogas is generated from the anaerobic digestion process and is both flammable and toxic.</p> <p>The digester gas consists of 4 major components and has a slightly variable composition as follows:</p> <p style="padding-left: 40px;">Methane: 55 - 59 Volume%</p> <p style="padding-left: 40px;">Carbon Dioxide: 40 - 44 Volume%</p> <p style="padding-left: 40px;">Hydrogen Sulphide: upto 200 ppmv</p> <p style="padding-left: 40px;">Ammonia: upto 100 ppmv</p> <p>Biogas can also contain up to 1 vol% oxygen.</p> <p>Incomplete combustion from the CHP, boiler & flare combustion processes could also lead to hazardous and toxic exhaust fumes being generated, however, these will be vented to a safe location through the CHP, boiler & Flare exhaust systems.</p> <p>The exhaust gases could have high nitrogen oxide (NO_x) levels as well as high sulphur oxide (SO_x) levels depending upon the composition of biogas available.</p> <p>Refrigerant gas R410a is used in the gas chiller system. Although, R410a gas is not considered a flammable material (i.e. auto-ignition temperature: >750°C), additional COSHH risk assessments should be undertaken to review the risks associated with the use and handling of an asphyxiant.</p> <p>Some process equipment include the use of lubrication oils (CHP engine and hydraulic power packs).</p>
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	<p>These oils typically have a flash point above 200°C and will not normally create a flammable atmosphere. However, as the oils are pumped, then there is potential for the formation of flammable mists. Mists of high-flashpoint fluids can ignite and produce explosions at temperatures below their flashpoint.</p> <p>Diesel is used on site and dispensed in a dedicated area. Diesel has a typical flash point of >55°C and will not normally create a flammable atmosphere. However, if diesel is heated or pumped, then there is potential for the formation of flammable mists. Mists of high-flashpoint fluids can ignite and produce explosions at temperatures below their flashpoint.</p>
<p>Properties of these substances (on attached list)</p>	<p>The typical flammability properties of biogas are: LEL: 7.44 - 7.98 vol% HEL: 15.06 – 15.07 vol%</p> <p>The typical flammability properties of Compressor / Lube Oil are: LEL: 0.9 vol% HEL: 7.0 vol% Flash Point: >230°C Boiling Point: > 316°C Auto Ignition Temp: > 250°C</p> <p>The typical flammability properties of Diesel are: LEL: 0.6 vol% HEL: 7.5 vol% Flash Point: >55°C Boiling Point: 163 - 357°C Auto Ignition Temp: > 250°C</p> <p>The flammable properties of the above materials are detailed on the attached list which is based upon one in BS EN 60079 Part 10-1 (see Appendix 2) and the attached data sheets (see Appendix 5).</p>
<p>Products produced / processes undertaken</p>	<p>Solid food waste is digested to produce biogas which is utilised in the CHP engine to generate electricity and heat.</p>

	<p>Biogas is combusted in a gas engine to generate electrical power, which is used on site. The site power is generally at 415V and the export power is transformed up to 11kV.</p> <p>Details are provided in section 2.0 - Description of the Process.</p>
<p>Circumstances of the Work – attach list for each product/ process</p>	<p>See details in section 2.0 - Description of the Process.</p>
<p>How are raw materials delivered to the area?</p>	<p>The raw material used for the Anaerobic Digestion plant is solid food waste from household waste collections. Liquid food waste will be used in the future.</p> <p>Liquid and solid food waste is generally non-hazardous. All digester feed material is delivered to site by lorry and is prepared, mixed and size reduced. After preparation, the digester feed material is transferred directly into the digesters, via a digester feed reception tank, where biogas is generated under controlled conditions.</p> <p>Delivery of all food waste is undertaken by trained delivery drivers to strict delivery procedures.</p> <p>Biogas produced from solid food waste, can often have a high hydrogen sulphide content. Hydrogen sulphide is an undesirable component of biogas due to its toxicity and its adverse effect upon the operation of the CHP gas engine. To reduce the hydrogen sulphide content in biogas, the feed material is dosed with ferric chloride solution. Ferric chloride solution destroys the hydrogen sulphide in solution before it is liberated to the gas phase.</p> <p>Ferric chloride is delivered to site by lorry in 1 m³ IBC containers and stored in a dedicated storage area on site.</p>

	<p>The materials are handled manually and are transported using fork lift trucks.</p> <p>Diesel is delivered to site by a tanker and stored in a dedicated container. It is dispensed by manual operation directly into vehicles or containers.</p> <p>Delivery of all chemicals is undertaken by a trained chemical supplier overseen by a site operator.</p> <p>Refrigerant gas R410a is used in the chiller process and this system is maintained by a specialist company. Gas cylinders of refrigerant gas are delivered to site by the maintenance company on a as required basis. The type and quantity of gas used is recorded as part of the maintenance records which will be kept by Welsh Water Organic Energy Ltd. This is a legal requirement under EU Regulation No 517/2014 on fluorinated greenhouse gases.</p>
<p>Frequency of deliveries</p>	<p>Delivery of food waste is regular and there can be several deliveries per day.</p> <p>Small quantities of lube oil and diesel are used on site and delivered irregularly on 'a as required' basis.</p> <p><i>No assessment has been undertaken to ascertain the need for compliance with The Dangerous Substances (Notification and Marking of Sites) Regulations 1990, requiring notification to the relevant body if 25 tonnes of dangerous substance can be held on site.</i></p> <p><i>It is believed that the site does not fall within the Control of Major Accident Hazards (COMAH) Regulations 2015, but this should be confirmed by assessment.</i></p>
<p>Are they stored in the area?</p>	<p>Solid food waste from household collections is delivered to site and stored in the food waste reception building before it is processed and fed to the digesters.</p> <p>Liquid feed material in the future will be stored in a new liquid feed tank (to be installed).</p>

	<p>Liquid feed will be delivered to site by tanker and will be fed to the digesters via the digester feed reception tank. There will be a direct connection between the tanker and the digester feed reception tank.</p> <p>All non-flammable chemicals / additives are stored in dedicated areas away from the main process plant area.</p> <p>The materials are handled manually or transported using telehandlers / forklift trucks.</p> <p>Diesel is stored in a dedicated container away from the main plant area.</p> <p>No refrigerant gas or spent gas is stored on site and is brought in / taken away by a specialist contractor, on a as required basis.</p> <p>Gas cylinders containing gases under pressure should be stored under the guidance provided by the British Compressed Gas Association guidance note GN2 - <i>Guidance for the Storage of Gas Cylinders in the Workplace</i>.</p> <p>Any chemicals stored on site should be stored in line with guidance provided by HSE Guidance document <i>HSG71 - Chemical Warehousing The storage of packaged dangerous substances</i>.</p>
<p>Hazards of material transfers, decanting and dispensing?</p>	<p>Solid food waste material is delivered to the food reception area by lorry and tipped onto the floor. When needed for processing, solid food waste is transported by a front loader to the Biorex Feed and Pre-treatment System (shredder and depackaging unit), where treated material is mixed and diluted with water. The food waste slurry is then fed to the digesters, via the digester feed reception tank.</p> <p>Liquid feed in the future will be delivered to site by tanker and will be fed to the digesters via the digester feed reception tank.</p>

	<p>All delivery of digester feed material is undertaken by a well-trained delivery driver.</p> <p>Biogas is stored in the digestate storage tank roof gas storage holder and transferred to the downstream processes by pipework.</p> <p>The spent digestate from the digesters is pasteurised, filtered (solids separated) and returned to the digestate storage tank. It is then removed by tanker for offsite disposal.</p> <p>The hazards associated with the handling and transfer of all flammable materials have been reviewed in the Hazardous Area Classification Study (see Appendix 3).</p> <p>For any spillages or leakages during the handling and transfer of raw materials there is a company procedure in place to avoid any ignition sources and ensure that any spillages are cleaned up immediately (WWOE 15).</p> <p>COSHH risk assessments have been completed for each chemical on site to determine handling procedures as well as required operator PPE.</p>
<p>Reactions taking place?</p>	<p>The main chemical reaction taking place on site for the anaerobic digestion plant is the anaerobic digestion of food waste.</p> <p>For the anaerobic digestion of food waste, bacteria and other micro-organisms are used to break down the feed material to produce biogas (digester gas). Biogas is primarily a mixture of methane and carbon dioxide but also contains some hydrogen sulphide, which is toxic, as well as Ammonia.</p> <p>Because of the adverse effect of hydrogen sulphide on the CHP gas engine, the feed materials are dosed with ferric chloride solution to destroy hydrogen sulphide before it is released. An air desulphurisation system with air blowers and air distribution pipework is also used to blow air into the digester. See 'Description of the Process.'</p>

	<p>Liquid condensate is removed from biogas, before biogas is used as a fuel in the site CHP gas engine.</p> <p>The CHP engine is connected to a generator to produce electricity which is used on site. The flue gas produced by the engine is exhausted to atmosphere after cooling. The heat from the gas engine (cylinder cooling and exhaust cooling) is used to maintain the digester temperatures at the desired level.</p> <p>A pasteurisation plant is used to treat spent digestate before the solids and liquor from the spent digestate are separated. The liquor from the solids separation plant is pumped to the digestate storage tank. The solids are collected and stored for offsite disposal.</p>
Anticipated releases	<p>The combustion process in the CHP engine, boiler and flare produces exhaust gases which are vented to the atmosphere via exhausts stacks. The combustion process generates no ash.</p> <p>The above is not flammable, however, may pose other hazards and risks which should be considered under other risk assessments.</p>
Accidental releases	<p>There are several potential events which could result in an accidental release in this process. The likely cause of an accidental release will be from leakage of food waste, biogas or digestate.</p> <p>Spillages of chemicals or compressor/lube oils is likely to occur either during the handling and transfer of chemicals and oils or during equipment operation.</p> <p>The chemical delivery system and oil systems use high integrity pipework with a minimum number of connecting flanges. The chemicals are pumped at low pressure to reduce the likelihood for leaks. The oils are pumped at low pressure to reduce the likelihood for the formation of any flammable mists.</p>

	<p>Delivery & filling operations of the chemical and oil systems is undertaken by trained operators or specialist maintenance contractors. If there is a leak, the operator/contractor will see the leak and stop the fill process.</p> <p>For any spillages or leakages, there is a company procedure in place to avoid any ignition sources and ensure that any spillages are cleaned up immediately. Site has a Spillage Procedure (WWOE 15).</p> <p>Exhaust gases containing carbon dioxide and carbon monoxide could be leaked into the CHP enclosures from a flange or fitting leak in the exhaust system. These are well ventilated and fitted with gas detection systems.</p> <p>The most likely cause of leakage from the refrigerant gas supply pipework will be from a fitting, flange or instrument nozzle on the process equipment. The chiller plant uses high integrity pipework with a minimum number of connecting flanges.</p> <p>The flammable hazards resulting from leakages and spillages have been reviewed in the Hazardous Area Classification Study in Appendix 3.</p>
<p>Products produced</p>	<p>The Welsh Water Organic Energy Ltd anaerobic digestion process produces electricity via a CHP engine that is used on site.</p> <p>Any spent food waste (digestate) is pasteurised before the liquor is pumped to the digestate storage tank and the solids are collected and stored for offsite disposal.</p> <p>Any excess biogas is oxidised/burnt in a ground flare.</p>
<p>Are they stored in the area?</p>	<p>Biogas is stored in the space below the inflatable gas storage holder above the digestate storage tank and stored above the slurry surface in the digester, post digester tank and the digestate storage tank.</p>

<p>How are products removed from the area?</p>	<p>Electricity is produced by the CHP engine for site usage.</p> <p>Biogas is flared if the CHP engine, boiler or site cannot take biogas .</p>
<p>Steps to minimise releases or prevent at source?</p>	<p>The plant is carefully constructed and maintained to limit the potential for leaks and is operated in the required manner as per the Operating and Maintenance manual.</p> <p>All the digesters are contained within a bunded area designed to limit the potential for discharges to the environment.</p> <p>The CHP gas engine is located within a well ventilated self-contained enclosure, to limit the impact of leaks. The boiler is located outside.</p> <p>There is a site preventive maintenance policy in place to ensure that equipment is regularly inspected and maintained to reduce the likelihood of leaks and equipment failure.</p> <p>All plant which could have a toxic or flammable atmosphere is enclosed and zoned, using the appropriate ATEX rated equipment to prevent ignition sources.</p> <p>For any spillages or leakages during the handling and transfer of materials there is a company procedure in place to avoid any ignition sources and ensure that any spillages are cleaned up immediately.</p> <p>All chemical containers and IBC's are positioned above portable bunds or spill trays designed to limit the potential for discharges to the environment.</p> <p>All operations staff are aware of the hazards and are trained to deal effectively and safely with leaks and spillages. This is part of the site Spillage Procedure (WWOE 15).</p>

<p>Have the number of employees exposed to the dangerous substances or explosive atmosphere been reduced to the minimum?</p>	<p>Yes – the number of operators used is the minimum number required for safe operation.</p> <p>Only 5 operators are needed to operate the AD plant. All operators are only present during the day shift from 6 am to 2 pm, or 2 pm to 10 pm, depending upon their defined roles. At night or on weekends, alarms are sent to their mobile phones if attendance is needed on site for any reason.</p> <p>The Welsh Water Organic Energy Ltd facility is operational 24 hrs a day and for 7 days a week.</p>
<p>Chemical reaction hazards</p>	<p>The main chemical reaction taking place for the AD plant is the anaerobic digestion of food waste, where bacteria and other micro-organisms are used to break down the feed material to produce biogas (digester gas). This is a relatively slow process with a total residence time of approximately 30-70 days. Biogas is primarily a mixture of methane and carbon dioxide but also contains some hydrogen sulphide, which is toxic, as well as Ammonia.</p> <p>Because of the adverse effect of hydrogen sulphide on the CHP gas engine, the feed material is dosed with ferric chloride solution to destroy the hydrogen sulphide in the digestate before it is transferred to the gas phase and emitted in the biogas.</p> <p>The reaction is:</p> $\text{FeCl}_2 + \text{H}_2\text{S} = \text{FeS} + 2\text{HCl}$ <p>A precise amount of ferric chloride must be added to the digestate as any excess could result in the excess production of hydrogen chloride, which will affect the pH of the digestate and the digestion process. Excess hydrogen chloride could potentially end up in the biogas and could cause corrosion problems in the gas engine, as it is an acid gas.</p> <p>In addition, air is also blown into the Digester using an air desulphurisation system to destroy the hydrogen sulphide in the digestate.</p>

By-products/wastes produced	<p>Spent digestate (liquid) is pasteurised before the solids and liquor from the spent digestate are separated. The liquor from the solids separation plant is pumped to the digestate storage tank. The solids are collected and stored for offsite disposal.</p> <p>Exhaust gases from the combustion of biogas in CHP engine, boiler or flare are vented through the CHP / boiler exhaust or Flare stacks to the atmosphere.</p> <p>All waste oils / chemicals are collected for offsite disposal by specialist contactors.</p>
Are any incompatible materials segregated?	<p>There are no obvious incompatible materials used on this site.</p> <p>However, all future incompatible materials will be adequately segregated. COSHH assessments will identify use and handling requirements as well as any segregation requirements.</p>
Is oxygen or any other oxidizing material used?	Oxygen and oxidising products are not used in this process.
Is any corrosive to metals substances used?	<p>Ferric Chloride (37-42%) Solution is added to the digestate to reduce the hydrogen sulphide concentration in biogas. Ferric Chloride is an acidic solution that maybe corrosive to metals.</p> <p>Ferric Chloride solution is used under controlled conditions and is suitably contained. The exposure to process equipment is limited and external corrosion that could cause structural damage of any equipment material and therefore reduce equipment integrity is unlikely.</p> <p>No other corrosive substances are currently used on this facility for the AD plant.</p>
Are any non-flammable gases under pressure used?	<p>The facility uses compressed air generated by a compressor for valve operation and dosing the digester.</p> <p>No gas cylinders are used on site.</p>

<p style="text-align: center;">Spillage and leak handling</p>	<p>Instructions for handling spills and leaks for the Welsh Water Organic Energy Ltd anaerobic digestion plant is contained in the Operating and Maintenance Manuals and Site Spillage Procedure.</p> <p>Any spills or leaks of liquids (feed, digestate etc.) should occur in a bunded area and hence will be retained to allow clean-up. Any spillage in this area should not seriously impact the local environment. As digestate could be mildly acidic, appropriate PPE will be used.</p> <p>For full handling details, see the COSHH Risk Assessment for digestate solution.</p> <p>Leaks of biogas are dangerous as the waste gas components are flammable, toxic and asphyxiants. For full details see the COSHH Risk Assessment for biogas.</p> <p>There are a number of detection systems for biogas leaks:</p> <ul style="list-style-type: none"> - Operators and contractors are equipped with personal gas monitors, which alarm if any flammable, toxic or asphyxiant gas is sensed. - There is a Gas Holder Leak Detection system which monitors the composition of air inside the gas holder to detect for any seepage of gas through the membrane between the gas space at the top of the digester and the air bubble on top of the digestate storage tank. - The CHP enclosure is monitored by two alarm systems: An internal flammable gas alarm system which indicates if any gas has been detected via a two tone klaxon and strobe light. An internal fire detection system which indicates if any fire/smoke has been detected via a two tone klaxon and a strobe light. <p>Instructions for handling spills and leaks from the site process operating equipment is contained in the Operating and Maintenance Manuals.</p> <p>A number of operational procedures are in place to ensure that any leaks or spillages are minimised.</p>
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	<p>These include operators being present during chemical deliveries, trained and skilled operators being used for operation of the plant including manual handling of chemicals, skilled forklift / telehandler drivers being used for all operations and regular inspection of equipment for leakage points.</p> <p>All storage containers and chemical IBC's are stored on portable bunds or spill trays designed to limit the potential for discharges to the environment.</p> <p>For any spillages or leakages outside bunded areas, there is a company site spillage procedure in place which includes instructions for handling spills and leaks. The procedure requires immediate clean up with the use of spill kits and other appropriate clean-up methods.</p> <p>Site has an Accident Management Plan and Emergency Response Plan.</p> <p>Any accident release from leakages or spillages resulting in flammable hazards have been reviewed in the Hazardous Area Classification Study in Appendix 3.</p>
Has the inventory been minimised?	Yes, as far as possible.
Other risk control measures	<p>Hazardous Area Classification (see Appendix 3).</p> <p>Operators and contractors have suitable PPE and are equipped with personal gas monitors to alarm if any flammable, toxic or asphyxiant gas is sensed.</p> <p>CHP enclosure has flammable gas and fire detection system providing alarms in the control room.</p> <p>The technical building pump room has flammable gas and fire detection system providing alarms in the control room.</p> <p>The plant control room, food reception hall and the LV area have fire detection systems providing alarms in the control room.</p>

	<p>A fire risk assessment for the site has been completed in November 2019 and was updated in August 2020.</p>
Equipment risks and their control	<p>Moving parts are guarded and any dismantling of pumps, mixing vessels, machinery etc., is a 'permit to work' activity or an activity using an approved method statement which has been risk assessed.</p> <p>All hot surfaces are insulated with warning and operators have appropriate PPE.</p> <p>All portable equipment and contractor's equipment will need to be certified and approved before use</p> <p>There are no other obvious equipment risks.</p>
Potential for release of dangerous substances?	<p>The potential for the release of flammable vapours are assessed in the HAZID and Hazardous Area Classification Studies (See Appendix 1 & 3).</p> <p>Leakage & spillages from equipment will be detected visually by the operator as operators will be regularly present in the plant areas during plant operation.</p> <p>Leakage from storage containers and drums will be detected by regular inspections by operators.</p> <p>The site delivery procedures as well as the use of ATEX equipment minimises the potential for ignition during delivery.</p>
Potential for explosive atmospheres to form within?	<p>The potential for explosive mixtures to form within equipment is assessed in the Hazardous Area Classification Study (See Appendix 3).</p>
Likely to generate ignition sources?	<p>Ignition sources are controlled by Hazardous Area Classification and ensure that the equipment within the Hazardous Areas complies with the requirements for installation in that area.</p>

	<p>The delivery and material transfer procedures minimise the potential for ignition during delivery.</p> <p>Persons on site do not carry any sources of ignition and any operations which require hot work and/or the ability to create sources of ignition are controlled by a risk assessment.</p> <p>The site operates a 'permit-to-work' system to assess and control any maintenance work, which requires a risk assessment of any proposed activity and where atmospheres are tested prior to commencement and at intervals to ensure that no flammable atmospheres exist. Personnel doing such work will use a personal monitor to detect any potentially flammable atmosphere.</p> <p>The design and operation of the Welsh Water Organic Energy Ltd anaerobic digestion facility seeks to ensure that explosive atmospheres are not created.</p>
<p>Steps to prevent the formation of explosive atmospheres?</p>	<p>The design and operation of the plant seeks to ensure that flammable atmospheres are not created except where intended (i.e. in the CHP engine / boiler / flare).</p> <p>Ignition sources for the processes are controlled by Hazardous Area Classification and all equipment within the Hazardous Areas complies with the requirements for installation in that area.</p> <p>The site has a preventive maintenance policy in place to ensure that equipment is regularly inspected and maintained to reduce the likelihood of leaks and equipment failure.</p> <p>The engineering and operations team manage, plan and control routine maintenance. Daily checks identify problems before they arise.</p> <p>Master copies of the maintenance records / procedures are available on the company server. Records are kept on site in the control room or offices. The site management maintains and keeps maintenance records / procedures up to date.</p>

	<p>All plant which could have a flammable atmosphere is enclosed, and if located within a zoned area, appropriate ATEX rated equipment is used to prevent ignition sources (see Appendix 3).</p> <p>Any equipment inside hazardous areas will be suitable for the ATEX zoning specified and is checked to ensure that it is suitable for the required Hazardous Area Classification / Zone.</p> <p><i>A zoned equipment audit of electrical and non electrical equipment is required under DSEAR Regulation 5(2) g.</i></p> <p><i>Hazardous Area Classification (HAC) Zoning Diagrams in both plan and elevation views are available and will need to be updated to identify the flammable ATEX zones identified in Appendix 3.</i></p> <p>The CHP enclosure is fitted with a methane gas detection system as well as a fire detection system. On methane gas detection the CHP engine is stopped but the enclosure ventilation will continue.</p> <p>The CHP engine enclosure has good ventilation.</p> <p>Any spillages or leakages are cleaned up straightaway to minimise the available time for a spillage to form a flammable vapour space.</p> <p>All site operations staff are aware of the hazards and will be trained to deal effectively and safely with leaks and spillages. This is part of the site Spillage Procedure.</p>
<p>Have steps been taken to collect, contain and remove any releases to a safe place (e.g. by ventilation)?</p>	<p>For the plant located outside, natural ventilation ensures that any leak of flammable Biogas is rapidly dispersed and that the maximum concentration of gas at any location is well below the LEL.</p> <p>For the self-contained CHP enclosure, a high level of artificial ventilation is maintained to ensure that any leak of flammable gas is rapidly dispersed and that the maximum concentration of gas at any location is well below the LEL.</p>

	<p>Any spillages within the manufacturing areas are contained and are cleaned up immediately.</p> <p>Good housekeeping and operator training ensure that any spillages are cleaned up as required.</p>
<p>Have adequate measures been taken to control or minimise the spread of fire, or explosion?</p>	<p>The plant where biogas is generated is located in a bunded area and the CHP Enclosure, where the gas is used to generate electrical power, is located some distance away.</p> <p>The plant area has break glass units and local fire extinguishers at strategic locations around the facility. This includes the plant room (control room), technology building and food reception hall.</p> <p>A fire risk assessment for the site has been updated in August 2020.</p>
<p>Control and mitigation measures</p>	<p>As above</p>
<p>Is equipment designed and installed to appropriate standards</p>	<p>Yes</p>
<p>Is equipment regularly inspected and maintained?</p>	<p>Yes</p>
<p>Are any gas monitors used with detection and alarm?</p>	<p>Yes</p> <p>A Gas Holder Leak Detection System, which monitors air quality between the inner and outer membrane of the gas storage holder, to check for any seepage of biogas through the membrane between the gas space at the top of the digesters and the gas storage holder on top of the digesters.</p> <p>The CHP gas engine enclosure is fitted with internal gas detection should a leak occur and provide alarms to the control room of any leakage inside the enclosures. The line supplying the digester gas to the CHP Enclosures is isolated by valve closure on gas detection.</p> <p>Operators and contractors are equipped with personal gas monitors to alarm if any flammable, toxic or asphyxiant gas is sensed.</p>

<p>Any special risks during maintenance?</p>	<p style="text-align: center;">Yes</p> <p>This DSEAR Risk assessment relates to normal operation. Risks are somewhat different during maintenance, especially during shut-down and start-up of the Anaerobic Digestion plant.</p> <p>The operation & maintenance manuals provided include start-up and shut-down procedures and where no procedures have been provided, the site has developed or will develop start-up and shutdown procedures.</p> <p>All significant maintenance work is undertaken when the relevant plant is not operating and will be subject to a risk assessment via a permit to work system or via a safe systems of work procedure.</p>
<p>What steps are taken to limit electrostatic discharge from equipment or people?</p>	<p>The plant has the application of adequate earthing. Appropriate certified equipment for Zones are used. There is Overload and Short Circuit protection. There is a risk assessment for the use of portable tools and test equipment.</p> <p>The site operates a 'permit-to-work' system to assess and control any maintenance work, which requires a risk assessment of any proposed activity.</p> <p>The site has adequate lightning protection around the main plant equipment such as the digesters.</p>
<p>Are the dangerous substances a risk to health?</p>	<p style="text-align: center;">Yes</p>
<p>Are they adequately handled by COSHH?</p>	<p style="text-align: center;">Yes</p>
<p>Precautions</p>	<p>COSHH Assessments for all raw materials used in the process and the products are available from the site Plant Manager / Dŵr Cymru Health & Safety Officer. These are available on the company server, with working copies kept on site in the main office room.</p> <p>COSHH Risk Assessments are updated regularly by the site Health and Safety officer and audited by site management.</p>

	<p>Biogas is highly flammable, toxic and can readily form ignitable and explosive mixtures with air at normal room temperatures.</p> <p>The risk of harm from biogas exposure is small as biogas is normally enclosed and any leaks will disperse, as biogas pipework for this site is normally uncongested and located in freely ventilated areas (outdoors).</p> <p>Welsh Water Organic Energy Ltd operators have appropriate PPE (Hi visibility clothing, safety boots / wellington boots, gloves, safety glasses, rain wear) and are trained to deal with biogas releases.</p> <p>Operators and contractors (where appropriate) use personal gas monitors which monitor flammables, H₂S and oxygen as a minimum.</p> <p>A site induction makes all personnel accessing the plant area aware of the hazards of flammable gases.</p> <p>Compressor / lube oils are flammable liquids which are used for the chiller unit and CHP engines and can be harmful if swallowed or inhaled and cause lung damage. Over exposure may cause skin dryness or cracking. The risk of harm from compressor / lube oil exposure is small as the oil is normally enclosed and any spillages and leaks are contained within the CHP enclosures.</p> <p>The operators have appropriate PPE and are trained to deal with any site spillages as part of the site Spillage Procedure.</p> <p>The principal hazards from compressor / lube oil storage are fires and explosions, with hazards arising from leaks resulting in a potential for a vapour cloud explosion. In this case, all ignition sources are removed (no smoking, flares, sparks or flames in immediate area). All equipment used when handling the product is grounded.</p> <p>Any accident release from leakages or spillages and the hazards resulting from leakages and spillages of flammable solvents have been reviewed in the Appendix 3.0.</p>
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	<p>Some plant areas have an 'Ex' sign warning all personnel that they are entering a potential flammable zone.</p> <p><i>Ensure that all 'Ex' areas are signed accordingly to identify any hazardous areas including all the main plant areas.</i> The sign should be located on the main entrance to each plant area to warn any personnel before they enter each ATEX Zoned area.</p> <p>Refrigerant gas R140a is used in the chiller process. R140a gas is not considered a flammable material. The COSHH risk assessment for refrigerant gases include the risks associated with the use and handling of these materials. Refrigerant is only handled by specialist maintenance contractors. Who wear suitable protective eyewear and clothing (overalls and gloves). Any spills or leakages are cleaned up using appropriate spill kits.</p> <p>The site utilises toxic chemicals such as ferric chloride. The COSHH risk assessments for these chemicals include the risks associated with the use and handling of these materials.</p>
Are the precautions adequate	When the above are available, then the arrangements are considered adequate
Sources of ignition?	Minimised in the Hazardous areas (see above)
Naked Flames?	<p>The only flames are in equipment requiring such (e.g. the CHP engine, boiler, flare).</p> <p>There are no naked flames in the process plant area, or any other areas of the site.</p>
Electrics/Instruments?	Equipment in Hazardous Areas will comply with the requirements for installation in such an area. The equipment will be installed and maintained by personnel / contractors who are experienced and qualified to do such work.

Mechanical friction?	<p>The likelihood of this appears remote, however the process does involve conveying of solids, pumping of digestate.</p> <p>All mechanical equipment is adequately classified for the required service and is earthed.</p> <p>All gas pipework is earthed as required.</p>
Electrostatics?	Earthing and suitable PPE is used to minimise the likelihood of this.
Hot surfaces?	<p>These should only occur in areas where combustion is intended or for heated systems.</p> <p>All hot surfaces are suitably insulated. Any hot surfaces which are not suitably insulated have warnings.</p> <p>Any hot work inside the plant area is subject to a Permit to Work and separate risk assessment.</p>
Others?	<p>Any areas where significant noise could be generated by process machinery (i.e. CHP engine Biorex Feed System etc, require suitable noise protection for the operators. Warning signs are affixed to the entrances to the high noise areas.</p> <p>A site noise risk assessment has been undertaken for the whole site.</p> <p>Impact barriers should be fitted as required to protect any equipment against impact damage from delivery tanks and forklift trucks.</p> <p>A site Traffic Management Policy is in place for normal operation of the AD plant to ensure that site vehicle incidents are prevented by the effective management of transport operations. This involves a one vehicle in, one vehicle out policy.</p>
What precautions are in place to minimise ignition sources?	<p>As above.</p> <p>For the whole facility including the main process areas, no smoking or naked lights are allowed.</p> <p>All mobile phones should be switched off.</p>

<p>Fire Precautions:</p>	<p>Break-glass units are located around the site.</p> <p>Fire detectors in the CHP enclosure, the technical building, the plant control room, food reception hall and the LV area are connected to an alarm and on activation the operators can call out the fire brigade.</p> <p>If a fire is detected in the CHP enclosures, the fire and smoke detection systems activate an audio and visual alarm with automatic shut off of the gas supply to the CHP engine.</p> <p>There are local fire extinguishers and there is a site fire safety management and evacuation plan. This is defined by the site regulatory fire risk assessment which determines the general fire safety requirements for the facility.</p>
<p>Is the workplace designed, constructed and maintained so as to provide adequate fire-resistance and/or explosion relief?</p>	<p>Yes – designed to the required regulations and standards.</p>
<p>Means of detection and alarm</p>	<p>Break-glass units are located around the site.</p> <p>Fire detectors in the CHP enclosure, the technical building, the plant control room, food reception hall and the LV area are connected to an alarm to the control room.</p> <p>On activation of an alarm, the operators can call out the fire brigade.</p>
<p>Means of escape</p>	<p>The site design ensures that there is alternative means of escape from each area of the plant.</p>
<p>Means of fighting fire</p>	<p>Fire extinguishers for small fires.</p> <p>Fire is fought mainly by preventing gas from reaching areas on fire by closing appropriate isolating valves which are able to be closed while the fire is taking place.</p>

Training in fire safety	<p>The operators have received fire training in the use of extinguishers. <i>However, this should be reviewed and updated.</i></p> <p>Large fires will be fought by the Fire Brigade.</p>
Date of last fire authority inspection	<p>A Fire Risk Assessment has been completed for the site in November 2019 and the local fire brigade has visited the site previously to inspect and acquaint them with the details of the operation and its risks.</p> <p>Briefing papers will be available at the site offices to update the local brigade if they are called to an incident.</p>
Effects of Fire/Explosion:	See Below
Is equipment designed in such a manner as to minimise risk of fire and/or explosion?	Yes – to relevant design standards and regulations.
Have appropriate safe systems of work been developed and communicated to the workforce?	Yes, included within operating procedures and Operating and Maintenance manuals.
Is a permit to work scheme required for working with the substance(s), or in the work area, and are these strictly enforced?	<p>The site operates a ‘permit-to-work’ system to assess and control any maintenance work, which requires a risk assessment of any proposed activity.</p> <p>The ‘permit-to-work’ system is controlled and enforced by the site management.</p>
Who might be harmed?	Operators, contractors, delivery drivers, maintenance personnel, office workers and site visitors.
Likely extent of fire	<p>The areas most at risk if there was a fire in the AD Plant are the food collection / storage area, digesters, the pasteurisation plant, the CHP gas engine enclosure, solids separation area, the site control room and the gas supply pipework.</p> <p>The CHP engine area, feed collection area, site offices are separated away from the main AD plant area and it appears unlikely that a fire in one would affect the other areas.</p>

	<p>There are no ignition sources within the plant area and the design and operation of the plant seeks to ensure that explosive / flammable atmospheres are not created except where intended (i.e. flare).</p> <p>The likelihood of fire is small due to the control procedures in place for the site.</p>
Likely extent of explosion	<p>The likelihood of explosion is small and can only result from a catastrophic fire event. The likelihood is minimised due to the control procedures in place for the site.</p>
Areas which are connected	<p>The Welsh Water Organic Energy Ltd facility is a large site and the Anaerobic Digestion plant is located at one end of the site. The facility consists of a feed reception building, process equipment area (housing Anaerobic Digestion process), control room, CHP containerised enclosure, boiler and the flare.</p> <p>There is also a separate office building and a car park area located outside the main plant area at the entrance of the site.</p> <p>The site is in a heavily populated industrial area of Cardiff, next to Welsh Waters Cardiff East Wastewater Treatment Works and Celsa Manufacturing (UK) Ltd Tremorfa Steel Works. Nearby are other industrial units.</p>
Are these areas affected?	<p>Yes – a large fire will affect the Anaerobic Digestion plant and potentially the surrounding area.</p> <p>The site is not near to any residential dwellings.</p>
Containment measures?	<p>The site has the ability to shut off supplies of gas thus starving the fire of fuel.</p> <p>The CHP enclosures have fire and smoke detection systems fitted. If a fire is detected in the CHP enclosure, audio and visual alarms are activated and an automatic valve shuts on the gas supply to the building.</p> <p>Each area is built to fire regulations.</p>

Has suitable Personal Protective Equipment (PPE) been provided, and have operatives been trained how to wear it correctly?	<p>Overalls, high vis clothing, safety footwear, eye protection, dust masks, safety helmets, rain wear and gloves are all available and used for some operations.</p> <p>Some of the chemicals used are hazardous and toxic and suitable protective equipment is used by operators as recommended in the COSHH risk assessment.</p> <p>There is no PPE specifically for fire protection and as such does not appear to be required.</p>
Additional Information	Site has a fire plan which involves the local fire brigade and includes the plant area, all buildings and all relevant external areas.
Skills/Knowledge/experience of employees	Operating procedures and operators are well trained and skilled in the operation of the plant.
Training of employees	<p>Yes – firefighting (use of fire extinguishers) and operating procedures.</p> <p>The operators have received a variety of training courses. This should be reviewed to see if the training needs to be updated.</p> <p>Also there are regular update sessions on Health & Safety.</p> <p>The operators are trained in operating the plant.</p>
Are only trained and competent persons involved in work with dangerous substances?	Yes
Supervision of employees	The operations staff are supervised by the senior management of the company.
Conclusions	The above enhancements if incorporated, along with the recommendations of the Hazardous Area Classification will represent general compliance with DSEAR.
What further steps are considered necessary to control and mitigate risks?	Documentation will need to be regularly updated to keep pace with equipment changes.
Is it necessary to classify hazardous areas?	Yes, a Hazardous Area classification has been completed in Appendix 3.0 and will need to be periodically updated in line with the above.

Appendix 1: Hazard Identification

Hazard ID	Hazard Identified	Cause	Potential Impact (Personnel / Environment / Assets)	Inherent Risk (3 = high, 1 = Low)	Safeguards shown or known to be present	Safeguards available but not shown or known to be present	Mitigating Factors	Likely Consequences		Residual Risk (3 = high, 1 = Low)	Recommended Safeguards	Comments
								Severity	Likelihood			
Overall Plant (Anaerobic Digestion Plant & CHP Engines)												
1.01	Fire or Explosion	External leak of flammable gas from equipment (loss of containment of biogas)	Death or injury to personnel, Equipment damage, environmental incident	3	Equipment design to relevant regulations. Minimum use of flanges is incorporated in the design.	DSEAR compliance, risk assessment [zoned areas]. Before start up, leak tested. Good ventilation as most of plant is outside and gas release will disperse readily. Site operators have personnel CH4 /H2S gas detection monitors.	Site fire plan and responsible local emergency services. Low gas supply pressure used only (4 mbarg).	Fatality	Possible within a 10 year period	2		
1.02	Fire or Explosion	External leak of flammable gas from condensate pot (loss of containment of biogas)	Death or injury to personnel, Equipment damage, environmental incident	3	Equipment design to relevant regulations.	DSEAR compliance, risk assessment [zoned areas]. Before start up, equipment leak tested. Good ventilation as most of plant is outside and gas release will disperse readily. Site operators have personnel CH4 /H2S gas detection monitors.	Site fire plan and responsible local emergency services. Low gas supply pressure used only (4 mbarg).	Fatality	Possible within a 10 year period	2		
1.03	Fire or Explosion	External leak of flammable gas from equipment inside CHP enclosure (loss of containment off biogas)	Death or injury to personnel, Equipment damage, environmental incident	3	Equipment design to relevant regulations. Minimum use of flanges is incorporated in the design. On gas detection the CHP engine will be stopped and the enclosure ventilation will continue.	Fire and gas detection within enclosure, DSEAR compliance, risk assessment [zoned areas]. Before start up, leak tested. Good ventilation typically around 100 ach will ensure that gas is not allowed to accumulate within the enclosure.	Site fire plan and responsible local emergency services. Low gas supply pressure used only.	Fatality	Possible within a 10 year period	2		The CHP engines are the supplier standard design and many installations of this design have been used for similar applications.
1.04	Fire or Explosion	Fire or Explosion - CHP engine lubrication leak from a screwed fitting or connection (oil mist if pumped)	Death or injury to personnel, Equipment damage, environmental incident	3	Plant equipment designed for oil pipework including consideration of material selection, and pressure testing / leak testing of connections during commissioning and after maintenance. Minimum use of screwed connections is incorporated in the design.	Fire detection within enclosure, DSEAR compliance, risk assessment [zoned areas]. Before start up, leak tested. Operator daily checks for leaks.	Site fire plan and responsible local emergency services. All leaks contained within a bund. CHP oil system is located within the CHP enclosure. Oil is pumped at low pressure.	Fatality	Possible within a 10 year period	1		The use of shrouding or flange guards will prevent this event from occurring. Oil is pumped at low pressure and always monitored.
1.05	Fire or Explosion	External leak of flammable gas from CHP exhaust due to uncombusted flammable gases being discharged and igniting (loss of containment of biogas)	Death or injury to personnel, Equipment damage, environmental incident	3	Equipment design to Machinery Standard Directive 2006/42/CE and EN 12061 & EN 60204-1. CHP engine design reduces likelihood of missed ignition and unspent gases venting through the exhaust system.	Fire and gas detection within enclosure, DSEAR compliance, risk assessment [zoned areas]. Before start up, leak tested. Good ventilation as gas release is to environment and will disperse readily.	Site fire plan and responsible local emergency services. CHP engine is protected by regulating systems against erratic and abnormal operation.	Fatality	Possible within a 10 year period	1		

Hazard ID	Hazard Identified	Cause	Potential Impact (Personnel / Environment / Assets)	Inherent Risk (3 = high, 1 = Low)	Safeguards shown or known to be present	Safeguards available but not shown or known to be present	Mitigating Factors	Likely Consequences		Residual Risk (3 = high, 1 = Low)	Recommended Safeguards	Comments
								Severity	Likelihood			
1.06	Fire or Explosion	External leak of flammable gas from flare system due to uncombusted flammable gases being discharged and igniting (flare failure)	Death or injury to personnel, Equipment damage, environmental incident	3	Equipment design Flare system design reduces likelihood of missed ignition and unspent gases venting vented through the flare stack.	DSEAR compliance, risk assessment [zoned areas]. Before start up, leak tested. Good ventilation as gas release is to environment and will disperse readily.	Site fire plan and responsible local emergency services. Flare system is protected by regulating systems against erratic and abnormal operation.	Fatality	Possible within a 10 year period	1		
1.07	Fire / Explosion	Lightning strike	Death or injury to personnel, Equipment damage, environmental incident	3	Equipment design. Suitable lightning protection fitted for digesters and digestate tank.	Adequate earthing and material design.	Risk assessment [zoning and COSHH].	Fatality	Within plant life time [30 years]	1		Some lightning protection rods are close to vent discharge points, however well outside any ATEX zoned area.
1.08	Fire or Explosion	Fire or Explosion - Food Macerator System - Hydraulic System lubrication leak from a screwed fitting or connection (potential for oil mist)	Death or injury to personnel, Equipment damage, environmental incident	3	Plant equipment designed for oil pipework including consideration of material selection, and pressure testing / leak testing of connections during commissioning and after maintenance. Minimum use of screwed connections is incorporated in the design.	DSEAR compliance, risk assessment [zoned areas]. Before start up, leak tested. Operator daily checks for leaks.	Site fire plan and responsible local emergency services. All leaks contained within food reception building .	Fatality	Possible within a 10 year period	1		The use of shrouding or flange guards will prevent this event from occurring. Oil is pumped at low pressure and always monitored.
1.09	Fire or Explosion	External leak of flammable diesel from storage tank (loss of containment of diesel)	Death or injury to personnel, Equipment damage, environmental incident	3	Plant equipment designed for diesel pipework including consideration of material selection, and pressure testing / leak testing of connections during commissioning and after maintenance.	DSEAR compliance, risk assessment [zoned areas]. Before start up, leak tested. Diesel tank has an integral bund to contain any leaks.	Site fire plan and responsible local emergency services. Diesel is only pumped into a bulk container and then into portable containers. At all times, the operator is present during bulk tank filling/emptying and can stop diesel transfer if there is a leak.	Fatality	Possible within a 10 year period	1		Diesel storage area is located within a dedicated area.
1.10	Fire or Explosion	External leak or spillage of flammable solvents.	Injury to personnel, Equipment damage, environmental incident	2	Very small quantities used on site only.	DSEAR compliance, risk assessment [zoned areas].	Site spillage and clean up procedures. Operator procedures for handling chemicals.	Fatality	Possible within a 10 year period	1		Likelihood is reduced for flammable releases due to small quantities used for maintenance.
1.11	Fire or Explosion	Methane gas or H2S generated from decomposing waste in waste reception area.	Death or injury to personnel, Equipment damage, environmental incident	3	Waste is not allowed to stand for long periods to ensure that there is insufficient time for decomposition. There is an EA permit which requires all food waste to be processed within 3 days.	DSEAR compliance, risk assessment [zoned areas]. Site operators have personnel CH4 / H2S gas detection monitors.	Site fire plan and responsible local emergency services.	Fatality	Possible within a 10 year period	1		

Hazard ID	Hazard Identified	Cause	Potential Impact (Personnel / Environment / Assets)	Inherent Risk (3 = high, 1 = Low)	Safeguards shown or known to be present	Safeguards available but not shown or known to be present	Mitigating Factors	Likely Consequences		Residual Risk (3 = high, 1 = Low)	Recommended Safeguards	Comments
								Severity	Likelihood			
1.12	Fire or Explosion	Build up of static on the pipe work leads to ignition risk	Death or injury to personnel	3	Equipment design.	Adequate earthing protection and material design at required locations.	Risk assessment [zoning and COSHH]. Maintenance and regular inspections of earthing systems.	Fatality	Within plant life time [30 years]	1		All gas pipework is stainless steel and earthed.
1.13	Fire or Explosion	Equipment failure during operation (CHP engine)	Death or injury to personnel, Equipment damage, environmental incident	3	Equipment designed to relevant standards. All flanged sections and fitting checked for tightness and leaks before start-up.	DSEAR compliance, & risk assessment [Zoned areas reduce sources of ignition].	Site fire plan and responsible local emergency services. Gas detection system in CHP control system will shut down process safely.	Fatality	Possible within a 10 year period	1		The CHP and Boiler are maintained by external organisations.
1.14	Fire or Explosion	Equipment failure during operation (Boiler)	Death or injury to personnel, Equipment damage, environmental incident	3	Equipment designed to relevant standards. All flanged sections and fitting checked for tightness and leaks before start-up.	Site fire and gas detection, DSEAR compliance, & risk assessment [Zoned areas reduce sources of ignition].	Site fire plan and responsible local emergency services. Boiler will shut down safely on failure.	Fatality	Possible within a 10 year period	1		
1.15	Fire or Explosion	External leak of flammable gas from flange or fitting leak on gas supply line (loss of containment of biogas).	Death or injury to personnel, Equipment damage, environmental incident	3	Equipment design to relevant regulations.	Site fire & gas detection, DSEAR compliance, risk assessment [zoned areas]. Before start up, leak tested. Good ventilation and gas release will disperse readily. Site operators have personnel CH4 /H2S gas detection monitors..	Site fire plan and responsible local emergency services. Low gas supply pressure used only (<200 mbarg).	Fatality	Possible within a 10 year period	2		The boiler is located outside and away from personnel areas.
1.16	Surface Fire	External sources (i.e. site operations, site equipment failure)	Death or injury to personnel, Equipment damage, environmental incident	3	Equipment design and location. Controlled access site. Operator training	DSEAR compliance, & risk assessment [Zoned areas reduce sources of ignition]. Before start up, equipment is checked and tested.	Site fire plan and responsible local emergency services. Site Fire Risk Assessment.	Fatality	Within plant life time [30 years]	2		A site fire risk assessment has been updated to review the requirements of fire detection systems for the facility.
1.17	Fire	Diesel Storage & Supply System	Death or injury to personnel, Equipment damage, environmental incident	3	All fuel is stored in an enclosed tank (which is banded) and away from sources of fire. Diesel tank is fitted with compliance instruments.	DSEAR compliance, & risk assessment [Zoned areas reduce sources of ignition].	Site fire plan and responsible local emergency services.	Fatality	Within plant life time [30 years]	1		Diesel storage area is located within a dedicated area.
1.18	Fire	Food waste in waste reception area.	Death or injury to personnel, Equipment damage, environmental incident	3	All food waste is stored in a dedicated area away from sources of fire. Waste is not allowed to stand for long periods to ensure that there is insufficient time for decomposition.	DSEAR compliance, risk assessment [zoned areas]. Site operators have personnel CH4 / H2S gas detection monitors.	Site fire plan and responsible local emergency services.	Fatality	Possible within a 10 year period	1	Consider whether fire and gas detection systems are required for the food reception building.	Food reception area does not have any fire detection system installed.

Hazard ID	Hazard Identified	Cause	Potential Impact (Personnel / Environment / Assets)	Inherent Risk (3 = high, 1 = Low)	Safeguards shown or known to be present	Safeguards available but not shown or known to be present	Mitigating Factors	Likely Consequences		Residual Risk (3 = high, 1 = Low)	Recommended Safeguards	Comments
								Severity	Likelihood			
1.19	Toxicity and Asphyxiation	External leak of toxic gas from equipment (loss of containment of biogas)	Death or injury to personnel	3	Equipment design	Closed system, equipment is checked and tested routinely. Site operators have personnel CH4 / H2S gas detection monitors.	Maintenance and regular inspections. Ventilation	Fatality	Possible within a 10 year period	1		
1.20	Toxicity and Asphyxiation	Leak of exhausts gas from CHP exhaust within enclosure	Death or injury to personnel	3	Equipment design to Machinery Standard Directive 2006/42/CE and EN 12061 & EN 60204-1. Minimum use of flanges incorporated in the design.	Fixed gas detection system inside enclosures. Individual personnel monitors for CO, CO2 gas detection.	COSHH risk assessment and good ventilation	Fatality	Possible within a 10 year period	1		
1.21	Toxicity and Asphyxiation	Leak of refrigerant R410a at pressure from chiller system	Death or injury to personnel	3	Equipment design and operator can see leak.	Good ventilation as chillers are located outdoors.	Regular inspections and appropriate operator PPE	Injury	Possible within a 10 year period	1		The chiller system is maintained by an external organisation.
1.22	Hot gas release	Hot gas release from process (biogas at 40 degC)	Personnel injury [Burns] or fatality	2	Insulation design. All hot pipes are not easily accessible to operators.	Site gas detection. Building Ventilation.	Risk assessment with operator having appropriate PPE	Severe Injury or fatality	Possible within a 10 year period	1		Regular inspection of flange and gaskets should reduce the likelihood of leaks.
1.23	Hot gas release	Hot exhaust gas release (CHP exhaust)	Personnel injury [Burns]	2	Equipment design. Minimum use of flanges incorporated in the design.	Ventilation and visual detection	Risk assessment with operator having appropriate PPE. Restricted access for operators.	Severe Injury	Possible within a 10 year period	1		Regular inspection of flange and gaskets should reduce the likelihood of leaks.
1.24	Cold gas release	Leak of refrigerant at pressure from chiller system	Personnel injury [Cold Burns]	2	Equipment design and operator can see leak.	Good ventilation as chillers are located outdoors.	Regular inspections and appropriate operator PPE	Injury	Possible within a 10 year period	1		Regular inspection of flange and gaskets should reduce the likelihood of leaks.
1.25	Air release	Air leak from air lines (pipe, flange/gasket leak)	Process inefficiency & Personnel injury if at pressure (8 barg).	2	Equipment design. Operator can hear leak	Maintenance and regular inspections.	Risk assessment. Daily operator checks for leaks.	Minor	Possible within a 10 year period	1		Regular inspection of flange and gaskets should reduce the likelihood of leaks.
1.26	Hot water release	Leak of hot water from hot water system (70-100 degC).	Personnel injury [Burns]	2	Equipment design and operator can see leak. Pipework is insulated and will prevent any spray of hot water.	Closed system and loss of water should be detected.	Regular inspections. Any works to the system will be undertaken when the system is not operating.	Injury	Possible within a 10 year period	1		Regular inspection of fittings and gaskets should reduce the likelihood of leaks.
1.27	Water release	Leak of hot water from hot water system	Personnel injury [slips]	2	Equipment design and operator can see leak.	Closed system and loss of water should be detected.	Regular inspections. Any works to the system will be undertaken when the system is not operating.	Injury	Possible within a 10 year period	1		

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								Severity	Likelihood			
1.28	Digestate release	External leak of digestate from equipment	Injury to personnel	2	Equipment design. Emergency shower.	Equipment is checked and tested routinely. Operator PPE.	Maintenance and regular inspections. Ventilation	Fatality	Possible within a 10 year period	1		
1.29	Chemical release	Chemical leak (ferric chloride) from equipment or spillage from delivery	Personnel injury (burns)	2	Equipment design and chemical stored in bunded area. Emergency shower.	Maintenance and regular inspections. Operator procedures for handling chemicals.	COSHH risk assessment with appropriate PPE	Injury	Possible within a 1 year period	1	Consider whether activation of emergency shower should result in an alarm within the control room. This will warn the control room that an operator could be in danger and be exposed to a hazardous chemical.	The COSHH risk assessment considers storage and delivery method as well as reactions with other chemicals on site.
1.30	Noise	Equipment noise	Personnel injury [hearing damage]	2	Equipment design and operating procedures	Maintenance and regular inspections. Regular noise measurements and site noise risk assessment.	Appropriate PPE	Injury	Within plant life time [30 years]	1	Consider whether the requirement for using hearing protection in high noise areas should be enforced	A site noise assessment for the site has been completed which identified areas of high noise. These areas are adequately labelled with warnings.
1.31	Personnel touching hot equipment surfaces from high equipment temperatures	General process conditions	Personnel injury [Burns]	2	Equipment design with an appropriate insulation	Insulation guarding and warning signs.	Risk assessment with operator having appropriate PPE	Injury	Possible within a 10 year period	1		
1.32	Personnel touching hot equipment surfaces from high equipment temperatures	Insulation break down	Personnel injury [Burns]	2	Insulation design	Insulation guarding and warning signs.	Risk assessment with operator having appropriate PPE	Injury	Possible within a 10 year period	1		
1.33	Plant damage	Impact or sabotage	Personnel injury and equipment damage	2	Operator training and procedures for vehicle operations. Main process equipment located in a bund which protects against impact damage from delivery tanks and fork lift trucks.	All maintenance work will be undertaken when the plant is shut down and not operational.	Controlled access for vehicles and crane operations. All contractors checked and vetted for competency before any works initiated.	Injury	Within plant life time [30 years]	1	Review whether additional impact protection is required for the food reception building against impact from food delivery trucks.	Armco type barriers could be used to protect the building against delivery truck impact and damage.
1.34	Plant damage	Failure to maintain instrumentation	Personnel injury and equipment damage	2	Maintenance procedures	All maintenance work will be undertaken by competent personnel and when plant is shutdown	Regular instrument inspections and checks. Instrument failure alarms which result in an operator call out.	Injury	Possible within a 10 year period	1		All ATEX equipment and instruments are maintained by an external organisation.
1.35	Plant damage	Failure to maintain pressure relief devices.	Death or injury to personnel, Equipment damage, environmental incident.	3	All over pressure protection devices inspected as identified in the O & M instructions.	Operating & maintenance procedures	Regular inspections.	Fatality	Possible within a 10 year period	2		AD Plant not fitted with any high pressure relief valves.
1.36	Plant damage	Cold ambient conditions and standing water within process	Potential equipment damage from standing water freezing, environmental incident	2	Residual heat in the system ensures freezing of standing water in pipelines is prevented.	Operating & maintenance procedures.	Regular inspections.	Equipment damage	Possible within a 10 year period	1		

Hazard ID	Hazard Identified	Cause	Potential Impact (Personnel / Environment / Assets)	Inherent Risk (3 = high, 1 = Low)	Safeguards shown or known to be present	Safeguards available but not shown or known to be present	Mitigating Factors	Likely Consequences		Residual Risk (3 = high, 1 = Low)	Recommended Safeguards	Comments
								Severity	Likelihood			
1.37	Plant damage	Cold ambient conditions and relief valve seal water freezes. Loss of pressure protection system.	Potential equipment damage from standing water freezing, environmental incident	2	Residual heat in the system ensures freezing of standing water in relief valves is prevented. Valves are trace heated.	Operating & maintenance procedures.	Regular inspections in cold weather conditions.	Equipment damage	Possible within a 10 year period	1		
1.38	Plant damage	Control System Failure.	Potential unsafe operation of the Plant.	3	Control system design ensures safe operation as long as the control system is maintained.	Operating & maintenance procedures	Regular inspections	Equipment damage	Possible within a 1 year period	1		
1.39	Plant damage	Increased corrosion issues due to corrosive digestate.	Injury to personnel, Equipment damage, environmental incident.	2	Equipment design with suitable corrosion resistance material used. Plant is located in a bunded area	Maintenance and regular inspections and operator procedures.	COSHH risk assessment with an appropriate PPE. Digestate on site is not corrosive and is at pH 7.	Injury / Equipment damage.	Possible within a 10 year period	1		All hazardous process chemicals require to be included in site COSHH assessment.
1.40	Plant damage	Increased corrosion issues due to corrosive chemicals used on site.	Injury to personnel, Equipment damage, environmental incident.	2	Equipment design with suitable corrosion resistance material used. Plant is located in a bunded area	Maintenance and regular inspections and operator procedures.	COSHH risk assessment with an appropriate PPE. Use of corrosive chemicals may be removed from site.	Injury / Equipment damage.	Possible within a 10 year period	1		All hazardous process chemicals require to be included in site COSHH assessment.
1.41	Power failure	Loss of control of plant, loss of lighting which might inhibit escape at night or inside enclosures.	Personnel injury and possible equipment damage	2	Backup power for all critical plant systems.	Emergency lighting, all critical systems will fail in safe state.	Routine inspection of pant safety shutdown systems.	Injury	Possible within a 10 year period	1		
1.42	Inadequate earthing	Deterioration of connections which goes undetected	Build up of static charges or electrical potential making electrical discharges more likely which increases the likelihood of explosions [acting as a source of ignition] and electrical shock.	2	Uncertain	Good connections on to equipment and earthing grid.	Routine electrical inspection of cables and wirings, switches and fuses in and outside electrical cabinets and motor connections is undertaken.	Injury or worse	Possible within a 10 year period	1		
1.43	Moving Parts	Operator touching moving plant such as motors etc.	Death or severe injury to personnel.	3	Equipment design. Operator can see moving parts and avoid.	Signs, Operator procedures, guards to protect against moving parts	Risk assessment	Severe Injury	Possible within a 1 year period	1		Operators trained under a site procedure which requires machine to be shut down first.
1.44	Odour	Food waste	Unpleasant working environment - excessive odours and operator discomfort. Possible breach of environmental permit.	1	Most of the plant is located outside. Food reception area building has good ventilation. Waste is not allowed to stand for long periods to ensure that there is insufficient time for decomposition.	Operator can smell odour. Site odour abatement system.	COSHH risk assessment with appropriate PPE (COSHH Assessment confirms waste storage and handling procedures).	Minor	Possible within a 1 year period	1		Site has odour abatement system connected to a bio-filter.
1.45	Toxicity and Asphyxiation	High odour emitted from pasteurised solid waste (Screenings)	Unpleasant working environment - excessive odours and operator discomfort. Possible breach of environmental permit.	1	The pasteurised solid waste is located within its own closed building.	Operator can smell odour.	COSHH risk assessment with appropriate PPE (COSHH Assessment confirms waste storage and handling procedures).	Minor	Possible within a 1 year period	1		The pasteurised waste odour could contain high levels of ammonia. Review whether Work Instruction or SOP should include opening of doors to dissipate odour and a check of ammonia levels is undertaken before operator enters the building.

Hazard ID	Hazard Identified	Cause	Potential Impact (Personnel / Environment / Assets)	Inherent Risk	Safeguards shown or known to be present	Safeguards available but not shown or known to be present	Mitigating Factors	Likely Consequences		Residual Risk	Recommended Safeguards	Comments
				(3 = high, 1 = Low)				Severity	Likelihood	(3 = high, 1 = Low)		
1.46	Pests	Pests (insects, rodents, animals (foxes and birds) attracted to food waste processing environment.	Potential for disease and hygiene risks.	1	Good housekeeping and cleaning around site.	Pest control in food / waste handling area.	Pest Control	Minor	Possible within a 1 year period	1		
1.47	Toxicity and Asphyxiation	Standing water (emergency showers) could have bacterial growth (legionella)	Injury to personnel.	2	Equipment designed to reduce risk of Legionella.	Maintenance and regular inspections.	Site Legionella Risk Assessment.	Injury	Possible within a 1 year period	1	A Site Legionella Risk Assessment will need to be undertaken to include all standing water systems including the emergency shower.	
1.48	Groundwater contamination	Leaks from silage seepage, leaking pipes.	Injury to personnel, environmental incident.	2	Equipment design. Adequate collection systems available with collection pits.	Maintenance and regular inspections.	Risk assessment. Routine operator checks for leaks.	Environmental	Possible within a 10 year period	1		
1.49	Toxicity and Asphyxiation	Bio-filter not working and pasteurisation process operational. Flammable / toxic odour routed to food reception hall.	Death or injury to personnel	3	Operator has facility to open valve on line from pasteurisers to vent to atmosphere.	Site operators have personnel CH4 /H2S gas detection monitors..	Food reception hall is a large area and the odourised vapour from the pasteurisers will be small in volume.	Serious Injury	Possible within a 10 year period	1	Review whether operator has to check and confirm odour abatement system (bio-filter) is operational prior to pasteurisation proceeding. If not, then Work Instruction (SOP), should require the operator to open odour line vent valve to atmosphere.	The odour abatement system form the main food reception hall and pasteuriser is connected.
1.50	Toxicity and Asphyxiation	Gas leak from Nitrogen gas cylinders during maintenance	Death or injury to personnel	3	Plant equipment designed for gas pipework including consideration of material selection, and pressure testing / leak testing of connections during commissioning and after maintenance.	Cylinders are stored in open areas during maintenance only.	Inspection prior to use.	Serious Injury	Possible within a 10 year period	1		Nitrogen gas used for maintenance for purging. Not store don site for normal operation.
1.51	Groundwater contamination	Spillage within digester bund	Environmental incident.	2	Equipment design and integrity.	Maintenance and regular inspections.	Risk assessment. Routine operator checks for leaks.	Environmental	Possible within a 10 year period	1	Confirm the integrity of the bund is maintained due a loss of containment situation.	The bund is fitted with access doors to allow truck entry.
1.52	Falling Waste	Pasteurised solid (Screened material) from separator falls from height onto a pile on the floor.	Personnel injury.	2	Waste material falls at a slow speed and in very small quantities (operator injury unlikely)	Operator can see falling waste	Operator / Maintenance procedures requiring operator not to stand under the separator outlet chute.	Injury	Possible within a 1 year period	1		

HAZID Actions

Case	Action
1.18	Consider whether fire and gas detection systems are required for the food reception building.
1.29	Consider whether activation of emergency shower should result in an alarm within the control room. This will warn the control room that an operator could be in danger and be exposed to a hazardous chemical.
1.30	Consider whether the requirement for using hearing protection in high noise areas should be enforced
1.33	Review whether additional impact protection is required for the food reception building against impact from food delivery trucks.
1.45	The pasteurised waste odour could contain high levels of ammonia. Review whether Work Instruction or SOP should include opening of doors to dissipate odour and a check of ammonia levels is undertaken before operator enters the building.
1.47	A Site Legionella Risk Assessment will need to be undertaken to include all standing water systems including the emergency shower.
1.49	Review whether operator has to check and confirm odour abatement system (bio-filter) is operational prior to pasteurisation proceeding. If not, then Work Instruction (SOP), should require the operator to open odour line vent valve to atmosphere.
1.51	Confirm the integrity of the bund is maintained due a loss of containment situation.

Appendix 2: Identified Dangerous Substances

A2.1 Identified Dangerous Substances

Chemical and physical hazards associated with the main materials used/handled in the Welsh Water Organic Energy Anaerobic Digestion Plant are given below:

Air - Compressed is considered non-combustible.

Antifreeze (Ethylene Glycol) is a clear coloured liquid and is considered non-combustible.

Ammonia (CAS Number: 7664-41-7) is a natural occurring flammable gas with a characteristic pungent odour and is a constituent of biogas.

Biogas is a flammable gas produced from the anaerobic fermentation of carbohydrates in plant material or waste by bacteria. It is mainly composed of methane and carbon dioxide with some trace gases such as ammonia and hydrogen sulphide.

Carbon Dioxide (CAS Number: 124-38-9) is a colourless, odourless gas produced by burning carbon / organic compounds and by respiration. It is naturally present in air as a trace gas and is considered non-combustible.

Diesel (CAS Number: 68334-30-5) is a clear amber flammable liquid which vaporises, and the vapour can be considered as very flammable.

Digestate is the material remaining after the anaerobic digestion of a biodegradable feedstock and is considered non-combustible.

Ferric Chloride (CAS Number: 7705-08-0) is a dark red corrosive solution and is considered non-combustible. This is stored on site and used in the process.

Hydrogen Sulphide (CAS Number: 7783-06-4) is a colourless flammable gas with a characteristic pungent rotten egg odour and is a constituent of biogas.

Lube oil is a clear amber flammable liquid which if vaporises under pressure or from a high temperature, the vapour can be considered as very flammable. For this site, a flammable oil mist generated from fitting leak under pressure is considered.

Nitrogen Gas (CAS Number: 7727-37-9) is an odourless, colourless, non-toxic gas and is considered non-combustible.

Rapeseed Oil (CAS Number: 8002-13-9) is a vegetable oil used on site as an anti-foaming agent. Rape seed oil is flammable with an auto-ignition temperature of approx. 400°C.

Refrigerant R410a is a colourless gas used for cooling and can be considered as non-combustible.

Water (CAS Number: 7732-18-5) is considered non-combustible.

The properties of the flammable materials used for the anaerobic digestion plant (i.e. biogas, diesel and lube oil) are provided in sections A2.3 & A2.4.

A2.2 Other Hazards**A2.2.1 Dusts**

There are no flammable powders or dusts used in this process.

A2.2.2 Hazardous Reactions

There are no hazardous reactions that could result in explosive atmospheres in this system.

A2.2.3 Exothermic Reactions

There are no exothermic or runaway reactions in this system.

A2.2.4 Oxidising Reactions

There are no oxidising reactions that could result in explosive atmospheres in this system.

A2.2.5 Pyrophoric Reactions

There are no pyrophoric reactions in this system.

A2.2.6 External Fire

The consequence of an external fire in the process /storage areas may lead to:

- Accelerated vapour release,
- Evolution of toxic substances due to burning,
- Over pressurisation of vessels (process and storage) with the potential for loss of containment.
- Personnel injury in plant area and possibly in adjacent areas such as the control room.

Current legislation⁵ requires the employer to carry out a fire risk assessment to determine the general fire safety requirements for the workplace and implement those requirements, including maintaining a general fire safety management plan. A fire risk assessment will need to be reviewed separately to the Hazardous Area Classification/DSEAR study.

⁵ General fire safety requirements in the workplace in England and Wales are applied through the Regulatory Reform (Fire Safety) Order 2005 (SI 2005/1541). In Scotland, The Fire Safety (Scotland) Regulations 2006 apply.

A2.3: Flammable Properties of Liquids

Diesel (CAS Number: 68334-30-5)

The typical properties of Diesel are shown below⁶ in Table 1:

Table 1: Properties of Diesel

MW (g/mol)	Density at 20°C (kg/m ³)	Flash Point (°C)	Boiling Point (°C)	Auto-ignition Temp. (°C)	LEL (vol%)	UEL (vol%)	Vapour press. @20°C (mbar)
~ 130	~ 5.8	> 55	163- 357	250	0.6	7.5	4.0

The molecular weight of diesel is ~130 and the vapour is therefore much heavier than air. If there is a leak or spillage of diesel in the building, diesel vapour will tend to move downwards and disperse along the floor area.

For area classification purposes, diesel vapour is regarded as a dense gas which will tend to disperse downwards, at low velocities.

Compressor / Lube Oil

The typical properties of Lube Oil are shown below⁷ in Table 2:

Table 2: Properties of Lube Oil

MW (g/mol)	Vapour Density at 20°C (kg/m ³)	Flash Point (°C)	Boiling Point (°C)	Auto-ignition Temp. (°C)	LEL (vol%)	UEL (vol%)	Vapour press. @20°C (mbar)
~ 130	~ 5.8	> 210	> 316	250	0.9	7.0	0.13

The molecular weight of lube oil is ~130 and the vapour is therefore much heavier than air. If there is a leak or spillage of oil in the building, lube oil vapour will tend to move downwards and disperse along the floor area.

For area classification purposes, lube oil vapour (mists) is regarded as a dense gas which will tend to disperse downwards, at low velocities.

⁶ Diesel fuel properties taken from Shell, Exxon Mobil & BP MSDS.

⁷ Lube oil properties taken from CEPSA, Shell, Exxon Mobil & BP MSDS. Lube oil has similar properties to compressor oil

A2.4: Flammable Properties of Gases**Biogas**

Anaerobic digestion of food waste within the site digesters will generate biogas. Due to the variability in food waste to be used for the process, the composition of biogas generated will vary. Generally, the typical composition of biogas will be as shown in Table 3:

Table 3: Composition of Biogas

Component	Formula	Molecular Weight	Typical Concentration
Methane	CH ₄	16.04	55 – 59 Vol %
Carbon Dioxide	CO ₂	44.01	44 – 40 Vol %
Oxygen	O ₂	32.00	1%
Hydrogen Sulphide	H ₂ S	34.08	200 ppmv
Ammonia	NH ₃	17.02	>100 ppmv
Water Vapour	H ₂ O	18.02	Saturated @ 38°C

The typical properties of biogas are shown below in Table 4:

Table 4: Properties of biogas

MW (g/mol)	Density at 38°C (kg/m ³)	Specific gravity	LEL ⁴ (vol%)	UEL ⁸ (vol%)	Polytropic constant
27.4 - 28.6	1.1196 - 1.0745	0.96 – 0.92	7.44 – 7.98	15.06 - 15.07	1.2934 - 1.2940

The molecular weight of biogas gas varies between 28.57 (for a 55% methane content gas) and 27.45 (for a 59% methane content gas). The corresponding molecular weight of air is around 28.9 g/mol. As biogas for this site will not have a specific gravity less than approximately 80% of that of air, biogas can be regarded as non-buoyant for area classification purposes. If there was a leak of biogas from the process, the released gas will tend to disperse downwards, at low velocities.

It should be noted that biogas will contain both hydrogen sulphide and ammonia gases, which are both flammable materials. The amount of ammonia and hydrogen sulphide present in biogas will be small and there will never be a direct release of these gases to atmosphere, as they will always be combined within biogas. The potential presence of small concentrations of hydrogen sulphide and ammonia will not alter the equipment classification.

⁸ LEL/UEL properties based on air

A2.6 Flammable Material List and Characteristics

Hazardous Area Classification Data Sheet - Part 1: Flammable substance list and characteristics													
Plant/Area:		Welsh Water Organic Energy, Cardiff Food AD Plant, Wales.							Drawing No:		Not Applicable		
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Flammable Material								Volatility		LEL	Ex characteristics		
No.	CAS Number	Mol. Wt	Density gas/air kg/m ³	Polytropic Index of Adiabatic Expansion	Flash Point °C	Auto Ignition Temp °C	Boiling Point °C	Vapour Pressure @ 20°C (mbar)	Vol (%)	Equip-ment Group ⁹	Temp. Class	Other Relevant Information and Remarks	
1	Biogas *	---	27.4 - 28.6	1.12 – 1.08	1.29	---	---	---	---	7.44 - 7.9	IIA	T1	
2	Diesel Fuel	68334-30-5	~ 130	~ 5.8	~ 1.04	> 55	250	163-357	4.0	0.6	IIA	T3	ATEX equipment only needed if oil vaporises or a mist is formed.
3	Compressor / Lube Oil ¹⁰	N/A	~ 130	~ 5.8	~ 1.04	> 210	250	>316	0.13	0.9	IIA	T3	ATEX equipment only needed if lube oil vaporises or a mist is formed.

* Biogas composition will typically consist of 55 – 59 vol% Methane, 44 - 40 vol% Carbon Dioxide, 1% Oxygen, 200 ppm Hydrogen Sulphide and 100 ppm Ammonia.

--- indicates no data available.

⁹ Electrical equipment classification for places with an explosive gas atmosphere. Subdivision A is for Group II gases which require at least 260 Microjoules to ignite the most explosive mixture of the gas with air.

¹⁰ Compressor oil and lube oil have similar flammable properties.

Appendix 3: Hazardous Area Classification

The following areas for normal operation will be assessed for Hazardous Area Classification and flammable area zoning:

a. Anaerobic Digestion Process Plant

- Food Waste Reception Building
 - Reception Hall
 - Front loader (used to load food waste into a trough)
 - Biorex Feed System and Pre-treatment System (shredder and de-packaging unit)
 - Water Dilution System
 - Reception building washdown and leachate collection sump
- New Liquid feed Tank (To be installed)
- One concrete 510 m³ Digester Feed Reception Tank (TK-15101)
- One concrete 3108 m³ Digester (TK-41101)
- One concrete 3108 m³ Post Digester Tank (TK-42101)
- One concrete 7688 m³ Digestate Storage Tank (TK-45101) with Roof Gas Storage Holder
- Biogas Pipework
- Technology Building (Pump Room) located between Digester and Post Digester Tank
 - Condensate collection pit in Technology Room (Pump Room)
 - Air Desulphurisation System (Digester TK-41101) with air blowers and air distribution pipework
 - Substrate Distribution Pipework
 - Site air compressor
- Gas Boosters
- Chiller System
- Condensate Trap
- One CHP Engine located within its own enclosure
- One Biogas Boiler
- Transformer
- Condensate trap at flare and
- Emergency Flare
- Post digestion pasteurisation plant (three tanks)
- Pasteurised Solids Separation Room in Food Reception Building (containing solids separator, solids floor storage area and odour abatement system connection)
- 9.2 m³ Solids Separator System Liquid Collection Tank (TK-53101)
- Ferric Chloride IBC area with Emergency Shower
- Nutrient Dosing
- Odour abatement system (i.e. a bio-filter)
- Biogas analysis equipment purge
- Plant Room (site control room) adjacent to main food waste reception building
- Weighbridge facility
- Site Office (located offsite and away from main plant area at the side of the facility)

3.1 Anaerobic Digestion Process Plant

The Welsh Water Organic Energy anaerobic digestion plant receives various types of solid food waste from house hold waste collections by Cardiff Council and the Vale of Glamorgan Council. The facility can process up to 35 000 tonnes per year of food waste.

In all cases, food waste is delivered to the site by delivery trucks, pre-treated and fed into the anaerobic digesters. Biogas composed of mainly methane and carbon dioxide with small amounts of hydrogen sulphide is produced from the anaerobic digestion of food waste within the digesters. The digesters are located close together and are all constructed of concrete walls, fitted with external insulation.

Digestate is stored in a digestate storage tank fitted with an inflatable plastic membrane roof which collects and stores biogas from the digesters and feed reception tank.

The digesters, the feed reception tank and the digestate storage tank are each fitted with two identical resealable liquid relief valves for over and under pressure protection. The digesters are normally controlled at a pressure of 4 mbarg, with the relief valves set to operate at a slightly higher pressure of 5 mbarg.

Biogas from the digesters is routed to a CHP engine and a biogas boiler via the biogas main. The biogas main is fitted with condensate collection vessels to collect water/condensate from biogas.

A pasteurisation plant is used to treat spent digestate before the solids and liquor from the spent digestate are separated. The liquor from the solids separation plant is pumped to the digestate storage tank. The solids are collected and stored for offsite disposal.

3.1.1 Food Waste Reception Building

Solid food waste material is delivered by delivery trucks to the food reception area, which is located within the Food Reception Building and is a large open building. Food waste is transferred by a diesel operated front loader to a BioRex Feed preparation System (a shredder, transfer conveyor and de-packaging unit), to reduce the size of the material and remove any packaging material (i.e. plastics). Water is then added from a 5 m³ Dilution Tank (PIT-13301) to convert the solid food waste into an organic slurry feedstock for anaerobic digestion.

There is potential for any waste that is allowed to stand for long periods to decompose and produce methane or hydrogen sulphide gas. However, the site has an environmental permit which requires all food waste to be processed within 36 hours (3 days), and prevents new waste being received into the food waste reception building if new waste cannot be processed within a short target time frame. This ensures that food waste material is not allowed to stand for long periods, which prevents decomposition of waste from occurring. In addition, the feed reception building is well ventilated and fitted with an odour abatement system which includes extractive ventilation connected to a biofilter to remove any hydrogen sulphide gas.

Food waste is often wet with a high moisture content and any dusts generated are likely to be too wet to support any combustion. In addition the material is moved in a large open area and it is unlikely that a sufficient enough concentration of dust would be available for a combustible dust cloud to form.

Therefore, the food waste storage area within the Food Waste Reception Building can be classified as non-hazardous as no flammable materials are present.

The areas within the solid waste processing equipment (BioRex Feed preparation System, collection skip, Water slurry addition) can be classified as non-hazardous as no flammable materials are present.

Building washdowns and leachates from food material are collected in a collection sump within the food reception building. The pit is fitted with a discharge pump connected to a high and low level control system to automatically empty the pit on high level.

Under normal operation, only water and leachate (which is not considered flammable) will be collected in this sump. Therefore, the reception building washdown and leachate collection sump can be classified as **non-hazardous** as no flammable materials are present.

It should be noted that the original zoning of a Zone 2 internal area within the sump is very conservative and is not needed for this sump.

The food waste pre-treatment equipment is fitted with hydraulic power packs. The oil used for the hydraulic power packs will typically have a flash point above 250°C and will not normally create a flammable atmosphere. However, as the oil is pressurised, then there is potential for the formation of a flammable mist, in the event of a leak. Mists of high-flashpoint fluids such as diesel, kerosene and lubricating oils can ignite and produce explosions at temperatures below their flashpoint.

The hydraulic power pack systems will use a high standard of integrity of pipelines and be operated at low pressure. For a flange or fitting leak, the use of flange guards will prevent the formation of mists and will act as a barrier against flammable vapour release that will allow a pool of oil to be formed. This will then require a robust site spillage procedure to ensure that any spillages of thermal oil are cleaned up straightaway.

Maintenance of the power pack systems is undertaken by a specialist contractor and if there was a leak during maintenance, the contractor would see the leak and stop the activity. The operator and maintenance contractor would then implement the clean-up procedure.

3.1.2 New liquid feed tank and transfer system (to be installed)

The site propose to install a liquid feed system, where brewery waste will be delivered to site by tanker and fed into the Digester Feed Reception Tank using a slurry transfer pump.

Typically, brewery wastewater is mostly water by weight and is not considered flammable. The typical characteristics of brewery wastewater effluents are:

- High levels of sugar and alcohol
- Solids that easily turn into sludge
- Low pH levels
- Average BOD of over 3000 mg/L
- Total Suspended Solids (TSS) average 1800 mg/L

The formation of a flammable atmosphere is not expected to occur in normal operation and, therefore the area within the new liquid feed tank and slurry transfer pump, when installed can be classified as **non-hazardous**. Any leaks would not generate any flammable material or vapours.

During the transfer of liquid waste materials from the feed tank to the digester feed reception tank, there should be no flammable vapour inside the pipework and the inside of the pipework does not need to be zoned.

3.1.3 Digester Feed Reception Tank (TK-15101)

The processed food waste slurry is transferred into a 510 m³ Digester Feed Reception Tank (TK-15101) using a slurry transfer pump. The food waste slurry is held in the Digester Feed Reception Tank for approximately 3 days to allow hydrolysis of the food waste to generate volatile fatty acids. As the liquid feed material could contain sufficient micro-organisms to begin significant anaerobic digestion, there is limited potential for the evolution of biogas. The biogas main connecting the Digester (TK-41101), Post Digester Tank (TK-42101) and Digestate Storage Tank (TK-45101) is directly connected to the Digester Feed Reception Tank (TK-15101). This means that biogas will always be present in the headspace of Digester Feed Reception Tank (TK-15101).

Biogas composed of mainly methane and carbon dioxide with small amounts of hydrogen sulphide and ammonia is produced from the anaerobic digestion of food waste.

Digester Feed Reception Tank (TK-15101) is a concrete tank fitted with a fixed concrete roof. Biogas generated in the digester feed reception tank is routed to the gas storage holder above the digestate storage tank via a biogas main.

The feed reception tank, digesters and the digestate storage tank are each fitted with two identical resealable liquid pressure / vacuum relief valves for over and under pressure protection. The resealable liquid relief valve is activated on high pressure to allow gas to escape to atmosphere and on low pressure to allow air into the buffer tank.

The digesters are normally controlled at a pressure of 4 mbarg, which will be the pressure within the digester feed reception tank, due the connection to the biogas main. The two relief valves are set to operate at a slightly higher pressure of 5 mbarg (full activation at 7 mbarg).

Each relief valve assembly is located within a dedicated service box, which is fixed to the tank with sealed bolted flanges. The service boxes are installed gas-tight and also contain the following:

- Propeller mixers, electrically operated
- Piping for transfer of biogas.
- Visual inspection ports normally closed and gas-tight
- Service box installation flange

The digester feed reception tank roof is fitted with a foam valve which will lift during high foaming incidents or during an overpressure event within the tank.

Feed material is constantly added to the digester feed reception tank and internal mixing is achieved using mechanical liquid mixers.

During the transfer of processed food waste slurry from the pre-treatment system to the digester feed reception tank, there should be no flammable vapour inside the pump, or pipework and the inside of the pump and pipework does not need to be zoned.

The following areas have been identified for the digester feed reception tank where there is potential for a flammable atmosphere to occur:

- Inside digester feed reception tank
- Biogas leakage in gap between tank wall and insulation
- Biogas leakage from gas main
- Activation of relief valve (resealing liquid type)
- Release from the Service Box
- Release from Foam Valve

a. Inside Digester Feed Reception Tank (TK-15101)

During normal operation, the gas space within the digester feed reception tank will not contain enough oxygen to create a flammable/explosive gas atmosphere between the liquid surface and the vapour space in the tank. Even, the filling with fresh feed and removal of spent digestate should not draw in enough atmospheric oxygen to create an internal flammable/explosive gas atmosphere within the digester feed reception tank.

However, under abnormal conditions the pressure/vacuum relief valve may operate under negative pressure, allowing air to be drawn into an atmosphere, which would otherwise be at a concentration above the LEL, and thus giving rise to an explosive gas/air mixture. The internal area within the digester feed reception tank can therefore be classified as **Zone 1**.

Scottish Water Document Reference: SSP-SP-GUI-02000204 entitled 'Guidance for the Assessment and Zoning of Hazardous Areas Version 2.1' provides standard solutions on hazardous area classification of digesters and recommends a Zone 1 classification for internal area within the digester.

This is also in line with the requirements of Dŵr Cymru Welsh Water DSEAR Handbook Version 19.1 (May 2020), which classified the internal space within digesters as Zone 1.

b. Gap between tank wall and insulation

In the event of a leak of biogas, there is potential for biogas to accumulate in the gap between the outside wall of the feed reception tank and insulation.

The area of the gap between the outside wall of the feed reception tank and insulation can be classified as a **Zone 2** Area.

A gas release from the digesters due to leaks in glands, seals and joints is considered a secondary release that is not expected to occur under normal operation. As such, the gas release that accumulates in the gap between the tank outside wall and insulation would normally be considered a Zone 2.

c. Biogas Main

During normal operation, the gas space within the biogas main and any pipework containing biogas can be classified as **Zone 1**, as a flammable gas atmosphere inside the biogas supply pipe work could occur periodically or occasionally in normal operation.

The biogas main connects the Digester (TK-41101), Post Digester Tank (TK-42101), Digestate Storage Tank (TK-45101) and Digester Feed Reception Tank (TK-15101) to the inlet of the CHP engine, biogas boiler and flare. If there was a fitting or flange leak from the biogas pipework, a flammable and toxic gas would be released to atmosphere.

The extent of release can be determined from the guidance given by the Gas Industry technical standard IGEM/SR/25 Edition 2.

IGEM/SR/25 Edition 2 suggests that the leakage calculations for flange gaskets, screwed fittings, in joints as a metal to metal gap and at valve stem seals installed on non-vibratory pipework, which are well maintained, but are rarely broken (flanges) or infrequently used (valves), should be based on a leakage area of 0.25 mm² for normal conditions and taken as 2.5 mm² for adverse conditions.

Adverse conditions include flanges, valves, etc., installed on vibratory pipework (e.g. connected to blowers/compressors) or items broken or used more regularly. As the biogas pipework is non vibratory and operated at low pressure, a leakage area of a 0.25 mm² can be used for hazardous area classification purposes.

The composition of biogas generated varies between 55% to 59% due to the variability in the feed waste processed. The explosion limits and molecular weights calculated for the different biogas mixtures is provided in

Table 5.

Table 5: Biogas properties at different compositions

Biogas Composition	MW g/mol	LEL vol%	UEL Vol%
55 vol%	28.57	7.98	15.07
59 vol%	27.42	7.44	15.06

The molecular weight of biogas gas varies between 28.57 (for a 55% methane content gas) and 27.45 (for a 59% methane content gas). The corresponding molecular weight of air is around 28.9 g/mol. As biogas for this site will not have a specific gravity less than approximately 80% of that of air, biogas can be regarded as non-buoyant for area classification purposes. If there was a leak of biogas from the process, the released gas will tend to disperse downwards, at low velocities.

The release rate calculation for a leak from a flange or fitting and Hazardous Area Classification as defined by BS EN 60079-10 – Part 10-1:2015, is shown as follows for biogas with a 59% methane content:

The positive pressure of the digester feed reception tank is 4 mbarg:

$p = 101725$ Pa	Pressure in system (pipework)
$p_o = 101325$ Pa	Atmospheric pressure
$T = 311$ °K (38 °C)	Gas Temperature
$M = 27.42$	kg/kmol
$S = 2.5 \times 10^{-7}$ m ²	Hole size
$\gamma = 1.2940$	Calculated Polytropic Index
$C_p = 1321$ j/kgK	Specific Heat
$R = 8314$ j/kmolK	Gas Constant

To determine if the release is either choked (sonic) or non-choked (subsonic) flow, the critical pressure can be calculated using the following equation:

$$p_c = p_a \left(\frac{\gamma + 1}{2} \right)^{\gamma / (\gamma - 1)} \quad (\text{Pa})$$

$$= 101325 \times ((1.2940+1)/2)^{1.2940/0.2940}$$

$$= \mathbf{185301 \text{ Pa}}$$

As $p < p_c$, the flow is non choked (subsonic).

The release is non choked flow (subsonic velocity) and, therefore, the following equation can be used to calculate the release rate (W_g) for a non-choked gas velocity:

$$W_g = C_d S p \sqrt{\frac{M}{ZRT} \frac{2\gamma}{\gamma-1} \left[1 - \left(\frac{p_a}{p} \right)^{(\gamma-1)/\gamma} \right]} \left(\frac{p_a}{p} \right)^{1/\gamma} \quad (\text{kg/s})$$

$C_d = 1.0$	Discharge coefficient (dimensionless)
$S = 2.5 \times 10^{-7}$ m ²	Hole size
$p = 101725$ Pa	Pressure in system
$\gamma = 1.2940$	Calculated Polytropic Index
$M = 27.42$	kg/kmol
$T = 311$ °K (38 °C)	Gas Temperature

$Z = 1.0$ Compressibility Factor
Flammable release rate (based on 59% flammable gas content) = 4.32×10^{-6} kg/s

The characteristic of release in m^3/s can be calculated from the following equation:

$$\frac{W_g}{\rho_g k LFL}$$

$W_g = 4.32 \times 10^{-6}$ kg/s Flammable release rate
 $LFL = 7.44$ (vol/vol%) Lower flammability limit
 $\rho_g = 1.0739$ kg/m³ Gas density
 $k = 0.5$ Safety Factor (0.25 continuous / primary grades of release, 0.5 secondary grades of release)

Characteristic of release rate = 1.08×10^{-6} m³/s

BS EN 60079-10 – Part 10-1:2015 provides a chart for estimating hazardous area distances (Figure D1), using the characteristic of release rate value. However, the minimum characteristic of release rate provided on the chart is 0.01 m³/s and therefore the zone extent is not available for low pressure cases. The hypothetical volume which is proportional to mass release rate of a leak divided by the air change rate can be used to determine if a zone extent for low pressure release rate is applicable.

The hypothetical volume V_z gives a guide as to the volume of flammable envelope from a source of release. It should be noted that the flammable envelope will not normally equate to the volume of the hazardous area, as the shape of the hypothetical volume is not defined. This will be influenced by factors such as ventilation, the degree and availability of ventilation and the release point.

To ascertain a hypothetical volume, it is necessary to establish the theoretical minimum ventilation flow rate of fresh air to dilute a given release of flammable material to the required concentration below the lower explosive limit. This can be calculated using the following equation:

$$(dV/dt)_{\min} = \frac{(dG/dt)_{\max}}{k \times LEL_m} \times \frac{T}{293}$$

Where:

$$LEL_m = 0,416 \times 10^{-3} \times M \times LEL_v$$

$dG/dt = 4.32 \times 10^{-6}$ kg/s Flammable release rate
 $LEL_m = 0.0849$ kg/m³ lower explosive limit (mass per volume, kg/m³)
 $M = 27.42$ kg/kmol
 $T = 311$ °K (38 °C) Gas Temperature
 $k = 0.5$ Safety Factor (0.25 continuous / primary grades of release, 0.5 secondary grades of release)

Minimum air dilution rate = 1.08×10^{-4} m³/s

The hypothetical volume can be calculated using the following equation:

$$V_z = f \times V_k = \frac{f \times (dV/dt)_{\min}}{C}$$

$C = 0.03 \text{ s}^{-1}$ number of fresh air changes per unit time (s^{-1})

$f = 1$ efficiency of the ventilation ($f = 1$ ideal flow, $f = 5$ impeded air flow).

For an outdoor release, an approximation of 100 air changes per hour (0.03/s) can be used.

The calculated hypothetical volume is: $V_z = \underline{\underline{0.0039 \text{ m}^3}}$

As the hypothetical volume is less than 0.1, the leakage site for all flanges, seals and instrument fittings for normal operation for the biogas pipework can be considered to be of negligible extent (**NE**).

The persistence time can be calculated using equation below:

$$t = \frac{-f}{C} \ln \frac{LEL \times k}{X_o}$$

$C = 0.03 \text{ s}^{-1}$ number of fresh air changes per unit time (s^{-1})

$f = 1$ efficiency of the ventilation ($f = 1$ ideal flow, $f = 5$ impeded air flow).

$X_o = 59\%$ Initial concentration of flammable substance (%vol)

$LEL = 7.44\%$ lower explosive limit (volume per volume %)

$t = \underline{\underline{99.5 \text{ seconds}}}$ (which is fairly short)

The release rate calculation for a biogas leak from a flange or fitting and Hazardous Area Classification as defined by BS EN 60079-10 – Part 10-1:2015, using a leakage area of 0.25 mm² are as follows:

P	Pressure Inside	mbarg	4
T	Gas Temperature	°C	38
S	Hole Size	mm ²	0.25
Q _g	Flammable Release Rate	kg/sec	4.32E-06
LEL _v	Lower Explosive Limit	Vol %	7.44
	Grade of Release		S
k	Safety Factor		0.5
(dV/dt) _{min}	Min Flow Fresh Air	m ³ /sec	1.08E-04
f	Quality factor		1
C	Number of Air Changes	/hr	100
V _z	Hypothetical Volume	m ³	0.0039
t	Persistence Time	sec	100
X	Dispersion Distance	m	NE

The degree of ventilation is high and the availability is good since the biogas main is located outdoors. The leakage site for all flanges, seals and instrument fittings for normal operation for the biogas pipework from the digester feed reception tank is a **Zone 2** Hazardous Area of negligible extent (**NE**), as the hypothetical volume is less than 0.1 m³.

Assessment: Zone 2 of negligible extent (NE), at flanges, seals and instrument fittings of the biogas main from the Digester Feed Reception Tank (TK-15101), Digester (TK-41101), Post Digester Tank (TK-42101) and Digester Feed Reception Tank (TK-15101) to the inlet of the CHP engine gas booster, and Flare gas booster.

Note: For biogas with a 55% methane content, the hypothetical volume was calculated as less than 0.1 (0.0033 m³), with no change to the calculated hazardous area classification.

d. Digester Feed Reception Tank (TK-15101) Liquid Seal Type Relief valve

The digester feed reception tank is fitted with two resealable liquid type over pressure and vacuum relief valves at the top of the tank roof. The relief valves are activated on high pressure to allow gas to escape to atmosphere and on low pressure to allow air into the tank. The digester feed reception tank is normally controlled at a pressure of 4 mbarg, the overpressure relief valve is set to operate at 5 mbarg (7 mbarg setting). The under pressure relief valve is set to operate at -0.7 mbarg.

The overpressure and under pressure safety device is designed according to the immersion cup principle, where the relieving set pressure can be adjusted by the weight of the valve cap¹¹.

If there is overpressure sufficient to lift the valve cap, water is pushed from the inside to the outside of the valve cap, releasing biogas to atmosphere. The valve closes again when the pressure reduces as the displaced water flows back again.

Sealing liquid is only lost through natural evaporation or aerosol formation when the safety device is activated or when the overpressure safety device is fully activated. Water is replenished at intervals and excess water can drain through the syphon tube.

The opening of the valve takes place only during abnormal operation of the plant and should not pass during normal plant operation. ANERGIA have stated in the original hazardous area classification study, that two zones (Zone 1 and Zone 2) are applied to the relief valve as per ANERGIA Product branch recommendation, from operational experience of their plants.

For liquid seal type relief valves, regular seepage / leakage at the relief point without full activation is not a typical characteristic for this type of relief valve, however, a seepage rate must be specified for the relief valve as it the valve suppliers recommendation.

¹¹ Description obtained from Anaergia Document: 61516000 Q02 01 Hazardous Area Classification Rev 4 dated 26.10.2016

The maximum design biogas production rate at the digesters is 751 Nm³/hr. Although much less biogas is produced in the digester feed reception tank, the tank is connected to the digesters via the biogas main. The over pressure relief valve for the digester feed reception tank is therefore capable of venting the full gas production of 751 Nm³/hr to atmosphere.

The biogas main connects the following tanks, each fitted with two relief valves:

- 510 m³ Digester Feed Reception Tank (TK-15101)
- 3108 m³ Digester (TK-41101)
- 3108 m³ Post Digester Tank (TK-42101)
- 7688 m³ Digestate Storage Tank (TK-45101)

In the event of all end users failing to take biogas (Flare, boiler and CHP engine), 751 Nm³/hr of biogas would be vented through eight overpressure valves. A worst case scenario would be if the biogas main is isolated for a single tank, and you could have 751 Nm³/hr vented through two relief valves (375.5 Nm³/hr each).

To be conservative, the worst case scenario can be considered, with a maximum venting rate through each of the digester feed reception tank relief valves taken as 375.5 Nm³/hr.

Scottish Water Document Reference: SSP-SP-GUI-02000204 entitled 'Guidance for the Assessment and Zoning of Hazardous Areas Version 2.1' provides guidance on the likely seepage rate and states this as approximately 1% of the maximum relieving flow.

The hypothetical volume of the gas release calculated on 1% of the maximum relieving flow of the digester feed reception tank valve at 7 mbarg for biogas containing 59% methane is: **$V_z = 1.19 \text{ m}^3$** .

The hypothetical volume is small but not negligible (and greater than 0.1 m³), so a zone extent needs to be determined.

For low pressure gas releases, the Scottish Water Document Reference: SSP-SP-GUI-02000204 entitled 'Guidance for the Assessment and Zoning of Hazardous Areas Version 2.1' quotes the following equation for calculating the extent of the Hazardous Area or Zone for a gas dispersion from a low velocity release:

$$X = \left(\frac{42300 \times Q_g \times f}{M \times E \times w} \right)^{0.55} \times 1.2$$

where:

X = dispersion distance (m)

Q_g = gas flow rate (kg/s)

E = lower explosive limit of flammable gas (%vol)

f = air exchange effectiveness factor

M = molecular weight of gas or vapour

w = wind speed (0.5m/s for a low level point source, 1.0m/s for high level point source)

Based on the above equation, the extent of the zone is calculated as follows:

$$X = 0.42 \text{ m}$$

To be conservative, the calculated zone extent should be rounded up to 0.5 m.

The release rate calculation for a biogas seepage from the liquid seal type relief valve and Hazardous Area Classification as defined by BS EN 60079-10 – Part 10-1:2015, based on 1% of the maximum relieving flow are as follows:

P	Pressure Inside	mbarg	7
T	Gas Temperature	°C	38
	Gas Flow	Nm ³ /h	3.76
Q _g	Flammable Release Rate	kg/sec	6.61E-04
LEL _v	Lower Explosive Limit	Vol %	7.44
	Grade of Release		P
k	Safety Factor		0.25
(dV/dt) _{min}	Min Flow Fresh Air	m ³ /sec	3.31E-02
f	Quality factor		1
C	Number of Air Changes	/hr	100
V _z	Hypothetical Volume	m ³	1.19
t	Persistence Time	sec	125
X	Dispersion Distance	m	0.42

The degree of ventilation is high and the availability is good since the relief valve is located outdoors. The leakage site for seepage of the liquid seal type relief valve is a **Zone 1** Hazardous Area with **0.5 m** sphere radius from the centre on the relief valve outlet.

Under abnormal conditions the pressure/relief valve may operate under high pressure and release flammable gas. The outlet of the relief valve is therefore regarded as a secondary grade of release and results in a **Zone 2** hazardous area for a distance from this source.

The release rate calculation for activation of the liquid seal type relief valve and Hazardous Area Classification as defined by BS EN 60079-10 – Part 10-1:2015, based on 100% of the maximum relieving flow are as follows:

P	Pressure Inside	mbarg	7
T	Gas Temperature	°C	38
	Gas Flow	m ³ /h	375.5
Q _g	Flammable Release Rate	kg/sec	6.61E-01
LEL _v	Lower Explosive Limit	Vol %	7.44
	Grade of Release		S
k	Safety Factor		0.5
(dV/dt) _{min}	Min Flow Fresh Air	m ³ /sec	1.65
f	Quality factor		1
C	Number of Air Changes	/hr	100
V _z	Hypothetical Volume	m ³	59.5
t	Persistence Time	sec	100
X	Dispersion Distance	m	5.06

The degree of ventilation is high and the availability is good since the relief valve is located outdoors. For full activation of the digester feed reception tank relief valve is a **Zone 2** Hazardous Area with a **5.1 m** sphere radius from the centre on the relief valve outlet.

Assessment: Digester Feed Reception Tank Relief Valve: a Zone 1 Hazardous Area with 0.5 m sphere radius extending to a Zone 2 Hazardous Area with a radial distance of 5.1 m in any direction from the centre on the relief valve outlet.

The above assessment is in line with the guidance solution for fixed and floating roof digesters provided “Thames Water Utilities Limited Document Reference TWUL/E04 entitled ‘Standard Practice Document E04, Zoning of Hazardous Areas, and Issue 4.0’ dated May 2009,” (see Figure 1 below). This is based on a biogas with 40% methane.

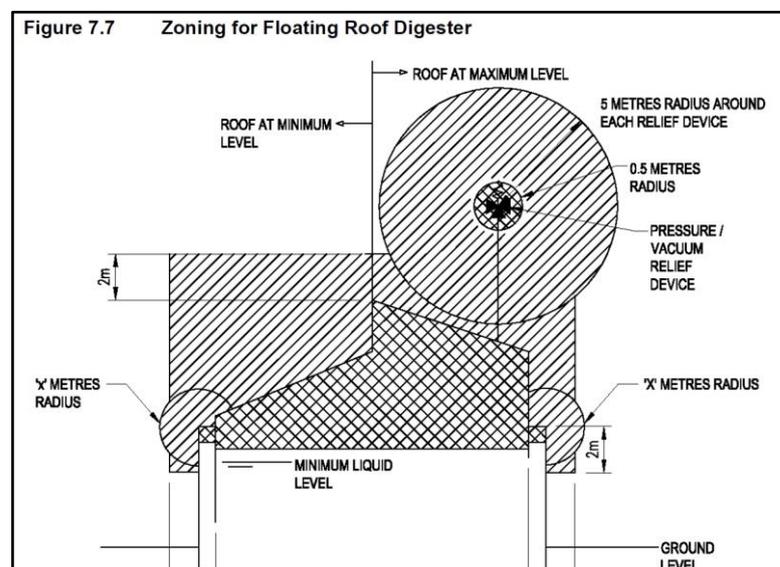


Figure 1: Extract from Thames Water Utilities Limited Document Reference TWUL/E04

Notes:

- a. For biogas with a 55% methane content, there is with no change to the calculated hazardous area classification.
- b. The above hazardous area classification is very conservative and greater than the following zones recommend by ANERGIA as per the ANERGIA Product branch recommendation:
 - **Zone 1** with **1 m** radius from discharge point.
 - **Zone 2** with **3 m** radius from discharge point.
- c. In the event of all the biogas users not being available and all eight relief valves are activated, then a Zone 2 of 2.5 m radius from the discharge point was calculated, which is similar to the zone extent calculated by ANERGIA.

e. Release from the Service Boxes (SB-15101 or SB-15102)

The Digester Feed Reception Tank (TK-15101) is fitted with two service boxes (SB-15101 or SB-15102), which are fixed with sealed bolted flanges. The service boxes are installed gas-tight and each service box contains access to:

- Electrically operated propeller mixers
- Piping for transfer of biogas, fitted with a manual valve to isolate the tank from the entire biogas system.
- Over and under pressure safety valves (vent is located outside)
- Visual inspection ports with access opening for maintenance (normally closed and gas-tight)
- Service box installation flange

For the service box, any leaks from the glands, seals and joints will be captured within the internal area of the service box enclosure. There is no zone outside the service box enclosure as biogas will be contained and accumulate within the enclosure or be dispersed from the enclosure.

To be conservative, the area within the service box can be classified as **Zone 1**, as a flammable gas atmosphere inside the service box could occur periodically or occasionally in normal operation.

Assessment: Zone 1 Hazardous Area within the service box internal area.

The service boxes are normally closed gas-tight, however, for maintenance and inspection of the mixers, the Service Boxes are opened under a safe system of work procedure. The mixers are lifted for inspection approximately twice a year. A gas blower is used to remove any residual biogas within the service box and the water seal around the service box curtain is maintained to ensure no biogas escapes.

ANERGIA have stated in the original hazardous area classification study, that the opening of the service box should be considered as a failure case during maintenance and could result in venting of biogas from the service box doors, if the blower fails and the water seal around the service box curtain is lost.

For a gas leak from a flange or fitting, the extent of release can be determined from the guidance given by the Gas Industry technical standard IGEM/SR/25 Edition. IGEM/SR/25 Edition 2 suggests that the leakage calculations for flange gaskets, screwed fittings, in joints as a metal to metal gap and at valve stem seals installed on non-vibratory pipework, which are well maintained, but are rarely broken (flanges) or infrequently used (valves), should be based on a leakage area of 0.25 mm² for normal conditions and taken as 2.5 mm² for adverse conditions.

Adverse conditions include flanges, valves, etc., installed on vibratory pipework (e.g. connected to blowers/compressors) or items broken or used more regularly. As the water seal is not as strong as a flange or fitting seal and as the seal may be subject to disturbance in very windy conditions, an abnormal leakage area of a maximum of 25 mm² can be used to calculate the leakage area.

The release rate calculation for a leak from a seal and Hazardous Area Classification as defined by BS EN 60079-10 – Part 10-1:2015, is shown as follows:

P	Pressure Inside	mbarg	4
T	Gas Temperature	°C	38
S	Hole Size	mm ²	25
Q _g	Flammable Release Rate	kg/sec	4.32E-04
LEL _v	Lower Explosive Limit	Vol %	7.44
	Grade of Release		S
k	Safety Factor		0.5
(dV/dt) _{min}	Min Flow Fresh Air	m ³ /sec	1.08E-02
f	Quality factor		1
C	Number of Air Changes	/hr	100
V _z	Hypothetical Volume	m ³	0.38
t	Persistence Time	sec	100
X	Dispersion Distance	m	0.32

The degree of ventilation is high and the availability is good since the service box is located outdoors. The leakage site from the service box doors during maintenance is a **Zone 2** Hazardous Area with a 0.35 m radial distance.

Assessment: Zone 2 Hazardous Area with a radial distance of 0.35 m around the service box door during maintenance.

Note: For biogas with a 55% methane content, there is no change to the calculated hazardous area classification.

f. Release from Foam Valve (FM-41101)

Digester Feed Reception Tank (TK-15101) is fitted with foam valve which will lift during high foaming incidents or during an overpressure event within the tank.

The foam valve is a weighted flap valve made of steel with rubber gaskets. Under normal operation, the hazardous zoning for a seal can be considered, which is a Zone 2 NE.

Under abnormal operation, the valve will lift at 20 mbarg pressure resulting in biogas being vented through the valve vent. As the relief valves lift at 7 mbarg, the foam vent valve should not ever see a high enough pressure where it is fully lifted.

ANERGIA have stated in the original hazardous area classification study, that the foam valve has lifted opening in their other plants in the past (due to Operator error).

To be conservative, the hazardous area classification for the foam valve can be calculated using 25% of the overpressure valve release rate. Both relief valves will also be operational and venting, and it is assumed the Digester Feed Reception Tank biogas main is isolated from the other tanks.

Under abnormal conditions the foam valve may operate under high pressure and release flammable gas. The outlet of the foam valve is therefore regarded as a secondary grade of release and results in a **Zone 2** hazardous area for a distance from this source.

The release rate calculation for activation of the foam valve and Hazardous Area Classification as defined by BS EN 60079-10 – Part 10-1:2015, based on 25% of the maximum relieving flow are as follows:

P	Pressure Inside	mbarg	20
T	Gas Temperature	°C	38
	Gas Flow	m ³ /h	94.38
Q _g	Flammable Release Rate	kg/sec	1.65E-02
LEL _v	Lower Explosive Limit	Vol %	7.44
	Grade of Release		S
k	Safety Factor		0.5
(dV/dt) _{min}	Min Flow Fresh Air	m ³ /sec	0.43
f	Quality factor		1
C	Number of Air Changes	/hr	100
V _z	Hypothetical Volume	m ³	14.9
t	Persistence Time	sec	100
X	Dispersion Distance	m	2.36

Assessment: Digester Feed Reception Tank Foam Valve: a Zone 2 Hazardous Area with a radial distance of 2.4 m in any direction from the centre of the foam valve outlet.

3.1.4 Digester (TK-41101) & Post Digester Tank (TK-42101)

The concrete digester and post digester tanks are identical in design, operating at approximately 38°C and 4 mbarg. Biogas composed of mainly methane and carbon dioxide with small amounts of hydrogen sulphide and ammonia is produced from the anaerobic digestion of food. The concrete digester and post digester tanks are in a bunded area and are all constructed of concrete walls, fitted with external insulation. The concrete digester and post digester tanks are fitted with a flat concrete roofs which collect biogas. Biogas from the concrete digester and post digester tanks is routed to the inflatable gas storage roof of the Digestate Storage Tank (TK-45101) and then to the CHP engine, Boiler or Flare via a biogas main. The biogas main connects the Digester (TK-41101), Post Digester Tank (TK-42101), Digestate Storage Tank (TK-45101) as well as the Digester Feed Reception Tank (TK-15101).

The digesters, the feed reception tank and the digestate storage tank are each fitted with two identical resealable liquid pressure / vacuum relief valves for over and under pressure protection. The resealable liquid relief valve is activated on high pressure to allow gas to escape to atmosphere and on low pressure to allow air into the buffer tank.

The design of the digesters is the same as the design of the Digester Feed Reception Tank (TK-15101) covered in section 3.1.3 and the following hazardous area classification applies:

	Digester (TK-41101)	Post Digester Tank (TK-42101)
Substrate pipework & Pump	No Zone	No Zone
Tank (Internal area)	Zone 1	Zone 1
Wall Gap - insulation	Zone 2	Zone 2
Biogas Main (internal area)	Zone 1	Zone 1
Biogas Main (flanges / fittings)	Zone 2 NE	Zone 2 NE
Liquid Seal Type Relief valve	Zone 1, 0.5 m sphere extending to Zone 2, 5.1 m sphere	Zone 1, 0.5 m sphere extending to Zone 2, 5.1 m sphere
Service Box (internal area)	Zone 1	Zone 1
Service Box Doors (maintenance)	Zone 2, 0.35 m from service doors	Zone 2, 0.35 m from service doors
Foam Valve	Zone 2, 2.4m sphere	Zone 2, 2.4 m sphere
Anti-foam addition	No Zone	No Zone

Rape seed oil is added as an antifoam agent, manually. Rape seed oil has a flash point of above 400°C and will not create a flammable atmosphere. Any spillages are cleaned up immediately.

3.1.5 Digestate Storage Tank (TK-45101) with Roof Gas Storage Holder

Spent digestate is transferred and stored in a 7688 m³ Digestate Storage Tank (TK-45101) using a slurry transfer pump. The digestate storage tank is a circular, precast, concrete tank, with an inflatable double membrane (PVC) roof, which is used to store biogas.

The design of the Digestate Storage Tank (TK-45101), apart from the roof and not being externally cladded is similar to the Digester Feed Reception Tank (TK-15101) and is covered in section 3.1.3. The following hazardous area classification can be applied to tank TK-45101:

Digestate Storage Tank (TK-45101)	
Substrate pipework & Pump	No Zone
Tank (Internal area)	Zone 1
Biogas Main (internal area)	Zone 1
Biogas Main (flanges / fittings)	Zone 2 NE
Liquid Seal Type Relief valve	Zone 1, 0.5 m sphere extending to Zone 2, 5.1 m sphere
Service Box (internal area)	Zone 1
Service Box Doors (maintenance)	Zone 2, 0.35 m from service doors
Foam Valve	Zone 2, 2.4 m sphere
Anti-foam addition	No Zone

The following additional areas have been identified for the Digestate Storage Tank where there is potential for a flammable atmosphere to occur:

- Inside gas storage canopy
- Seal leakage between the gas storage canopy and the top of the digester wall
- Biogas leakage in gap between membranes of inflatable PVC roof

a. Digester and Gas Storage Canopy

During normal operation, the gas space within the digesters can be classified as **Zone 1**.

b. Seal between the gas storage balloon and the top of the digester wall

The gas storage roof is tightly clamped to the top of the digester wall. The inflatable roof has a skirt surrounding the gas storage canopy and this skirt is trapped between the flange at the top of the wall of the digester. A loose flange arrangement which fits on top of this skirt acts as a gasket between the two flange systems. This gasket is normally completely gas-tight but can leak if it is damaged in any way. There could be some small gaps allowing an uncontrolled flammable gas release to atmosphere.

For a gas leak from a flange or fitting, the extent of release can be determined from the guidance given by the Gas Industry technical standard IGEM/SR/25 Edition. IGEM/SR/25 Edition 2 suggests that the leakage calculations for flange gaskets, screwed fittings, in joints as a metal to metal gap and at valve stem seals installed on non-vibratory pipework, which are well maintained, but are rarely broken (flanges) or infrequently used (valves), should be based on a leakage area of 0.25 mm² for normal conditions and taken as 2.5 mm² for adverse conditions.

Adverse conditions include flanges, valves, etc., installed on vibratory pipework (e.g. connected to blowers/compressors) or items broken or used more regularly. As the digester PVC roof seal is not as strong as a flange or fitting seal and as the seal may be subject to disturbance in very windy conditions, an abnormal leakage area of a maximum of 25 mm² can be used to calculate the leakage area.

The release rate calculation for a leak from a seal and Hazardous Area Classification as defined by BS EN 60079-10 – Part 10-1:2015, is shown as follows:

P	Pressure Inside	mbarg	4
T	Gas Temperature	°C	38
S	Hole Size	mm ²	25
Q _g	Flammable Release Rate	kg/sec	4.32E-04
LEL _v	Lower Explosive Limit	Vol %	7.44
	Grade of Release		S
k	Safety Factor		0.5
(dV/dt) _{min}	Min Flow Fresh Air	m ³ /sec	1.08E-02
f	Quality factor		1
C	Number of Air Changes	/hr	100
V _z	Hypothetical Volume	m ³	0.38
t	Persistence Time	sec	100
X	Dispersion Distance	m	0.32

The degree of ventilation is high and the availability is good since the digestate storage tank is located outdoors. The leakage site from the seal between the gas storage balloon and the top of the digestate storage tank wall is a Zone 2 Hazardous Area with a 0.35 m radial distance.

Assessment: Zone 2 Hazardous Area with a radial distance of 0.35 m in any direction from the seal between the gas storage balloon and the top of the digester wall.

Note: For biogas with a 55% methane content, there is no change to the calculated hazardous area classification.

c. Gap between membranes

There is potential for leakage inside the inner membrane of the gas storage roof and the outer shell leading to a release of flammable gas to atmosphere. Air is continuously blown through the inner gap to maintain the dome structure which provides good ventilation. The outlet of the air stream is also monitored for methane leakage with a fixed gas detection system.

Any leakage would result from a small leak and would be diluted to a level below the flammability (LEL) level of biogas by the continuous air stream between the membranes. It is therefore not necessary to zone the internal membrane layer between the inner membrane and the outer shell of the gas storage roof. The exhaust from the ventilation system also does not need to be zoned.

It should be noted that Dŵr Cymru Welsh Water DSEAR Handbook Version 19.1 (May 2020), classifies the internal space between membrane layers of the gas storage bubble as a Zone 1 area and states *“There is a Zone 1 area in the gap between the inflatable dome and the outer shell which has continuously pumped ventilation. The exhaust from the ventilation system should also be zoned. Default suggestions are Zone 1 sphere of 0.5-meter radius and Zone 2 plume of 4 meter length”*.

The Dŵr Cymru Welsh Water DSEAR Handbook Version 19.1 (May 2020), also classifies a Zone 2, 2m boundary around the external area of the gas storage bubble.

The original zoning is:

- The external volume up to 3m from the roof is classified as **Zone 2**.
- The membrane roof air discharge point is classified as **Zone 1** with **1m** radius.

The Dŵr Cymru Welsh Water and original classification are very conservative for the external areas around the gas membrane storage roof and should be reconsidered for this site.

3.1.6 Biogas Boosters and CHP Plant

The AD Plant currently has one 2 MW CHP engine, operating at approximately 200 mbarg. Biogas is routed from the Digestate Storage Tank (TK-45101) to the CHP engine (via a chiller, condensate trap and gas booster) to generate heat and electricity. The CHP engine is located within its own enclosure inside a dedicated area external to the main bund area.

The biogas main from the digestate storage tank to the CHP engine is routed from the digesters, through a chiller system to the CHP enclosure via above ground pipework. The pressure in the biogas main to the CHP engine inlet is approximately 4 mbarg, where it is increased to 200 mbarg using gas boosters, prior to being used in the CHP engine.

During normal operation, the gas space within the biogas main, the chiller, the condensate trap and any pipework containing biogas can be classified as **Zone 1**.

The leakage site for all flanges, seals and instrument fittings for normal operation of the biogas pipework from the digestate storage tank (through the chillers) to the inlet of the gas boosters is a **Zone 2** Hazardous Area of negligible extent (**NE**).

The gas boosters are located outside. During normal operation, the gas space within the gas boosters can be classified as **Zone 1**, as a flammable gas atmosphere inside the biogas supply pipe work could occur periodically or occasionally in normal operation.

The release rate calculation for a biogas leak at the boosted pressure after the gas boosters to the inlet of the CHP engine from a flange or fitting and Hazardous Area Classification as defined by BS EN 60079-10 – Part 10-1:2015, using a leakage area of 0.25 mm² are as follows:

P	Pressure Inside	mbarg	200
T	Gas Temperature	°C	38
S	Hole Size	mm ²	0.25
Q _g	Flammable Release Rate	kg/sec	3.10E-05
LEL _v	Lower Explosive Limit	Vol %	7.44
	Grade of Release		S
k	Safety Factor		0.5
(dV/dt) _{min}	Min Flow Fresh Air	m ³ /sec	7.54E-04
f	Quality factor		1
C	Number of Air Changes	/hr	100
V _z	Hypothetical Volume	m ³	0.03
t	Persistence Time	sec	100
X	Dispersion Distance	m	NE

The degree of ventilation is high, and the availability is good since the pipe work above ground is located outdoors. The leakage site for all flanges, seals and instrument fittings for normal operation for the biogas pipework from the gas booster to the inlet of the CHP engine is a **Zone 2** Hazardous Area of negligible extent (**NE**), as the hypothetical volume is less than 0.1 m.

Assessment: Zone 2 of negligible extent (NE), at flanges, seals and instrument fittings of the biogas main to the CHP engine after the gas booster.

The CHP enclosures are all fitted with extractive ventilation systems which can all typically achieve 100-400 air changes per hour. For the CHP engine, biogas pressure is at 200 mbarg and in the event of a leak in the CHP engine enclosure, the leakage site for all flanges, seals and instrument fittings for normal operation of the biogas pipework inside the CHP engine enclosure is a **Zone 2** Hazardous Area of negligible extent (**NE**).

During normal operation, the gas space within the CHP engine (up to the combustion chamber) can be classified as **Zone 1**.

For guidance, the following should apply for the CHP plant:

1. All plant and equipment installed will be designed for a CHP operation and all statutory test certificates should be stored on site with test dates recorded. Equipment will be remotely monitored and is designed to fail safe.
2. The CHP enclosure should be restricted and controlled access only.
3. The CHP enclosure should be fitted with gas detection systems which will isolate gas supply causing shut down.
4. Maintenance work should only be undertaken by competent personnel with the relevant work permits for work on site (i.e. hot work permit system).
5. Smoke and gas detectors should be installed in the gen set containers and trip the plant on detection of smoke and isolate gas supply.
6. All staff who work inside the gen set area should have gas detectors which monitor the levels of natural gas and carbon monoxide (the alarm should be suitable to ensure the user is adequately warned).
7. Gas levels in the pipeline should be monitored electronically to the control room.
8. All containers should be constructed from steel and will be adequately earth bonded and therefore any chance of electrical charge is minimal. The integrity of the earth bonding should be checked.
9. The enclosure should have a high degree of extractive ventilation. A fault on the ventilation system should not shut down the CHP engine, however, flammable gas detection should cause an engine shut down preventing the generation of a flammable / explosive atmosphere.

Lube Oil

The lube oil used for the CHP engine will typically have a flash point above 250°C and will not normally create a flammable atmosphere. However, as the lube oil is pumped, then there is potential for the formation of a flammable mist. Mists of high-flashpoint fluids such as diesel, kerosene and lubricating oils can ignite and produce explosions at temperatures below their flashpoint.

The lube oil system uses a high standard of integrity of pipelines and is operated at low pressure. For a flange or fitting leak, the use of flange guards will prevent the formation of mists and will act as a barrier against flammable vapour release that will allow a pool of oil to be formed. This will then require a robust site spillage procedure to ensure that any spillages of thermal oil are cleaned up straightaway.

Delivery & filling operations for the lube oil system is undertaken by a specialist contractor and if there is a leak the contractor will see the leak and stop the fill process. The operator can then implement any clean up procedure.

CHP Exhaust

Under normal operation, the CHP exhaust gas will consist of carbon dioxide and nitrogen oxides gases. These gases are not flammable so under normal operation the exhaust system can be classified as a **non-hazardous** area.

Exhaust gases containing carbon dioxide and carbon monoxide could be leaked in the CHP enclosure from a flange or fitting leak in the exhaust system. The CHP enclosure is fitted with a carbon monoxide detection system and all flange/fittings are regularly leak tested and checked for tightness. The CHP enclosure has forced ventilation and is fitted with extraction fans.

Condensate Trap (above ground)

The biogas main is connected to a condensate trap to collect water/condensate from biogas. Due to the extremely low gas pressure (4 mbarg) of the digesters, no methane gas should be entrained within the condensate. Therefore, no methane will be released from the condensate trap and therefore, the outlet of the condensate trap does not need to be zoned.

3.1.7 Flare System

A single emergency ground flare is located at one end of the anaerobic digestion plant. If the flare ignites biogas will be combusted in the flare with no release of uncombusted gas to atmosphere.

Heat radiation from an elevated flare is less than that for an open flare because the flame is enclosed, at high level and will reduce the minimum separation distance to an object exposed to thermal radiation. The thermal radiation requirements should determine the minimum separation distance of the flare from other plant and buildings.

The biogas pipe pressure to the flare is typically boosted to 200 mbarg and before the gas booster, the biogas main to the flare is operated at 4 mbarg pressure. The flare system uses biogas pilot.

Additional gas boosters are located outside, near to the flare. During normal operation, the gas space within the gas boosters can be classified as **Zone 1**, as a flammable gas atmosphere inside the gas boosters could occur periodically or occasionally in normal operation.

The leakage site for all flanges, seals and instrument fittings for normal operation of the biogas pipework from to the inlet of the flare system is a **Zone 2** Hazardous Area of negligible extent (**NE**).

The biogas main from the gas boosters to the inlet of the flare is operated at 200 mbarg pressure.

The release rate calculation for a biogas leak at the boosted pressure at the flare from a flange or fitting and Hazardous Area Classification as defined by BS EN 60079-10 – Part 10-1:2015, using a leakage area of 0.25 mm² are as follows:

P	Pressure Inside	mbarg	200
T	Gas Temperature	°C	38
S	Hole Size	mm ²	0.25
Q _g	Flammable Release Rate	kg/sec	3.10E-05
LEL _v	Lower Explosive Limit	Vol %	7.44
	Grade of Release		S
k	Safety Factor		0.5
(dV/dt) _{min}	Min Flow Fresh Air	m ³ /sec	7.54E-04
f	Quality factor		1
C	Number of Air Changes	/hr	100
V _z	Hypothetical Volume	m ³	0.03
t	Persistence Time	sec	100
X	Dispersion Distance	m	NE

The degree of ventilation is high, and the availability is good since the pipe work above ground is located outdoors. The leakage site for all flanges, seals and instrument fittings for normal operation for the biogas pipework from the gas booster to the Flare is a **Zone 2** Hazardous Area of negligible extent (**NE**), as the hypothetical volume is less than 0.1 m.

Assessment: Zone 2 of negligible extent (NE), at flanges, seals and instrument fittings of the biogas main to the flare after the gas booster.

The Thames Water Utilities Limited Document Reference TWUL/E04 entitled 'Standard Practice Document E04, Zoning of Hazardous Areas, and Issue 4.0' dated May 2009 provides guidance for zoning of ground flares (see Figure 2 below).

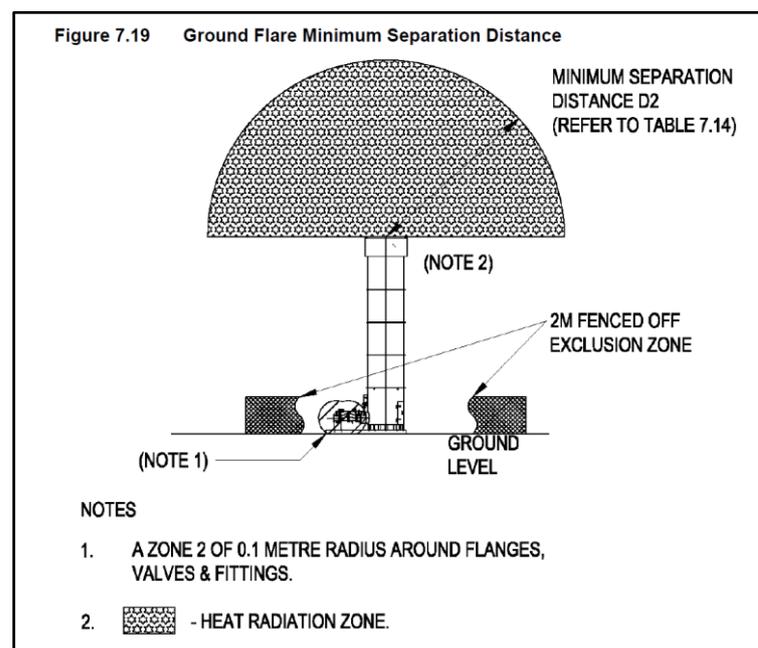


Figure 2: Extract from Thames Water Utilities Limited Document Reference TWUL/E04

Although, there is guidance for classifying the area around flanges, valves and fittings, if a gas leak does occur, the leak must be expected to find a source of ignition, either directly at the flames, or by a surface heated by a flame. In these circumstances, hazardous area classification, and appropriate selection of ATEX equipment is not suitable as a basis of safety for preventing fire and explosion risks. Instead, safety should be achieved by a combination of a high standard of integrity of fuel and process pipelines, together with a means of rapid detection and isolation of any pipes that do fail. The consequences of the failure of a pipe carrying process materials to the flare should be considered in a HAZOP study.

The Thames Water Utilities Limited Document Reference TWUL/E04 entitled 'Standard Practice Document E04, Zoning of Hazardous Areas, provides guidance for zoning of ground flares, however, the same analogy could be used for elevated flares.

Condensate Trap (above ground)

The biogas main is connected to a condensate trap at the flare to collect water/condensate from biogas. Due to the extremely low gas pressure (4 mbarg) of the digesters, no methane gas will be entrained within the condensate. Therefore, no methane will be released from the condensate trap and therefore, the outlet of the condensate trap does not need to be zoned.

3.1.8 Biogas Boiler & Hot Water Heating System

The site uses a boosted biogas supply at approximately 200 mbarg, for the site hot water system boiler.

The connections (flanges, fittings, joints) of the biogas pipeline to the boiler are considered to act as secondary source of release and give rise to a zone, in which a flammable atmosphere is not likely to occur in normal operation and if it does will only exist for a short time. This area can be classified as **Zone 2 of negligible extent (NE)** after the gas booster to the boiler as identified for the CHP engine and flare system.

The use of hazardous area classification, and appropriate selection of ATEX equipment are used to remove ignition sources in a flammable area. As the boiler is naturally hot during normal operation and can act as a source of ignition, hazardous area classification and the use of ATEX equipment is not a suitable basis of safety for the boiler in preventing fire and explosion risks.

HSE website¹² provides information on the use of steam boilers operating on natural gas and states:

"Low pressure pipelines carrying mains gas to gas burning equipment have not traditionally been considered as sources of hazardous leaks, and area classification has not been applied in such circumstances. Boiler houses are normally well ventilated, but the ventilation has usually been designed to provide air for combustion and to control room temperatures, rather than help disperse small leaks. The security of gas pipework operating at any pressure should at least be considered in any risk assessment made under DSEAR.

12. <http://www.hse.gov.uk/electricity/atex/issues.htm>

Pipework is most likely to be reliably gas tight if:

- *it has been installed to a recognised relevant code,*
- *it has been properly maintained, including periodic pressure testing or leakage testing from the joints, and*
- *there are no external influences likely to cause early failure, e.g. by corrosion, impact or vibration.*

There is ongoing work to assess the size of any potentially explosive gas cloud which may be expected to form, arising from the combination of the range of mains gas pressures and holes of specified sizes in such pipework.

Burner control packages mounted on the face of a boiler are often very close to hot surfaces, or air intakes that are directly connected to the internal flames. In these circumstances, it makes little sense to assign a hazardous area around the gas fittings or use ATEX-compliant electrical parts so close to other permanent sources of ignition. It is appropriate to design the pipework and gas control train to minimise the risk of a leak”.

In these circumstances, hazardous area classification, and appropriate selection of ATEX equipment is not suitable as a basis of safety for preventing fire and explosion risks. Instead, safety should be achieved by a combination of a high standard of integrity of fuel and process pipelines, together with regular maintenance and testing.

3.1.9 Technology Building

The Technology Building is located between the Digester and Post Digester Tank and contains the substrate pumps, as well as the Air Desulphurisation System for Digester TK-41101.

The following equipment within the Technology Building do not need to be zoned as no flammable material is generated and therefore can be considered as **non-hazardous**.

- Substrate pumps and distribution pipework
- Air Desulphurisation System with air blowers and air distribution pipework
- Site air compressor

There is a washdown and condensate/water collection sump within the Technology Building. The pit is fitted with discharge pump connected to a high and low level control system which empties the pit on high level.

Under normal operation, only water and wash water (which is not considered flammable) will be collected in this sump. Therefore, the Technology Building condensate collection sump can be classified as non-hazardous as no flammable materials are present.

It should be noted that the original zoning of a Zone 2 internal area within the sump was very conservative and is not needed for this sump.

3.1.10 Pasteurisation Plant

A pasteurisation plant is used to treat spent digestate before the solids from the spent digestate are separated. The liquor from the solids separation plant is collected in a separator tank (TK-53101) and routed to the Digestate Storage Tank (TK-45101). Spent digestate is pasteurised for one hour at 73°C in a batch operation to kill off all pathogens.

Spent digestate is routed to one of three 10 m³ pasteurisation vessels at a rate of 7350 kg/hr. Heat is recovered from the process by preheating the digestate and by removing heat from the pasteurised product. During the filling stage, air inside the pasteuriser vessel will be displaced to the odour abatement system (bio-filter). Biogas could be released from spent digestate; however, it will be a limited amount for a short time period (during the initial fill before pasteurisation starts). A flammable atmosphere is not expected to form during normal operation in the pasteurisers.

To be conservative, the gas space within the pasteurisers and connecting gas pipework to the odour abatement system can be classified as **Zone 2**. This is just in case biogas is released from spent digestate.

The connecting substrate pipework from the digestate storage tank to the pasteurisers is fitted with a number of relief valves which have been included in the design, if the pipework gets isolated and there is any gas build up resulting in an overpressure.

During normal operation, the substrate pipes are always full of substrate and there should be no flammable vapour inside the pipework. Therefore, the inside of the pipework does not need to be zoned.

The fitting of relief valves on substrate pipework for gas build up is very conservative and normally not required. The design condition is venting of substrate, rather than biogas to protect pipework mechanical integrity.

In this case, a hazardous area classification is not required around the relief valves, and Dŵr Cymru Welsh Water should ensure that a robust company clean-up procedure is in place to avoid any ignition sources during a substrate relief valve activation. The procedure should ensure that the available time for the spilled digestate to form a flammable vapour is minimised.

ANERGIA have stated in the original hazardous area classification study, that a substrate containing 7% Total Solids, 70% Volatile Solids has a gas potential of 150 Nm³/t.VS and can produce 7.4 m³ of gas in 3 weeks from 1 m³ of substrate. Therefore, significant biogas evolution from substrate will not be immediate.

It should be noted that the original zoning around the substrate relief valve is a **1m radius Zone 2 sphere**, which is very conservative.

3.1.11 Solids Separation & Odour Abatement System

Solids Separation

Solids from the pasteurised digestate are separated using Separator (SEP-53120) and stored within the solids separation building, before being collected for offsite disposal. The separated liquor is collected in a 9.2 m³ Liquid Collection Tank (TK-53101) before being transferred to the digestate storage tank.

The following systems of the separation plant will only contain spent and pasteurised digestate, with no flammable materials and therefore do not need to be zoned.

- Inside area of Separator (SEP-53120)
- Inside area of Liquid Collection Tank (TK-53101)
- Pipeline from the pasteurisers to the separation plant
- Separated solids collection area (building room)
- Pipeline from the separation plant to the liquid collection tank TK-53101
- Any vent connections of the liquid collection tank.

Odour Abatement System

The odour abatement system is connected to the Pasteurisers and the Food Waste Reception Building.

No flammable odour should be received from the Food Waste Reception Building; however, some flammable biogas could be received from the Pasteuriser Tanks. For this reason, the internal gas space within the odour abatement plant and connecting gas pipework from the pasteuriser tanks can be classified as **Zone 2**.

3.1.12 Diesel & Electric Power Transformer

Diesel

Diesel is used on site and is dispensed in a dedicated area. Diesel has a typical flash point of >55°C and will not normally create a flammable atmosphere. However, if diesel is heated or pumped, then there is potential for the formation of flammable mists. Mists of high-flashpoint fluids can ignite and produce explosions at temperatures below their flashpoint.

Diesel is delivered to site by tanker and stored in a dedicated tank. It is dispensed by manual operation directly into vehicles or containers. Delivery & filling operations is undertaken by trained personnel and if there is a leak the operator will see the leak and stop the fill process. The operator can then implement any clean up procedure.

Electric Power Transformer

The Electric Power transformer is located at one end of the site. Mineral Oil is used within the transformer and there is a known phenomenon associated with transformer oils where hydrocarbons are broken down to produce hydrogen gas. Any gas production will be contained within the transformer enclosure and routine oil analysis will determine degradation of oils.

3.1.13 Purge System for Analysis Equipment

The biogas analysis system purges gas through small diameter pipe, discharged directly into the atmosphere.

The biogas analysis system can be considered as a piece of standard laboratory equipment and in line with general DSEAR principles and specific HSE guidance for laboratory applications, is not considered suitable for zoning. Instead a safe basis of operation should be used and a risk assessment should be in place which should include the following points:

- Sampling procedures
- Pipework connections will be leak tested during installation/commissioning, minimising any likelihood of leak
- Pipework connections will be subjected to repeat leak testing following any need for connections to be broken, thus minimising any likelihood of leak
- The analyser is sited such that good practice is achieved to ensure equipment is not subject to any obvious forms of vibration or impact damage.

In addition, the emission of dangerous substances is limited to small amounts contained in the apparatus of analysis.

Due to the above, the analysis equipment is not considered as zoned.

3.1.14 Other Plant Areas

The following plant areas can be classified as non-hazardous as no flammable materials are present during normal operation:

- Plant Room (site control room) adjacent to main food waste reception building
- Ferric Chloride IBC area with Emergency Shower
- Weighbridge facility
- Site Office located offsite and away from main plant area at the side of the facility.

Appendix 4: Hazardous Area Classification Data Sheet**Normal Operation**

Hazardous Area Classification Data Sheet - Part 2: List of Sources of Release													Sheet: 1 of 4			
Plant/Section: Welsh Water Organic Energy, Cardiff Food AD Plant, Wales - normal operation												Drawing: Not Applicable				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
No.	Source of Release				Flammable Material			Ventilation			Hazardous Area			Relevant information and remarks		
	Description	Location	Grade of Release ^a	Rate of Release (kg/s)	Reference ^b	Operating temperature and pressure		State ^c	Type ^d	Degree of Dilution ^e	Availability ^f	Zone Type 0-1-2	Zone Extent (m)		Reference	
						°C	mbarg						Vertical			Horizontal
1	Digester Feed Reception Tank, Digester, Post Digester Tank & Digestate Storage Tank headspace		C	---	1	38	4	G	+	+	+	Zone 1	Whole volume inside vessel headspace		A3.1.3 A3.1.4 A3.1.5	Flammable atmosphere present periodically
2	Digestate Storage Tank headspace & roof gas storage holder		C	---	1	38	4	G	+	+	+	Zone 1	Whole volume inside vessel headspace and gas storage holder		A3.1.5	Flammable atmosphere present periodically
3	Seal between the roof gas storage holder and the top of the Digestate Storage Tank wall		S	4.3 x 10 ⁻⁴	1	38	4	G	N	DM	G	Zone 2	0.35 m in any direction from the seal		A3.1.5	Leakage to outside atmosphere

a C = Continuous; P = Primary; S = Secondary

b Quote number on list in Appendix A2.6

c G = Gas; L = Liquid; LG = Liquefied Gas; S = Solid; Dust

d N = Natural; A = Artificial

e DH = High Dilution; DM = Medium Dilution; DL = Low Dilution

f G = Good Availability; F = Fair Availability; P = Poor Availability

+ Ventilation / Release rate not applicable as zoning is internal space in vessel

Hazardous Area Classification Data Sheet - Part 2: List of Sources of Release													Sheet: 2 of 4			
Plant/Section: Welsh Water Organic Energy, Cardiff Food AD Plant, Wales - normal operation												Drawing: Not Applicable				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
No.	Source of Release				Flammable Material			Ventilation			Hazardous Area			Relevant information and remarks		
	Description	Location	Grade of Release ^a	Rate of Release (kg/s)	Reference ^b	Operating temperature and pressure		State ^c	Type ^d	Degree of Dilution ^e	Availability ^f	Zone Type 0-1-2	Zone Extent (m)		Reference	
						°C	mbarg						Vertical			Horizontal
4	Digester Feed Reception Tank, Digester, Post Digester Tank: Gap between insulation and concrete wall		S	---	1	38	4	G	+	+	+	Zone 2	Whole volume inside gap space	A3.1.3 A3.1.4 A3.1.5	Leakage to atmosphere within gap space	
5	Inside Biogas main		C	---	1	38	4	G	+	+	+	Zone 1	Whole volume inside pipe	A3.1.3 A3.1.4 A3.1.5	Flammable atmosphere present periodically	
6	Biogas Main: flanges, seals and instrument fittings		S	4.3×10^{-6}	1	38	4	G	N	DM	G	Zone 2	NE	A3.1.3 A3.1.4 A3.1.5	Leakage to outside atmosphere	
7	Digester Feed Reception Tank, Digester, Post Digester Tank & Digestate Storage Tank: Liquid seal type relief valve		P	6.6×10^{-4}	1	38	7	G	N	DM	G	Zone 1	0.5 m in any direction from discharge point	A3.1.3 A3.1.4 A3.1.5	Leakage to outside atmosphere	
			S	6.6×10^{-1}	1	38	7	G	N	DM	G	Zone 2	5.1 m in any direction from discharge point	A3.1.3 A3.1.4 A3.1.5	Leakage to outside atmosphere	

a C = Continuous; P = Primary; S = Secondary

b Quote number on list in Appendix A2.6

c G = Gas; L = Liquid; LG = Liquefied Gas; S = Solid; Dust

d N = Natural; A = Artificial

e DH = High Dilution; DM = Medium Dilution; DL = Low Dilution

f G = Good Availability; F = Fair Availability; P = Poor Availability

+ Ventilation / Release rate not applicable as zoning is internal space in vessel

Hazardous Area Classification Data Sheet - Part 2: List of Sources of Release													Sheet: 3 of 4			
Plant/Section: Welsh Water Organic Energy, Cardiff Food AD Plant, Wales - normal operation												Drawing: Not Applicable				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
No.	Source of Release				Flammable Material			Ventilation			Hazardous Area			Relevant information and remarks		
	Description	Location	Grade of Release ^a	Rate of Release (kg/s)	Reference ^b	Operating temperature and pressure		State ^c	Type ^d	Degree of Dilution ^e	Availability ^f	Zone Type 0-1-2	Zone Extent (m)		Reference	
						°C	mbarg						Vertical			Horizontal
8	Digester Feed Reception Tank, Digester, Post Digester Tank & Digestate Storage Tank: Service Box (internal)		S	---	1	38	4	G	+	+	+	Zone 2	Whole volume inside service box	A3.1.3 A3.1.4 A3.1.5	Leakage to atmosphere within service box	
9	Digester Feed Reception Tank, Digester, Post Digester Tank & Digestate Storage Tank: Service Box (External)		S	4.3 x 10 ⁻⁴	1	38	4	G	N	DM	G	Zone 2	0.35 m in any direction from service box door	A3.1.3 A3.1.4 A3.1.5	Leakage to outside atmosphere during maintenance	
10	Digester Feed Reception Tank, Digester, Post Digester Tank & Digestate Storage Tank: Foam Valve		S	1.7 x 10 ⁻²	1	38	20	G	N	DM	G	Zone 2	2.4 m in any direction from discharge point	A3.1.3 A3.1.4 A3.1.5	Leakage to outside atmosphere during maintenance	
11	Biogas Main: flanges, seals and instrument fittings from Gas Boosters to CHP Engine		S	3.1 x 10 ⁻⁵	1	38	200	G	N	DM	G	Zone 2	NE	A3.1.6	Leakage to outside atmosphere	
12	Inside CHP Engine Gas Boosters		C	---	1	38	200	G	+	+	+	Zone 1	Whole volume inside area	A3.1.6	Flammable atmosphere present periodically	

a C = Continuous; P = Primary; S = Secondary

b Quote number on list in Appendix A2.6

c G = Gas; L = Liquid; LG = Liquefied Gas; S = Solid; Dust

d N = Natural; A = Artificial

e DH = High Dilution; DM = Medium Dilution; DL = Low Dilution

f G = Good Availability; F = Fair Availability; P = Poor Availability

Hazardous Area Classification Data Sheet - Part 2: List of Sources of Release													Sheet: 4 of 4			
Plant/Section: Welsh Water Organic Energy, Cardiff Food AD Plant, Wales - normal operation												Drawing: Not Applicable				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
No.	Source of Release				Flammable Material			Ventilation			Hazardous Area			Relevant information and remarks		
	Description	Location	Grade of Release ^a	Rate of Release (kg/s)	Reference ^b	Operating temperature and pressure		State ^c	Type ^d	Degree of Dilution ^e	Availability ^f	Zone Type 0-1-2	Zone Extent (m)		Reference	
						°C	mbarg						Vertical			Horizontal
13	Inside CHP Engine (up to combustion)		S	---	1	38	100	G	+	+	+	Zone 1	Whole volume inside Engine	A3.1.6	Flammable atmosphere present periodically	
14	Inside CHP Enclosure: flanges, seals and instrument fittings.		S	3.1 x 10 ⁻⁵	1	38	100	G	N	DM	G	Zone 2	NE	A3.1.6	Leakage to outside atmosphere	
15	Biogas Main: flanges, seals and instrument fittings from Gas Boosters to Flare		S	3.1 x 10 ⁻⁵	1	38	200	G	N	DM	G	Zone 2	NE	A3.1.7	Leakage to outside atmosphere	
15	Inside Flare Gas Boosters		C	---	1	38	200	G	+	+	+	Zone 1	Whole volume inside area	A3.1.7	Flammable atmosphere present periodically	
16	Biogas Main: flanges, seals and instrument fittings from Gas Boosters to Boiler		S	3.1 x 10 ⁻⁵	1	38	200	G	N	DM	G	Zone 2	NE	A3.1.8	Leakage to outside atmosphere	
17	Inside Pasteurisers & Odour Control Unit Ductwork		S	---	1	38	50	G	+	+	+	Zone 2	Whole volume inside ductwork	A3.1.11	Flammable atmosphere not expected under normal operation	

a C = Continuous; P = Primary; S = Secondary

b Quote number on list in Appendix A2.6

c G = Gas; L = Liquid; LG = Liquefied Gas; S = Solid; Dust

d N = Natural; A = Artificial

e DH = High Dilution; DM = Medium Dilution; DL = Low Dilution

f G = Good Availability; F = Fair Availability; P = Poor Availability

Appendix 5: Material Data Sheets

MATERIAL SAFETY DATA SHEET

Methane

This data sheet has been developed from information on Material Safety Data Sheets from Air Liquide, Air Products and BOC Limited.

METHANE SECTION 1. PRODUCT IDENTIFICATION

PRODUCT NAME: Methane **FORMULA:** CH₄
CHEMICAL NAME: Methane, Saturated Aliphatic Hydrocarbon, Alkane
SYNONYMS: Methyl Hydride, Marsh Gas, Fire Damp

METHANE SECTION 2. COMPOSITION / INFORMATION ON INGREDIENTS

CAS NUMBER: 74-82-8

METHANE SECTION 3. HAZARD IDENTIFICATION

EMERGENCY OVERVIEW

Methane is a flammable, colourless, odourless gas. It poses an immediate fire and explosion hazard when mixed with air at concentrations exceeding 5.0%. High concentrations that can cause rapid suffocation are within the flammable range and should not be entered.

ACUTE POTENTIAL HEALTH EFFECTS:

ROUTES OF EXPOSURE:

EYE CONTACT: No harmful effect.

INGESTION: Not applicable

INHALATION: Methane is nontoxic. It can, however, reduce the amount of oxygen in the air necessary to support life. Exposure to oxygen-deficient atmospheres (less than 19.5 %) may produce dizziness, nausea, vomiting, loss of consciousness, and death. At very low oxygen concentrations (less than 12 %) unconsciousness and death may occur without warning. It should be noted that before suffocation could occur, the lower flammable limit for Methane in air will be exceeded; causing both an oxygen deficient and an explosive atmosphere.

SKIN CONTACT: No harmful effect.

POTENTIAL HEALTH EFFECTS OF REPEATED EXPOSURE:

ROUTE OF ENTRY: None

SYMPTOMS: None

TARGET ORGANS: None

MEDICAL CONDITIONS AGGRAVATED BY OVEREXPOSURE: None

CARCINOGENICITY: Methane is not listed as a carcinogen or potential carcinogen.

METHANE SECTION 4. FIRST AID MEASURES

EYE CONTACT: No treatment necessary.

INGESTION: Not applicable

INHALATION: In high concentrations may cause asphyxiation. Remove person to fresh air. If not breathing, administer artificial respiration. If breathing is difficult, administer oxygen. Obtain prompt medical attention.

SKIN CONTACT: No treatment necessary.

NOTES TO PHYSICIAN: Treatment of overexposure should be directed at the control of symptoms and the clinical condition

METHANE SECTION 5. FIRE FIGHTING MEASURES

FLASH POINT:
-306 °F (-187.8 °C)

AUTOIGNITION:
999 °F (537 °C)

FLAMMABLE RANGE:
5.0% - 15%

EXTINGUISHING MEDIA: Dry chemical, carbon dioxide, or water.

SPECIAL FIRE FIGHTING INSTRUCTIONS: Evacuate all personnel from area. If possible, without risk, shut off source of methane, and then fight fire according to types of materials burning. Extinguish fire only if gas flow can be stopped. This will avoid possible accumulation and re-ignition of a flammable gas mixture. Keep adjacent cylinders cool by spraying with large amounts of water until the fire burns itself out. Self-contained breathing apparatus (SCBA) may be required.

HAZARDOUS COMBUSTION PRODUCTS: Carbon monoxide

METHANE SECTION 6. ACCIDENTAL RELEASE MEASURES

STEPS TO BE TAKEN IF MATERIAL IS RELEASED: Evacuate immediate area. Eliminate any possible sources of ignition and provide maximum explosion-proof ventilation. Use a flammable gas meter (explosimeter) calibrated for Methane to monitor concentration. Never enter an area where Methane concentration is greater than 1.0% (which is 20% of the lower flammable limit). An immediate fire and explosion hazard exists when atmospheric Methane concentration exceeds 5.0%. Use appropriate protective equipment (SCBA and fire resistant suit). Shut off source of leak if possible. Isolate any leaking cylinder. If the leak is in the user's system, close the valves, safely vent the pressure, and purge with an inert gas before attempting repairs.

METHANE SECTION 7. HANDLING AND STORAGE

STORAGE: There should be no sources of ignition. All electrical equipment should be explosion-proof in the storage areas. Flammable storage areas must be separated from oxygen and other oxidizers by a minimum distance of 20 ft. or by a barrier of non-combustible material at least 5 ft. high having a fire resistance rating of at least 1/2 hour. Post "No Smoking or Open Flames" signs in the storage or use areas. Do not allow storage temperature to exceed 125 °F (52 °C). Storage should be away from heavily travelled areas and emergency exits. .

HANDLING: Use piping and equipment adequately designed to withstand pressures to be encountered. All piped systems and associated equipment must be grounded. Electrical equipment should be non-sparking or explosion-proof.

METHANE SECTION 8. EXPOSURE CONTROLS AND PERSONAL PROTECTION

ENGINEERING CONTROLS:

VENTILATION: Provide adequate natural or explosion-proof ventilation to prevent accumulation of gas concentrations above 1.0% Methane (20% of LEL).

RESPIRATORY PROTECTION:

Emergency Use: Do not enter areas where Methane concentration is greater than 1.0% (20% of the LEL). Exposure to concentrations below 1.0% do not require respiratory protection.

EYE PROTECTION: Safety glasses and/or face shield.

SKIN PROTECTION: Fire resistant suit and gloves in emergency situations.

METHANE SECTION 9. PHYSICAL AND CHEMICAL PROPERTIES

APPEARANCE, ODOUR AND STATE: Colourless, odourless, flammable gas.

MOLECULAR WEIGHT: 16.04

BOILING POINT (1 atm): -258.7 °F (-161.5 °C)

SPECIFIC GRAVITY (Air = 1): 0.554

FREEZING POINT / MELTING POINT: -296. 5 °F (-182.5 °C)

VAPOR PRESSURE (At 70 F (21.1 C)): Permanent, noncondensable gas.

GAS DENSITY (At 70 F (21.1 C) and 1 atm): 0.042 lb/ft³

SOLUBILITY IN WATER (vol/vol): 3.3 ml gas / 100 ml

METHANE SECTION 10. STABILITY AND REACTIVITY

CHEMICAL STABILITY: Stable

INCOMPATIBILITY (Materials to Avoid): Oxygen, Halogens and Oxidizers

REACTIVITY:

A) HAZARDOUS DECOMPOSITION PRODUCTS: None

B) HAZARDOUS POLYMERIZATION: Will not occur

METHANE SECTION 11. TOXICOLOGICAL INFORMATION

LC50 (Inhalation): Not applicable. Simple asphyxiant.

LD50 (Oral): Not applicable

LD50 (Dermal): Not applicable

SKIN CORROSIVITY: Methane is not corrosive to the skin.

ADDITIONAL NOTES: None

METHANE SECTION 12. ECOLOGICAL INFORMATION

AQUATIC TOXICITY: Not determined

MOBILITY: Not determined

PERSISTENCE AND BIODEGRADABILITY: Not determined

POTENTIAL TO BIOACCUMULATE: Not determined

REMARKS: This product does not contain any ozone depleting chemicals.

METHANE SECTION 13. DISPOSAL CONSIDERATIONS

DISPOSAL INFORMATION: Residual product in the system may be burned if a suitable burning unit (flare or incinerator) is available on site. This shall be done in accordance with regulations. Wastes containing this material may be classified as hazardous waste by characteristic (i.e., Ignitability, Corrosivity, Toxicity, and Reactivity). Waste streams must be characterized by the user to meet requirements.

METHANE SECTION 14. TRANSPORT INFORMATION

Flammable gas

SPECIAL SHIPPING INFORMATION: Transport in a secure upright position in a well-ventilated truck. Never transport in passenger compartment of a vehicle. Ensure valves are properly closed.

METHANE SECTION 15. REGULATORY INFORMATION**METHANE SECTION 16. OTHER INFORMATION**

DISCLAIMER OF LIABILITY: Details given in this document are believed to be correct at the time of printing. Whilst proper care has been taken in the preparation of this document, no liability for injury or damage resulting from its use can be accepted. Before using this product in any new process or experiment, a thorough material compatibility and safety study should be carried out.

MATERIAL SAFETY DATA SHEET

Carbon Dioxide

This data sheet has been developed from information on Material Safety Data Sheets from Air Liquide, Air Products and BOC Limited.

CARBON DIOXIDE SECTION 1. PRODUCT IDENTIFICATION

Product name: Carbon Dioxide

Chemical formula: CO₂

Synonyms: Carbon dioxide, Carbonic Anhydride, Carbonic Acid Gas, Carbon Anhydride

CARBON DIOXIDE SECTION 2. COMPOSITION / INFORMATION ON INGREDIENTS

CARBON DIOXIDE SECTION 3. HAZARD IDENTIFICATION

Emergency Overview

Can cause rapid suffocation. Avoid breathing gas. Self contained breathing apparatus (SCBA) may be required.

Potential Health Effects

Inhalation: Concentrations of 10% CO₂ or more can produce unconsciousness or death. Unlike simple asphyxiants, carbon dioxide has the ability to cause death even when normal oxygen levels (20-21%) are maintained. Carbon Dioxide is physiologically active, affecting circulation and breathing. At concentrations between 2 and 10%, carbon dioxide can cause nausea, dizziness, headache, mental confusion, increased blood pressure and respiratory rate. In high concentrations may cause asphyxiation. Symptoms may include loss of mobility/consciousness. Victim may not be aware of asphyxiation. Asphyxiation may bring about unconsciousness without warning and so rapidly that victim may be unable to protect themselves.

Eye contact: Contact with liquid may cause cold burns/frostbite.

Skin contact: Contact with liquid may cause cold burns/frostbite.

Ingestion: Ingestion is not considered a potential route of exposure.

Chronic Health Hazard: Not applicable.

Exposure Guidelines

Primary Routes of Entry: Inhalation

Target Organs: None.

Symptoms: Shivering fit. Sweating. Blurred vision. Headache. Increased pulse rate. Shortness of breath. Rapid respiration. Exposure to oxygen deficient atmosphere may cause the following symptoms: Dizziness. Salivation. Nausea. Vomiting. Loss of mobility/consciousness.

Aggravated Medical Condition : None known.

CARBON DIOXIDE SECTION 4. FIRST AID MEASURES

General advice: Remove victim to uncontaminated area wearing self-contained breathing apparatus. Keep victim warm and rested. Call a doctor. Apply artificial respiration if breathing stopped.

Eye contact: In the case of contact with eyes, rinse immediately with plenty of water and seek medical advice. Keep eye wide open while rinsing.

Skin contact: Wash frost-bitten areas with plenty of water. Do not remove clothing. Cover wound with sterile dressing.

Ingestion: Ingestion is not considered a potential route of exposure.

Inhalation: Move to fresh air. If breathing has stopped or is laboured, give assisted respirations. Supplemental oxygen may be indicated. If the heart has stopped, trained personnel should begin cardiopulmonary resuscitation immediately. In case of shortness of breath, give oxygen.

CARBON DIOXIDE SECTION 5. FIRE FIGHTING MEASURES

Suitable extinguishing media: All known extinguishing media can be used.

Specific hazards: Product is non-flammable and does not support combustion. Move away from container and cool with water from a protected position. If possible, stop flow of product. Keep adjacent containers cool by spraying with large amounts of water until the fire burns itself out.

Special protective equipment for fire-fighters: Wear self-contained breathing apparatus for firefighting if necessary.

CARBON DIOXIDE SECTION 6. ACCIDENTAL RELEASE MEASURES

Personal precautions: Monitor carbon dioxide level. Evacuate personnel to safe areas. Wear self-contained breathing apparatus when entering area unless atmosphere is proved to be safe. Ventilate the area. Monitor oxygen level.

Environmental precautions: Should not be released into the environment. Do not discharge into any place where its accumulation could be dangerous. Prevent further leakage or spillage. Prevent from entering sewers, basements and workpits, or any place where its accumulation can be dangerous.

Methods for cleaning up: Ventilate the area.

Additional advice: If possible, stop flow of product. Increase ventilation to the release area and monitor oxygen level. Try to close any leaking valve, safely vent the pressure, and purge with an inert gas before attempting repairs.

CARBON DIOXIDE SECTION 7. HANDLING AND STORAGE

Handling: Do not allow storage area temperature to exceed 50°C (122°F). Know and understand the properties and hazards of the product before use. Ensure the complete gas system is compatible for pressure rating and materials of construction. Ensure the complete gas system has been checked for leaks before use. Never attempt to repair or modify container valves or safety relief devices. Do not subject containers to abnormal mechanical shocks which may cause damage to their valve or safety devices. Never use direct flame or electrical heating devices to raise the pressure of a container. Containers should not be subjected to temperatures above 50°C (122°F). Prolonged periods of cold temperature below -30°C (-20°F) should be avoided.

Storage: Protect containers stored in the open against rusting and extremes of weather. Containers should not be stored in conditions likely to encourage corrosion. Store containers in location free from fire risk and away from sources of heat and ignition. Do not allow storage temperature to exceed 50°C (122°F).

CARBON DIOXIDE SECTION 8. EXPOSURE CONTROLS AND PERSONAL PROTECTION

Engineering measures: Provide natural or mechanical ventilation to prevent accumulation above exposure limits. Provide natural or mechanical ventilation to prevent oxygen deficient atmospheres below 19.5% oxygen.

Personal protective equipment: Respiratory protection: Self-contained breathing apparatus (SCBA) or positive pressure airline with mask are to be used in oxygen-deficient atmosphere. Air purifying respirators will not provide protection. Users of breathing apparatus must be trained.

Hand protection: Sturdy work gloves are recommended for handling cylinders. The breakthrough time of the selected glove(s) must be greater than the intended use period.

Eye protection: Safety glasses recommended when handling cylinders.

Skin and body protection: Safety shoes are recommended when handling cylinders.

Special instructions for protection and hygiene: Ensure adequate ventilation, especially in confined areas.

Exposure limit(s):

Short Term Exposure Limit (STEL): (ACGIH, NIOSH, OSHA): 30,000 ppm
Recommended TWA Limit (ACGIH, NIOSH, OSHA): 5,000 ppm

CARBON DIOXIDE SECTION 9. PHYSICAL AND CHEMICAL PROPERTIES

Odour:	No odour warning properties.
Molecular Weight:	44.01 g/mol
Relative vapour density:	1.519 (air = 1)
Relative density:	0.82 (water = 1)
Vapour pressure :	831.04 psia (57.30 bar) at 68 °F (20 °C)
Density:	0.112 lb/ft ³ (0.0018 g/cm ³) at 70 °F (21 °C) Note: (as vapour)
Specific Volume :	8.74 ft ³ /lb (0.5456 m ³ /kg) at 70 °F (21 °C)
Boiling point/range:	-127 °F (-88.1 °C)
Critical temperature:	88 °F (31.1 °C)
Melting point/range:	-70 °F (-56.6 °C)
Water solubility:	2.000 g/l

CARBON DIOXIDE SECTION 10. STABILITY AND REACTIVITY

Stability: Stable under normal conditions.

CARBON DIOXIDE SECTION 11. TOXICOLOGICAL INFORMATION**Acute Health Hazard**

Ingestion: No data is available on the product itself.

Inhalation : Unlike simple asphyxiants, carbon dioxide has the ability to cause death even when normal oxygen levels (20-21%) are maintained. 5% CO₂ has been found to act synergistically to increase the toxicity of certain other gases (CO, NO₂). CO₂ has been shown to enhance the production of carboxy- or met-haemoglobin by these gases possibly due to carbon dioxide's stimulatory effects on the respiratory and circulatory systems.

Dermal: No data is available on the product itself.

CARBON DIOXIDE SECTION 12. ECOLOGICAL INFORMATION**Ecotoxicity effects**

Aquatic toxicity: No data is available on the product itself.

Toxicity to fish

Carbon dioxide LC50 (1 h) : 240 mg/l Species : Rainbow trout (*Oncorhynchus mykiss*).

Carbon dioxide LC50 (96 h): 35 mg/l Species: Rainbow trout (*Oncorhynchus mykiss*).

Toxicity to other organisms: No data available.

Persistence and degradability

Biodegradability: No data is available on the product itself.

Mobility: No data available.

Bioaccumulation: No data is available on the product itself.

Further information: When discharged in large quantities may contribute to the greenhouse effect.

CARBON DIOXIDE SECTION 13. DISPOSAL CONSIDERATIONS

Do not discharge into any place where its accumulation could be dangerous. Discharge to atmosphere in large quantities should be avoided.

CARBON DIOXIDE SECTION 14. TRANSPORT INFORMATION

Avoid transport on vehicles where the load space is not separated from the driver's compartment. Ensure vehicle driver is aware of the potential hazards of the load and knows what to do in the event of an accident or an emergency. The transportation information is not intended to convey all specific regulatory data relating to this material.

CARBON DIOXIDE SECTION 15. REGULATORY INFORMATION

Not classified as dangerous preparation/substance. No EC labelling required.

CARBON DIOXIDE SECTION 16. OTHER INFORMATION

Asphyxiant in high concentrations. Do not breathe the gas. Ensure all national/local regulations are observed. The hazard of asphyxiation is often overlooked and must be stressed during operator training.

DISCLAIMER OF LIABILITY: Details given in this document are believed to be correct at the time of printing. Whilst proper care has been taken in the preparation of this document, no liability for injury or damage resulting from its use can be accepted. Before using this product in any new process or experiment, a thorough material compatibility and safety study should be carried out.

MATERIAL SAFETY DATA SHEET

Hydrogen Sulphide

This data sheet has been developed from information on Material Safety Data Sheets from Air Liquide, Air Products and BOC Limited.

HYDROGEN SULPHIDE SECTION 1. PRODUCT IDENTIFICATION

PRODUCT NAME: Hydrogen Sulphide

FORMULA: H₂S

SYNONYMS: Sulphuretted Hydrogen; Hydrogen Sulphide; Hydrosulphuric Acid; Sulphur Hydride; Sewer Gas; Sour Gas

HYDROGEN SULPHIDE SECTION 2. COMPOSITION / INFORMATION ON INGREDIENTS

CAS NUMBER: 7783-06-4

EXPOSURE LIMITS:

Time Weighted Average (ACGIH): 10 ppm

Short Term Exposure Limit (ACGIH): 15 ppm

HYDROGEN SULPHIDE SECTION 3. HAZARD IDENTIFICATION

EMERGENCY OVERVIEW

Hydrogen Sulphide is a toxic, flammable, colourless gas. Hydrogen Sulphide has a distinct "rotten-egg" smell. The odour cannot be relied on as an adequate warning of the presence of Hydrogen Sulphide because at high concentrations olfactory fatigue and paralysis occurs. Inhalation of high concentrations of this gas can result in unconsciousness, coma, and death. Hydrogen Sulphide poses an immediate fire hazard when mixed with air. The gas is heavier than air and may spread long distances. Distant ignition and flashback are possible. Flame or high temperature impinging on a localized area of a cylinder of Hydrogen Sulphide can cause the cylinder to explode without activating the cylinder's relief devices. Provide adequate fire protection during emergency response situations.

ACUTE POTENTIAL HEALTH EFFECTS:

ROUTES OF EXPOSURE:

EYE CONTACT: Inflammation and irritation of the eyes can occur at very low airborne concentration (less than 10 ppm). Exposure over several hours may result in "gas eyes" or "sore eyes" with symptoms of scratchiness, irritation, tearing and burning. Above 50 ppm, there is an intense tearing, blurring of vision, and pain when looking at light. Exposed individuals may see rings around bright lights. Most symptoms disappear when exposure ceases. However, in serious cases, the eye can be permanently damaged.

INGESTION: Ingestion of Hydrogen Sulphide is not a likely route of industrial exposure.

INHALATION: Inhalation of high concentrations of Hydrogen Sulphide can cause dizziness, headache, and nausea. Exposure to higher concentrations can result in respiratory arrest, coma, or unconsciousness. Exposure for more than 30 minutes at concentrations of greater than 600 ppm have been fatal. Continuous inhalation of low concentrations may cause olfactory fatigue, so that the odour is no longer an effective warning of the presence of Hydrogen Sulphide. Severe exposures which do not result in death may cause long-term symptoms such as memory loss, paralysis of facial muscles, or nerve tissue damage.

SKIN CONTACT: The gas may be irritating to the skin.

POTENTIAL HEALTH EFFECTS OF REPEATED EXPOSURE:

ROUTE OF ENTRY: Inhalation, skin contact

TARGET ORGANS: Respiratory system, skin, central nervous system.

SYMPTOMS: The most significant symptoms of chronic, low level exposure are related to the central nervous system, with potential nerve tissue damage. Repeated low level skin exposure may cause dermatitis.

MEDICAL CONDITIONS AGGRAVATED BY OVEREXPOSURE: Acute or chronic respiratory conditions or eye disorders may be aggravated by over-exposure to Hydrogen Sulphide.

CARCINOGENICITY: Hydrogen Sulphide is not found on Carcinogenicity lists.

Exposure via Inhalation		
<i>mg/m³</i>	<i>ppm</i>	<i>Signs and symptoms</i>
0.011	0.008	Odour threshold
2.8	2	Bronchial constriction in asthmatic individuals
5.0	4	Increased eye complaints
7 or 14	5 or 10	Increased blood lactate concentration, decreased skeletal muscle citrate synthase activity, decreased oxygen uptake
5 to 29	4 to 21	Eye irritation
28	20	Fatigue, loss of appetite, headache, irritability, poor memory, dizziness
>140	>100	Olfactory paralysis
>560	>402	Respiratory distress
≥700	≥502	Death

HYDROGEN SULPHIDE SECTION 4. FIRST AID MEASURES

EYE CONTACT: If irritation of the eye develops after exposure to Hydrogen Sulphide, open victim's eyes while under gentle, lukewarm, running water. Use sufficient force to open eyelids. Have victim "roll" eyes. Minimum flushing is for 15 minutes. Victim must seek immediate medical attention from an ophthalmologist.

INGESTION: Ingestion is an unlikely route of exposure for Hydrogen Sulphide.

INHALATION: Remove victim(s) to fresh air, as quickly as possible. Trained personnel should administer supplemental oxygen and/or cardio-pulmonary resuscitation, if necessary.

SKIN CONTACT: If irritation of the skin develops after exposure to gas, immediately begin decontamination with running water. Minimum flushing is for 15 minutes. Remove exposed or contaminated clothing, taking care not to contaminate eyes. Victim must seek immediate medical attention.

NOTES TO PHYSICIANS: Administer oxygen, if necessary and treat symptoms. Be observant for initial signs of pulmonary oedema.

HYDROGEN SULPHIDE SECTION 5. FIRE FIGHTING MEASURES

FLASH POINT:
Flammable gas

AUTOIGNITION:
500 °F (260 °C)

FLAMMABLE RANGE:
(LEL): 4.0% (UEL): 44.0%

EXTINGUISHING MEDIA: Extinguish Hydrogen Sulphide fires by shutting-off the source of the gas. Use water spray to cool fire-exposed containers, structures, and equipment. Other appropriate extinguishing media are dry chemical, foam, and carbon dioxide.

SPECIAL FIRE-FIGHTING PROCEDURES: Evacuate all personnel from area. If possible without risk, shut off source of gas, and then fight fire according to types of materials burning. Extinguish fire only if gas flow can be stopped. This will avoid possible accumulation and re-ignition of a flammable gas mixture. For small releases, if it is not possible to stop the leak, and it does not endanger personnel, let the fire burn itself out. Incipient fire responders should wear eye protection. Structural fire fighters must wear Self-Contained Breathing Apparatus and full protective equipment, including fire resistant clothing. Large fires should be fought from a distance with an unmanned hose holder or monitor nozzles. If this product is involved in a fire, fire run-off water should be contained to prevent possible environmental damage. If necessary, decontaminate fire-response equipment with soap and water solution.

UNUSUAL FIRE AND EXPLOSION HAZARDS: An extreme explosion hazard exists in areas in which the gas has been released but the material has not yet ignited.

HAZARDOUS COMBUSTION PRODUCTS: Oxides of sulphur

HYDROGEN SULPHIDE SECTION 6. ACCIDENTAL RELEASE MEASURES

STEPS TO BE TAKEN IF MATERIAL IS RELEASED: Evacuate immediate area. Eliminate any possible sources of ignition and provide maximum explosion-proof ventilation. Shut off source of leak, if possible. If leak is in user's system, close valves, safely vent pressure and purge with inert gas before attempting repairs. Protection of all personnel and the area must be maintained. All responders must be adequately protected from exposure. Monitoring should be done for the levels of Hydrogen Sulphide. Colorimetric tubes are available to detect the presence of Hydrogen Sulphide. Levels of Hydrogen Sulphide should be below levels listed in Section 2 (Composition / Information on Ingredients) and the atmosphere must have at least 19.5% oxygen before personnel can be allowed in the area without Self-contained breathing apparatus. Combustible vapour levels must be below 0.4%, which is 10% of the LEL of Hydrogen Sulphide, prior to entry.

HYDROGEN SULPHIDE SECTION 7. HANDLING AND STORAGE

STORAGE: There should be no sources of ignition. All electrical equipment should be explosion-proof in the storage areas. Flammable storage areas should be separated from oxygen and other oxidizers by a minimum distance of 20 ft. or by a barrier of non-combustible material at least 5 ft. high, having a fire resistance rating of at least 1/2 hour. Post "No Smoking or Open Flames" signs in the storage and use areas. Do not allow storage temperature to exceed 125 °F (52 °C). Consideration should be taken to install leak detection and alarm equipment for storage areas.

HANDLING: All piped systems and associated equipment must be grounded. Electrical equipment should be non-sparking or explosion-proof.

SPECIAL PRECAUTIONS: Be aware of any signs of dizziness or fatigue; exposures to fatal concentrations of Hydrogen Sulphide could occur without any significant warning symptoms. All work operations should be monitored in such a way that emergency personnel can be immediately contacted in the event of a release. All work practices should minimize the release of Hydrogen Sulphide.

HYDROGEN SULPHIDE SECTION 8. EXPOSURE CONTROLS AND PERSONAL PROTECTION

ENGINEERING CONTROLS:

VENTILATION: Hydrogen Sulphide detectors should be installed in or near areas where Hydrogen Sulphide is being used or stored. If appropriate, install automatic monitoring equipment to detect the level of oxygen and the presence of potentially explosive air-gas mixtures. Provide natural or explosion-proof ventilation adequate to ensure Hydrogen Sulphide does not reach exposure limits listed in Section 2. (Composition / Information on Ingredients). Local exhaust ventilation is preferred because it prevents gas dispersion into the work place by eliminating it at its source.

RESPIRATORY PROTECTION: Maintain exposure levels of Hydrogen Sulphide below the levels listed in Section 2 (Composition / Information on Ingredients). Use supplied air respiratory protection if Hydrogen Sulphide levels exceed exposure limits or during emergency response to a release of this product.

Emergency Use: Emergency or Planned Entry into Unknown or IDLH Concentration Conditions: Positive pressure, full-face piece SCBA; or positive pressure, full-face piece SAR with an auxiliary positive pressure SCBA. Gas mask with canister to protect against Hydrogen Sulphide; or escape-type SCBA. The ***Immediately Dangerous to Life or Health*** (IDLH) concentration for Hydrogen Sulphide is 100 ppm. High concentrations may be within the flammable range and must not be entered.

EYE PROTECTION: Safety glasses. Eye wash stations/safety showers should be near areas where Hydrogen Sulphide is used or stored.

SKIN PROTECTION: Wear chemically-resistant gloves when using this gas. Butyl rubber, chlorinated polyethylene, neoprene nitrile, and polyvinyl rubber are recommended. Use fire-resistant gloves and clothing in emergency situations. Use double gloves for spill response.

OTHER PROTECTIVE EQUIPMENT: Use body protection appropriate for task. Static-resistant clothing is recommended. Transfer of large quantities under pressure may require use of fire retardant and/or chemically impervious clothing.

HYDROGEN SULPHIDE SECTION 9. PHYSICAL AND CHEMICAL PROPERTIES

APPEARANCE, ODOUR AND STATE: Colourless gas. The liquid is also colourless. The odour for both the liquid and gas is similar to that of "rotten eggs".

MOLECULAR WEIGHT: 34.08

BOILING POINT (1 atm): -76.4 °F (-60.2 °C)

SPECIFIC GRAVITY (also called vapour density) (air = 1): 1.189

SPECIFIC GRAVITY (of liquid) (At 59 °F (15 °C)): 0.79

FREEZING/MELTING POINT: -117.2 °F (-82.9 °C)

VAPOUR PRESSURE (At 70 F (21.1 C)): 248.9 psig

GAS DENSITY (At 68 F (20 C) and 1 atm): 0.088 lb/ft³

SOLUBILITY IN WATER (At 68 F (20 C)): 0.317 lb/gal

HYDROGEN SULPHIDE SECTION 10. STABILITY AND REACTIVITY

CHEMICAL STABILITY: Stable

INCOMPATIBILITY (Materials to Avoid): Hydrogen Sulphide is a strong reducing agent and is highly reactive. Hydrogen Sulphide is not compatible with the following materials: oxidizing agents, organic peroxides, alkaline materials, metals (i.e. copper, lead), and metal oxides. Hydrogen Sulphide is corrosive to most metals, because it reacts with these substances to form metal sulphides.

REACTIVITY:**A) HAZARDOUS DECOMPOSITION PRODUCTS:** Hydrogen and sulphur**B) HAZARDOUS POLYMERIZATION:** Will not occur**HYDROGEN SULPHIDE SECTION 11. TOXICOLOGICAL INFORMATION**

LC50, TCLo, or LCLo (Inhalation): Human LCLo: 600 ppm/30 minutes; Man LDLo: 5700 mg/kg (Central Nervous System Effects, Pulmonary System Effects); Human LCLo: 800 ppm/5 minutes; Rat LC50: 444 ppm; Rat TCLo: 20 ppm (female 6-22 days post) (Reproductive Effects); Mammal LCLo: 800 ppm/5 minutes; Rat TCLo: 1200 mg/m³/2 hours/5 days-intermittent (Brain and Coverings-other degenerative changes; Biochemical - enzyme inhibition, induction, or change in blood or tissue levels - true cholinesterase); Rat TCLo: 100 ppm/8 hours/5 weeks-intermittent (Brain and Coverings - other degenerative changes; Lungs, Thorax, or Respiration - other changes; Biochemical - enzyme inhibition, induction, or change in blood or tissue levels – cytochrome oxidases (including oxidative phosphorylation)); Rat TCLo: 80 ppm/6 hours/90 days-intermittent (Brain and Coverings - changes in brain weight; Nutritional and Gross Metabolic - weight loss or decreased weight gain); Rat TCLo: 80 ppm/6 hours/90 days-intermittent (Nutritional and Gross Metabolic - weight loss or decreased weight gain; Related to Chronic Data - death); Mouse LC50: 634 ppm/1 hour; Rabbit TCLo: 40 mg/m³/5 hours/30 weeks-intermittent (Sense Organs and Special Senses (Eye) - conjunctive irritation); Rat TCLo: 20 ppm: female 6-22 day(s) after conception; lactating female 21 day(s) post-birth (Reproductive - Effects on Newborn - physical).

LD50, (Oral): No data currently available.**LD50 (Dermal):** No data currently available.**SKIN CORROSIVITY:** Hydrogen Sulphide is irritating to the skin.**CARCINOGENICITY:** Currently, Hydrogen Sulphide has not been found to be carcinogenic.**ADDITIONAL NOTES:** None**HYDROGEN SULPHIDE SECTION 12. ECOLOGICAL INFORMATION****AQUATIC TOXICITY:** Currently, the following aquatic toxicity data are available for Hydrogen Sulphide:

TLm (Asellussp) 96 hours = 0.111 mg/L

TLm (Cranfngonyx sp) 96 hours = 1.07 mg/L

TLm (Gammarrus) 96 hours = 0.84 mg/L

LC50 (fly inhalation) 960 minutes = 380 mg/m³LC50 (fly inhalation) 7 minutes = 1500 mg/m³TLm (*Lepomis macrochirus*, bluegill sunfish) 96 hours = 0.0478 mg/LTLm (*Lepomis macrochirus*, bluegill sunfish) 96 hours = 0.0448 mg/L at 21-22 °CTLm (*Pimephlaes promelas*, fathead minnow) 96 hours = 0.0071-0.55 mg/LTLm (*Salvenilis foninalis*, brook trout) 96 hours = 0.0216-0.038 mg/L at 8-12.5 °C**MOBILITY:** Hydrogen Sulphide will not be mobile in soil.**PERSISTENCE AND BIODEGRADABILITY:** Persistence: Converts to elemental sulphur upon standing in

water. Biodegradation: Microorganisms in soil and water are involved in oxidation-reduction reactions that oxidize Hydrogen Sulphide to elemental sulphur. Members of the genera *Beggiatoa*, *Thioploca*, and *Thiotrix* function in transition zones between aerobic and anaerobic conditions where both molecular oxygen and Hydrogen Sulphide are found. Also, some photosynthetic bacteria oxidize Hydrogen Sulphide to elemental sulphur. Members of the families *Chlorobiaceae* and *Chromatiaceae* (purple sulphur bacteria) are obligate aerobes and are phototropic, and are found in waters with high H₂S concentrations. The interactions of these organisms form part of the global sulphur cycle.

POTENTIAL TO BIOACCUMULATE: Hydrogen Sulphide does not have bioaccumulation or food chain contamination potential.**REMARKS:** Hydrogen Sulphide is not a Class I or Class II ozone depleting chemical (40 CFR Part 82).**HYDROGEN SULPHIDE SECTION 13. DISPOSAL CONSIDERATIONS**

Avoid discharge to atmosphere. Do not discharge into any place where its accumulation could be dangerous. Toxic and corrosive gases formed during combustion should be scrubbed before discharge to atmosphere. Do not discharge into areas where there is a risk of forming an explosive mixture with air. Waste gas should be flared through a suitable burner with flash back arrestor. Wastes containing this material may be classified as a hazardous waste by characteristic (such as ignitability, Corrosivity, Toxicity, Reactivity).

HYDROGEN SULPHIDE SECTION 14. TRANSPORT INFORMATION

SPECIAL SHIPPING INFORMATION: Hydrogen Sulphide is poisonous by inhalation. Shipments must be properly described as inhalation hazards. Never transport in passenger compartment of a vehicle. Ensure valve is properly closed.

HYDROGEN SULPHIDE SECTION 15. REGULATORY INFORMATION**HYDROGEN SULPHIDE SECTION 16. OTHER INFORMATION**

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MATERIAL SAFETY DATA SHEET

Ammonia

This data sheet has been developed from information on Material Safety Data Sheets from Air Liquide, Air Products and BOC Limited.

AMMONIA SECTION 1. PRODUCT IDENTIFICATION

PRODUCT NAME: Ammonia

CHEMICAL NAME: Ammonia

FORMULA: NH₃

AMMONIA SECTION 2. COMPOSITION / INFORMATION ON INGREDIENTS

CAS NUMBER: 7664-41-7

EXPOSURE LIMITS:

Time Weighted Average (TWA) (ACGIH): 25 ppm

Short Term Exposure Limit (STEL) (ACGIH) : 35 ppm

PPM	Effect on unprotected human body	Exposure Limits
20	Smell readily detected by most people	Unlimited
25	HSE long term exposure limit	8hrs per day 5 days per week
35	HSE short term exposure limit	15 mins per day, not more than 1 hour per week
50	Smell is distinctive and may be irritating	Do not stay longer than necessary
70	No dangerous effects on healthy people	Leave the area
400 – 700	Immediate irritation to eyes, nose, throat and respiratory system.	Under normal circumstances no serious injury in 1 hour
1700	Severe coughing, cramp, serious irritation to nose, eyes, throat and respiratory system	30 mins exposure can lead to serious injury
2000 – 5000	Severe coughing, cramp, serious irritation to nose, eyes, throat and respiratory system	30 mins exposure can lead to death
5000	Respiratory spasm, rapid asphyxia	Lethal within a few minutes

AMMONIA SECTION 3. HAZARD IDENTIFICATION

EMERGENCY OVERVIEW

Ammonia is an irritating, flammable, and colourless gas. Ammonia can cause severe eye, skin and respiratory tract burns. It poses an immediate fire and explosion hazard when concentrations exceed 15%; therefore, area must be ventilated before entering. Wear self-contained breathing apparatus (SCBA) when entering release area if concentrations exceed allowable exposure limits. Fully protective suits are required in large releases. Always be aware of fire and explosion potential in the case of large releases.

ACUTE POTENTIAL HEALTH EFFECTS:

ROUTES OF EXPOSURE:

EYE CONTACT: Exposure to Ammonia can cause moderate to severe eye irritation. Mild concentrations of product will cause conjunctivitis. Contact with higher concentrations of product will cause swelling of the eyes and lesions with a possible loss of vision.

INGESTION: Ingestion is not a likely route of exposure for Ammonia.

INHALATION: Ammonia is corrosive and severely irritating to nose, throat, lungs and all mucous type tissue. Symptoms may include burning sensations, coughing, wheezing, shortness of breath, headache, nausea and eventual collapse. Overexposure may also cause central nervous system effects including unconsciousness and convulsions. Upper airway (larynx and bronchi) damage is more likely and can result in bronchospasm (closing of the airway), oedema and chemical pneumonitis. Vocal cords are particularly vulnerable to corrosive effects of high concentrations. Lower airway damage may result in fluid build-up and haemorrhage. Pulmonary oedema and chemical pneumonitis are potentially fatal conditions. Death has occurred following a 5 minute exposure to 5000 ppm.

SKIN CONTACT: Vapour contact may cause irritation and burns. Mild concentrations of product will cause dermatitis or conjunctivitis. Contact with higher concentrations of product will cause caustic-like dermal burns and inflammation. Toxic level exposure may cause skin lesions resulting in early necrosis and scarring.

POTENTIAL HEALTH EFFECTS OF REPEATED EXPOSURE:**ROUTE OF ENTRY:** Inhalation, eye or skin contact**SYMPTOMS:** Repeated or prolonged skin exposure may cause dermatitis.**TARGET ORGANS:** Eyes, skin, central nervous and respiratory systems.**MEDICAL CONDITIONS AGGRAVATED BY OVEREXPOSURE:** Conditions generally aggravated by exposure include asthma, chronic respiratory disease (e.g., emphysema), dermatitis and eye disease.**CARCINOGENICITY:** Ammonia is not listed as a carcinogen or potential carcinogen by NTP, IARC, or OSHA.**AMMONIA SECTION 4. FIRST AID MEASURES****EYE CONTACT:** Flush eyes with large quantities of water for at least 15 minutes. Part eyelids to ensure complete flushing. Seek medical attention immediately. PERSONS WITH POTENTIAL EXPOSURE TO AMMONIA SHOULD NOT WEAR CONTACT LENSES.**INGESTION:** Ingestion is not a likely route of exposure for Ammonia.**INHALATION:** Remove person to fresh air wearing self-contained breathing apparatus. Quick removal from the contaminated area is most important. If not breathing, administer artificial respiration. Ensure that mucus or vomited material does not obstruct the airway by positional drainage. If breathing is difficult, administer oxygen. Keep victim warm and rested and obtain prompt medical attention.**SKIN CONTACT:** Remove contaminated clothing immediately. Flush affected area with large quantities of water for at least 15 minutes. If liquid comes in contact with skin, remove contaminated clothing and flush with plenty of lukewarm water for several minutes. Seek medical attention immediately.**NOTE TO PHYSICIAN:** Bronchospasm may be treated with the use of a bronchodilator such as albuterol and an anticholinergic inhalant such as Atrovent.**AMMONIA SECTION 5. FIRE FIGHTING MEASURES****FLASH POINT:**

Not applicable

AUTOIGNITION:

1204 °F-1274 °F (651 °C to 690 °C)

FLAMMABLE RANGE:

16% - 25%

The minimum ignition energy for ammonia is very high.

EXTINGUISHING MEDIA: Dry chemical, carbon dioxide or water.**SPECIAL FIRE FIGHTING INSTRUCTIONS:** Evacuate all personnel from area. If possible without risk, stop the flow of Ammonia, then fight fire according to types of materials that are burning. Extinguish fire only if gas flow can be stopped. This will avoid possible accumulation and re-ignition of a flammable gas mixture. Keep adjacent equipment cool by spraying with large amounts of water until the fire burns itself out. Self-contained breathing apparatus (SCBA) may be required.**UNUSUAL FIRE AND EXPLOSION HAZARDS:** Runoff from fire-fighting may be contaminated; check pH. Ammonia can form explosive compounds when combined with mercury.**HAZARDOUS COMBUSTION PRODUCTS:** Oxides of nitrogen (nitric oxide and nitrogen peroxide)**AMMONIA SECTION 6. ACCIDENTAL RELEASE MEASURES****STEPS TO BE TAKEN IF MATERIAL IS RELEASED:** Evacuate immediate area. Eliminate any possible sources of ignition and provide maximum explosion-proof ventilation. Shut off source of leak if possible. If the leak is in the user's system, close the gas supply, safely vent the pressure, and purge with an inert gas before attempting repairs. Ammonia vapours can be controlled with water spray, however; runoff may be contaminated. All responders must be adequately protected from exposure. Levels of Ammonia should be below levels listed in Section 2 (Composition / Information on Ingredients) and the atmosphere must have at least 19.5% oxygen before personnel can be allowed in the area without self-contained breathing apparatus (SCBA). Hose down area with water.**AMMONIA SECTION 7. HANDLING AND STORAGE****STORAGE:** Use only properly specified equipment which is suitable for this product. There should be no sources of ignition. All electrical equipment should be explosion-proof in the storage areas. Flammable storage areas should be separated from oxygen and other oxidizers by a minimum distance of 20 ft. or by a barrier of non-combustible material at least 5 ft. high having a fire resistance rating of at least ½ hour. Ammonia containers should not be stored near acids or acid-forming gases. Post "No Smoking or Open Flames" signs in the storage or use areas. Do not allow storage temperature to exceed 125°F (52°C). Storage should be away from heavily travelled areas and emergency exits.

HANDLING: Never apply flame or localized heat directly to any part of the container. Do not allow any part of the cylinder to exceed 125°F (52°C). All piped systems and associated equipment must be grounded. Electrical equipment should be non-sparking or explosion-proof. Use piping and equipment adequately designed to withstand pressures to be encountered. If liquid product is being used, ensure steps have been taken to prevent entrapment of liquid in closed systems. The use of pressure relief devices may be necessary. Dedicated inert gas cylinders with in line back-flow protection should be used for purging.

AMMONIA SECTION 8. EXPOSURE CONTROLS AND PERSONAL PROTECTION

ENGINEERING CONTROLS:

VENTILATION: Provide adequate natural or mechanical ventilation to maintain Ammonia concentrations below exposure limits.

RESPIRATORY PROTECTION:

Emergency Use: Self-contained breathing apparatus (SCBA) or positive pressure airline with full face mask with escape pack should be worn in areas of a large release or unknown concentration.

EYE PROTECTION: Safety glasses for handling cylinders. Chemical goggles with full face shield for connecting, disconnecting or opening cylinders.

SKIN PROTECTION: Leather gloves for handling cylinders. Rubber or Neoprene gloves, and chemical resistant outer garment should be worn when connecting or disconnecting cylinders. Total encapsulating chemical suit may be necessary in large release area. Fire resistant suit and gloves in emergency situations.

OTHER PROTECTIVE EQUIPMENT: Safety shoes are recommended when handling cylinders. Safety shower and eyewash fountain should be readily available. Keep suitable chemically resistant protective clothing readily available for emergency use. Keep self-contained breathing apparatus readily available for emergency use. Do not smoke while handling product.

AMMONIA SECTION 9. PHYSICAL AND CHEMICAL PROPERTIES

APPEARANCE, ODOUR AND STATE: Colourless gas with a sharp, strong odour similar to “smelling salts” which is readily detectable at 20 ppm

MOLECULAR WEIGHT: 17.0

BOILING POINT (1 atm): -28.1°F (-33.4°C)

SPECIFIC GRAVITY (air=1): 0.59

FREEZING POINT / MELTING POINT: -107.9°F (-77.7°C)

VAPOUR PRESSURE (At 70°F (21.1°C)): 114.4 psig

GAS DENSITY (At 70°F (21.1°C) and 1 atm): 0.045 lb/ft³

SOLUBILITY IN WATER (vol./vol. at 68°F): 0.848

OTHER DATA: Although this substance has flammability data, it is difficult to ignite in air and is classified as non-flammable.

AMMONIA SECTION 10. STABILITY AND REACTIVITY

CHEMICAL STABILITY: Stable

CONDITIONS TO AVOID: High temperatures (greater than 800°F (426°C)). Cylinders should not be exposed to temperatures in excess of 125°F (52°C).

INCOMPATIBILITY (Materials to Avoid): Copper, silver, cadmium and zinc and their alloys; mercury, tin, acids, alcohols, aldehydes, halogens and oxidizers.

REACTIVITY:

A) HAZARDOUS DECOMPOSITION PRODUCTS: Hydrogen at high temperatures.

B) HAZARDOUS POLYMERIZATION: Will not occur

AMMONIA SECTION 11. TOXICOLOGICAL INFORMATION

LC50 (Inhalation): 7338 - 11590 ppm (rat, 1 hour); 2000 ppm (rat, 4 hours)

LD50 (Oral): Not applicable

LD50 (Dermal): Not applicable

SKIN CORROSIVITY: Ammonia is corrosive to the skin.

ADDITIONAL NOTES: Rats exposed continuously to 180 ppm Ammonia for 90 days did not show any abnormalities of organs or tissues. Mild nasal irritation was observed in 12 out of 49 rats exposed to 380 ppm Ammonia. At 655 ppm Ammonia, 32 out of 51 rats died by day 25 of exposure and 50 out of 51 rats had died after 65 days of exposure. Toxic effects to the respiratory system, senses, liver, kidneys and bladder observed in mammalian species from prolonged inhalation exposures at above 100 ppm.

AMMONIA SECTION 12. ECOLOGICAL INFORMATION

AQUATIC TOXICITY: Currently, the following aquatic toxicity data are available for Ammonia:

Daphnia magna (48 hour) LC50 = 189 mg/l

Rainbow trout (24 hour) LC50 = 0.97 mg/l

Fathead minnow (96 hour) LC50 = 8.2 mg/l

MOBILITY: Not available

PERSISTENCE AND BIODEGRADABILITY: Not available

POTENTIAL TO BIOACCUMULATE: Not available

REMARKS: Do not release large amounts of Ammonia to the atmosphere. It does not contain any Class I or Class II ozone depleting chemicals.

AMMONIA SECTION 13. DISPOSAL CONSIDERATIONS

DISPOSAL: Small amounts of Ammonia may be disposed of by discharge into water. A ratio of ten parts water to one part Ammonia should be sufficient for disposal. The subsequent solution of ammonium hydroxide can be neutralized and should be properly disposed of in accordance with regulations. Avoid discharge to atmosphere. Do not discharge into any place where its accumulation could be dangerous. Do not discharge into areas where there is a risk of forming an explosive mixture with air. Waste gas should be flared through a suitable burner with flash back arrestor. Gas may be scrubbed in sulphuric acid solution. Gas may be scrubbed in water. Toxic and corrosive gases formed during combustion should be scrubbed before discharge to atmosphere.

AMMONIA SECTION 14. TRANSPORT INFORMATION

ADDITIONAL DESCRIPTION: Inhalation Hazard

SHIPPING LABEL(s): Nonflammable gas

PLACARD (When required): Nonflammable gas

SPECIAL SHIPPING INFORMATION: Containers should be transported in a secure upright position in a well-ventilated truck. Never transport in passenger compartment of a vehicle. Ensure valves are properly closed. Avoid transport on vehicles where the load space is not separated from the driver's compartment. Ensure vehicle driver is aware of the potential hazards of the load and knows what to do in the event of an accident or an emergency.

AMMONIA SECTION 15. REGULATORY INFORMATION**AMMONIA SECTION 16. OTHER INFORMATION**

Ensure operators understand the toxicity hazard. Users of breathing apparatus must be trained.

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Typical CHP Engine Oil

Technical Data Sheet

Previous Name: Shell Mysella MA

Shell Mysella S3 S 40

- Extra Protection
- Medium Ash Content for Four Stroke Engines

Medium Ash Gas Engine Oil

Shell Mysella S3 S is a high performance quality oil blended for use in 4-stroke, spark-ignition engines which require a 'medium ash' oil or use sour gases such as landfill, bio or sewage gas as fuel.

Shell Mysella S3 S is also suitable for engines that traditionally require a medium ash oil to protect the valve seating area of the cylinder head.

Shell Mysella S3 S satisfies the new generation of stationary gas engines designed to meet the emerging legislation limiting emissions of NO_x, and those which employ the latest 'lean' or 'clean' burn technology.

DESIGNED TO MEET CHALLENGES**Performance, Features & Benefits**

- **Extended oil life**

Significantly prolongs oil life by resisting oxidation and nitration, the high level of TBN (total base number) neutralises acids and provides corrosion protection, even when "sour" gases are in use.

- **Engine protection**

Shell Mysella S3 S is formulated with an optimised level of 'ash' components which helps prolong the life of valves in engines which prefer a medium ash oil. With a maximum phosphorus content of 300 ppm Shell Mysella S3 S is compatible with engines equipped with emission catalysts.

Main Applications

- Spark-ignited gas engines fuelled by natural gas requiring a medium ash oil
- Ideal for engines fuelled by sour gases
- "Dual-fuel" gas engines ignited by diesel pilot fuel

Specifications, Approvals & Recommendations

Shell Mysella S3 S is suitable in engine types where a "medium ash" oil is required.

Shell Mysella S3 S is Approved by:

- GE Jenbacher: Series 2, 3 Fuel Class B and C
- MAN: 3271-4
- Rolls Royce: KG-1, KG-2, KG-3 (Bio Gas Operation)
- Waukesha: Cogen Application (Pipeline Quality Natural Gas)

Shell Mysella S3 S Meets the requirement of:

- MAN: Ruston Engines (Natural Gas, Landfill/Digester gas/Biogas), Dual Fuel (Pilot Diesel)
- Wartsila: CR26

For engines under warranty, Shell advises contact with the engine manufacturer and Shell representative to choose the appropriate oil given the equipment operating conditions and customer maintenance practices.

For a full listing of equipment approvals and recommendations, please consult your local Shell Technical Help Desk.

Typical Physical Characteristics

Properties			Method	Shell Mysella S3 S 40	
SAE Viscosity Grade				40	
Kinematic Viscosity	@40°C	mm ² /s	ASTM D445	135	
Kinematic Viscosity	@100°C	mm ² /s	ASTM D445	13.5	
Density	@15°C	kg/m ³	ASTM D4052	894	
Flash Point, closed cup			°C	ASTM D93A	230
Pour Point			°C	ISO 3016	-18
BN			mg KOH/g	ASTM D2896	8.5
Sulphated Ash			%wt	ISO 3987	0.9
Phosphorus			ppm	ASTM D4047	300

These characteristics are typical of current production. Whilst future production will conform to Shell's specification, variations in these characteristics may occur.

Health, Safety & Environment

• Health and Safety

Shell Mysella S3 S is unlikely to present any significant health or safety hazard when properly used in the recommended application and good standards of industrial and personal hygiene are maintained.

Avoid contact with skin. Use impervious gloves with used oil. After skin contact, wash immediately with soap and water.

Guidance on Health and Safety is available on the appropriate Material Safety Data Sheet, which can be obtained from <http://www.epc.shell.com/>

• Protect the Environment

Take used oil to an authorised collection point. Do not discharge into drains, soil or water.

Additional Information

• Oil Analysis

For optimum results regular oil analysis is strongly recommended

• Advice

Advice on applications not covered here may be obtained from your Shell representative.

Note: this product is not designed for automotive gas engines

Appendix 6: DSEAR Overview

The Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR) were made under the Health and Safety at Work etc. Act 1974 and their main provisions came into force on 9 December 2002. The regulations implement the European Directives the Explosive Atmospheres Directive 99/92/EC (ATEX 137) and the Chemical Agents Directive 98/24/EC (CAD). DSEAR applies to all workplaces.

DSEAR like all new regulations is based on a risk assessment to workers and others due to the presence/processing of dangerous substances. Where there is a hazard leading to a risk of harm to people due to the dangerous substances having the potential to form explosive (flammable) atmospheres, protective measures must be put in place. In particular, it requires area classification, in terms of the potential to form explosive atmospheres, where suitable prevention methods are required including the provision of appropriate hazardous area equipment, implementation of suitable work systems, relevant training of workers and appropriate signs to denote hazardous areas.

The outcome is to be recorded in the Risk Assessment Record or equivalent documentation. Within classified areas any equipment within them must meet the requirements of 'ATEX 95' adopted within the UK as the *"Equipment for use in potentially explosive atmospheres regulation"*.

The main requirements of DSEAR are that employers shall:

- Carry out a risk assessment on all assets to identify where dangerous substances may be present;
- To record the significant findings of the assessment including:
 - ~ The measures to eliminate and/or reduce the identified risks as far as is reasonably practicable;
 - ~ Details of hazardous zones;
 - ~ Information to show that equipment and protective systems within these zoned areas are designed, operated and maintained with due regard to safety;
 - ~ Arrangements to deal with accidents, incidents and emergencies;
 - ~ Measures taken to inform, instruct and train employees.

The Health and Safety Executive (HSE) have produced a DSEAR Approved Code of Practice (L138) with supporting guidance on the implementation of the regulations.

Wherever practicable, plant and equipment must be designed to eliminate the risk from dangerous substances. Designers need to consider the hazards arising from the design of new or modified plant and equipment and the purpose of the risk assessment is to determine measures that will:

- Avoid or minimise the risk of spillage or release of a dangerous substance;
- Avoid the occurrence of explosive atmospheres;
- Prevent ignition of dangerous substances or explosive atmospheres;
- Prevent uncontrolled chemical reactions that can give rise to explosive atmospheres;
- Avoid the spread of fires or explosions through interconnecting plant and equipment;
- Mitigate the effect of a fire or explosion so as not to endanger people.

DSEAR recognises a hierarchy of measures to reduce risk in which elimination is regarded as the best solution and involves replacing a dangerous substance with a substance or process that eliminates the risk totally. In practice this is often difficult to achieve but replacement with a substance that is less hazardous or to design the process, so that is less dangerous, is more likely to be achievable.

Control measures can be applied to reduce the risk and shall be applied in the following priority order:

- Reduce the quantity of dangerous substances to a minimum (e.g. trade effluent control);
- Avoid or minimise releases (e.g. reduce retention time for sludge storage);
- Control releases at source (e.g. gas tight ducts and conduits);
- Prevent formation of an explosive atmosphere (e.g. use of gas detection to initiate emergency procedure);
- Collect, contain and remove any releases to a safe place (e.g. ventilation);
- Avoid ignition sources (e.g. segregation of mechanical and electrical equipment, MCC panels);
- Avoid adverse operating conditions that could lead to danger;
- Keep incompatible substances apart.

Mitigation measures should be applied depending on the risk involved and the nature of the operation including:

- Reduce the number of workers exposed to risk;
- Provide plant that is explosion resistant (i.e. plant constructed so as to withstand the overpressure likely in the event of an explosion);
- Provide explosion suppression or relief equipment (e.g. inert gas fire protection system (e.g. CO₂), pressure/vacuum relief on gas holders);
- Take measures to control or minimise the spread of fire or explosions (e.g. separation of storage areas or fire resisting structures);
- Provide suitable Personal Protective Equipment (anti-static footwear and clothing)

In general, the workplace must be designed, constructed and maintained so as to reduce risk, and have organisational measures, such as written instructions and permit to work employed, for work carried out in hazardous areas.

Flammable gas detectors can be installed at any location where there may be a risk of a release of flammable gas. The use of flammable gas detectors to monitor these applications will provide warning of a release before the concentration of gas reaches a value at which it is likely to explode. Gas monitors must be certified for the explosive atmosphere in which they may be required to operate.

For the DSEAR risk assessment, the most applicable regulations are Regulations 5, 6 & 7.

Regulation 5: Risk assessment

- (1) *Where a dangerous substance is or is liable to be present at the workplace, the employer shall make a suitable and sufficient assessment of the risks to his employees which arise from that substance.*
- (2) *The risk assessment shall include consideration of –*
- (a) the hazardous properties of the substance;*
 - (b) information on safety provided by the supplier, including information contained in any relevant safety data sheet;*
 - (c) the circumstances of the work including –*
 - (i) the work processes and substances used and their possible interactions;*
 - (ii) the amount of the substance involved;*
 - (iii) where the work will involve more than one dangerous substance, the risk presented by such substances in combination; and*
 - (iv) the arrangements for the safe handling, storage and transport of dangerous substances and of waste containing dangerous substances;*
 - (d) activities, such as maintenance, where there is the potential for a high level of risk;*
 - (e) the effect of measures which have been or will be taken pursuant to these Regulations;*
 - (f) the likelihood that an explosive atmosphere will occur and its persistence;*
 - (g) the likelihood that ignition sources, including electrostatic discharges, will be present and become active and effective;*
 - (h) the scale of the anticipated effects of a fire or an explosion;*
 - (i) any places which are or can be connected via openings to places in which explosive atmospheres may occur; and*
 - (j) such additional safety information as the employer may need in order to complete the risk assessment.*
- (3) *The risk assessment shall be reviewed by the employer regularly so as to keep it up to date and particularly if –*
- (a) there is reason to suspect that the risk assessment is no longer valid; or*
 - (b) there has been a significant change in the matters to which the risk assessment relates including when the workplace, work processes, or organisation of the work undergoes significant changes, extensions or conversions;*
and where, as a result of the review, changes to the risk assessment are required, those changes shall be made.
- (4) *Where the employer employs five or more employees, the employer shall record the significant findings of the risk assessment as soon as is practicable after that assessment is made, including in particular –*
- (a) the measures which have been or will be taken by him pursuant to these Regulations;*
 - (b) sufficient information to show that the workplace and work processes are designed, operated and maintained with due regard for safety and that, in accordance with the Provision and Use of Work Equipment Regulations 1998, adequate arrangements have been made for the safe use of work equipment; and*
 - (c) where an explosive atmosphere may occur at the workplace and subject to the transitional provisions in regulation 17(1) to (3), sufficient information to show –*
 - (i) those places which have been classified into zones pursuant to regulation 7(1);*
 - (ii) equipment which is required for, or helps to ensure, the safe operation of equipment located in places classified as hazardous pursuant to regulation 7(1);*
 - (iii) that any verification of overall explosion safety required by regulation 7(4) has been carried out; and*
 - (iv) the aim of any co-ordination required by regulation 11 and the measures and procedures for implementing it.*
- (5) *No new work activity involving a dangerous substance shall commence unless –*
- (a) an assessment has been made; and*
 - (b) the measures required by these Regulations have been implemented.*

Regulation 6: Elimination or reduction of risks from dangerous substances

- (1) Every employer shall ensure that risk is either eliminated or reduced so far as is reasonably practicable.*
- (2) In complying with his duty under paragraph (1), substitution shall by preference be undertaken, whereby the employer shall avoid, so far as is reasonably practicable, the presence or use of a dangerous substance at the workplace by replacing it with a substance or process which either eliminates or reduces the risk.*
- (3) Where it is not reasonably practicable to eliminate risk pursuant to paragraphs (1) and (2), the employer shall, so far as is reasonably practicable, apply measures, consistent with the risk assessment and appropriate to the nature of the activity or operation –*
- (a) to control risks, including the measures specified in paragraph (4); and*
 - (b) to mitigate the detrimental effects of a fire or explosion or the other harmful physical effects arising from dangerous substances, including the measures specified in paragraph (5).*
- (4) The following measures are, in order of priority, those specified for the purposes of paragraph (3)(a) –*
- (a) the reduction of the quantity of dangerous substances to a minimum;*
 - (b) the avoidance or minimising of the release of a dangerous substance;*
 - (c) the control of the release of a dangerous substance at source;*
 - (d) the prevention of the formation of an explosive atmosphere, including the application of appropriate ventilation;*
 - (e) ensuring that any release of a dangerous substance which may give rise to risk is suitably collected, safely contained, removed to a safe place, or otherwise rendered safe, as appropriate;*
 - (f) the avoidance of –*
 - (i) ignition sources including electrostatic discharges; and*
 - (ii) adverse conditions which could cause dangerous substances to give rise to harmful physical effects;**and*
 - (g) the segregation of incompatible dangerous substances.*
- (5) The following measures are those specified for the purposes of paragraph (3)(b) –*
- (a) the reduction to a minimum of the number of employees exposed;*
 - (b) the avoidance of the propagation of fires or explosions;*
 - (c) the provision of explosion pressure relief arrangements;*
 - (d) the provision of explosion suppression equipment;*
 - (e) the provision of plant which is constructed so as to withstand the pressure likely to be produced by an explosion; and*
 - (f) the provision of suitable personal protective equipment.*
- (6) The employer shall arrange for the safe handling, storage and transport of dangerous substances and waste containing dangerous substances.*
- (7) The employer shall ensure that any conditions necessary pursuant to these Regulations for ensuring the elimination or reduction of risk are maintained.*
- (8) The employer shall, so far as is reasonably practicable, take the general safety measures specified in Schedule 1, subject to those measures being consistent with the risk assessment and appropriate to the nature of the activity or operation.*

Regulation 7: Places where explosive atmospheres may occur

- (1) Every employer shall classify places at the workplace where an explosive atmosphere may occur into hazardous or non-hazardous places in accordance with paragraph 1 of Schedule 2 and shall classify those places so classified as hazardous into zones in accordance with paragraph 2 of that Schedule; and that Schedule shall have effect subject to the notes at the end of that Schedule.*
- (2) The employer shall ensure that the requirements specified in Schedule 3 are applied to equipment and protective systems in the places classified as hazardous pursuant to paragraph (1).*
- (3) Where necessary, places classified as hazardous pursuant to paragraph (1) shall be marked by the employer with signs at their points of entry in accordance with Schedule 4.*
- (4) Before a workplace containing places classified as hazardous pursuant to paragraph (1) is used for the first time, the employer shall ensure that its overall explosion safety is verified by a person who is competent in the field of explosion protection as a result of his experience or any professional training or both.*
- (5) The employer shall ensure that appropriate work clothing which does not give rise to electrostatic discharges is provided for use in places classified as hazardous pursuant to paragraph (1).*

Appendix 7: Principles of Hazardous Area Classification

A7.1 Introduction

Hazardous area classification is a means of describing the risk posed by a hazardous area with regards to explosion or fire. The approach is to reduce to an acceptable minimum level the probability of coincidence of an explosive atmosphere and an ignition source (electrical or non-electrical equipment). This objective is achieved by dividing or classifying a plant into zones, which take into account the likelihood of the existence of an explosive atmosphere. This classification provides a basis for the selection of mechanical and electrical apparatus that is protected to a degree appropriate to the risk involved and the nature of the flammable material. When the hazardous areas of a plant have been classified, the remainder will be defined as a non-hazardous or safe area.

Electrical equipment should be located in non-hazardous areas wherever practicable. However, it is recognised that excluding equipment from hazardous areas may not always be practical. It should also be noted that, sources of ignition other than electrical may be present and precautions will be necessary to prevent such sources compromising hazardous areas.

In applying area classification to a plant, it is a prerequisite that the facilities to which it is applied are designed, constructed, maintained and operated in accordance with good practice, so that releases of flammable materials are minimised.

A7.2 Hazardous areas

A hazardous area is an area in which an explosive gas atmosphere is present, or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of electrical apparatus and other sources of ignition. Traditionally when dealing with area classification, a three dimensional volume in space has been described as an area.

Hazardous areas are subdivided into zones, based on the likelihood and persistence of a flammable gas/air mixture being present:

- Zone 0 that part of a hazardous area in which an explosive gas atmosphere is continuously present or present for long periods.
- Zone 1 that part of a hazardous area in which an explosive gas atmosphere is likely to occur periodically or occasionally in normal operation.
- Zone 2 that part of a hazardous area in which an explosive gas atmosphere is not likely to occur in normal operation and if it occurs it will only exist for a short period.

The extent of a zone is the distance in any direction (vertically and horizontally) from the source of release to the point where the explosive atmosphere has been diluted by air to a value below the lower explosive limit.

An area which is not classified as a hazardous area is classified as a non-hazardous (or safe) area. Note, that it may, in part or whole, form part of a wider restricted area within a plant in which all work is carried out under control. There may, also, be other hazards present such as those of a toxic nature.

In addition to the definition of zones, area classification, also, defines grades of release of flammable material according to their expected frequency and duration:

- Continuous Grade Release - a release that is continuous, or nearly so, or one of relatively short duration that occurs frequently.
- Primary Grade Release - a release that is likely to occur periodically or occasionally in normal operation.
- Secondary Grade Release - a release that is unlikely to occur in normal operation and, in any event, will do so only infrequently and for short periods.

Grade of release is dependent solely on the frequency and duration of the release. It is completely independent of the rate and quantity of the release, the degree of ventilation or the characteristics of the fluid.

Assessment of the grade of release is not always obvious and requires experience and operational judgement. This is especially so for intermittent and irregular operations, such as venting, draining, sampling and opening up of equipment (e.g. changing of spades, filter cleaning, etc.).

It has been recommended for continuous or batch operated plant that releases should be regarded as:

- Continuous - release which is continuous or is expected to occur frequently or for long periods (release likely to be present for more than 1000 hours per year).
- Primary - release which can be expected to occur periodically or occasionally during normal operation (release likely to be present for 10 hours or more per year, but less than 1000 hours).
- Secondary – release which is not expected to occur in normal operation and, if it does occur, is likely to do so only infrequently and for short periods (release likely to be present for less than 10 hours per year and for short periods only).

Under unrestricted open air conditions (i.e. a high standard of ventilation exists), there is a direct relationship between grade of release and resultant zone type, namely:

- Continuous grade leads to Zone 0.
- Primary grade leads to Zone 1.
- Secondary grade leads to Zone 2.

It must be noted that grade of release and zone are not synonymous. Poor ventilation may require the application of a more stringent zone due to persistence of the flammable material. Some sources may have a dual grade of release with a small continuous or primary grade and a larger secondary grade. It should be noted that whilst a Zone 1 area may often be surrounded by a larger Zone 2 area, there is no specific requirement for this. The potential for any large, but infrequent release (e.g. a PRV relieving under abnormal operation), must be considered carefully to identify the requirement for a larger Zone 2 area.

A7.3 Ventilation

The size and type of a Hazardous Area are very dependent upon the degree and availability of ventilation in the area. The effectiveness of the ventilation in controlling dispersion and persistence of the explosive gas atmosphere will depend upon the degree of dilution, availability of ventilation and the design of the system. For example, ventilation may not be sufficient to prevent the formation of an explosive gas atmosphere but may be sufficient to avoid its persistence.

The most important factor is that the degree of dilution or amount of ventilation is directly related to the types of sources of release and their corresponding release rates. This is irrespective of the type of ventilation, whether it is wind speed or the number of air changes per time unit. Thus optimal ventilation conditions in the hazardous area can be achieved, and the higher the amount of ventilation in respect of the possible release rates, the smaller will be the extent of the zones (hazardous areas), in some cases reducing them to a negligible extent (non-hazardous area).

With increased ventilation, the extent of the zone will normally be reduced. Obstacles which impede the ventilation may increase the extent of the zone. On the other hand, some obstacles, for example, dykes, walls or ceilings, may limit the extent. Ventilation can be accomplished by the movement of air due to the wind and/or by temperature gradients or by artificial means such as fans.

So two main types of ventilation are thus recognised (i.e. section A7.3.1 & A7.3.2)

A7.3.1 Natural Ventilation

This is a type of ventilation which is accomplished by the movement of air caused by the wind and/or by temperature gradients. In open air situations, natural ventilation will often be sufficient to ensure dispersal of any explosive gas atmosphere which arises in the area. Natural ventilation may also be effective in certain indoor situations (for example, where a building has openings in its walls and/or roof). For outdoor areas, the evaluation of ventilation should normally be based on an assumed minimum wind speed of 0.5 m/s, which will be present virtually continuously. In many places the wind speed will frequently be above 2 m/s. However, in particular situations, it may be below 0.5 m/s (for example, at the immediate surface of the ground). In this case a wind speed of approximately 0.5 m/s will provide an air exchange rate of more than 100/h (0.03/s).

A7.3.2 Artificial ventilation, general or local

The air movement required for ventilation is provided by artificial means, for example, fans or extractors. Although artificial ventilation is mainly applied inside a room or enclosed space, it can also be applied to situations in the open air to compensate for restricted or impeded natural ventilation due to obstacles. The artificial ventilation of an area may be either general or local and, for both of these, differing degrees of air movement and replacement can be appropriate. With the use of artificial ventilation it is possible to achieve reduction in the type and/or extent of zones; shortening of the time of persistence of an explosive gas atmosphere and prevention of the generation of an explosive gas atmosphere.

A7.4 Degree of Dilution

The degree of dilution is a measure of the ability of ventilation or atmospheric conditions to dilute a release to a safe level and depends not only on the ventilation, but also on the nature and the type of the expected release of gas.

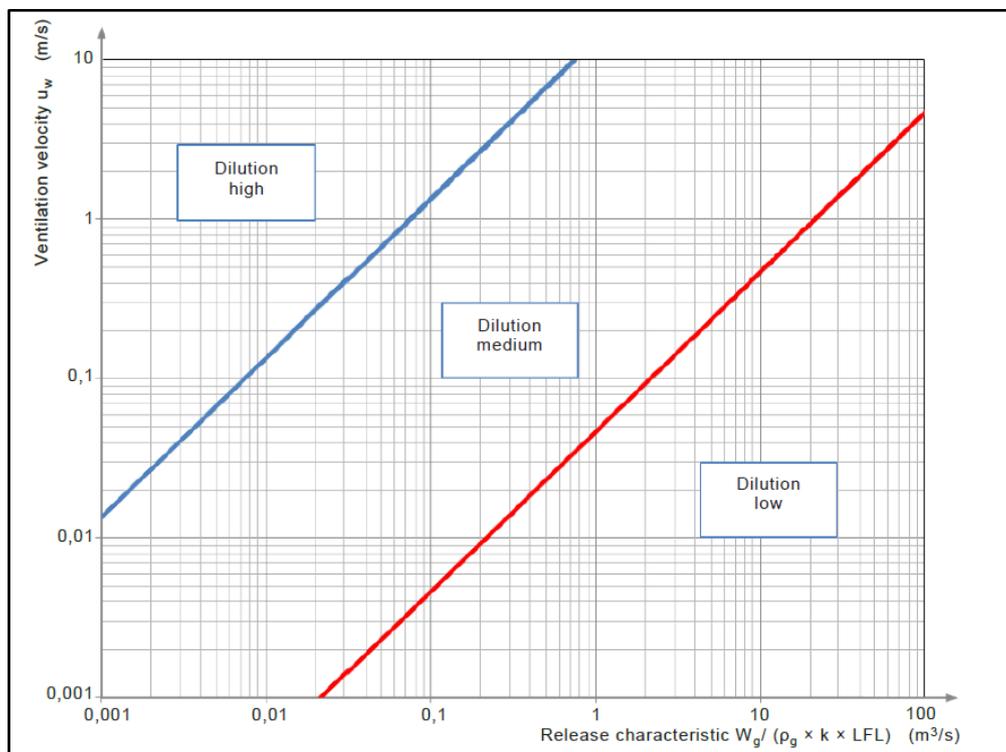
The following three degrees of dilution are recognised:

High Dilution - can reduce the concentration at the source of release quickly and there will be virtually no persistence after the release has stopped.

Medium Dilution - Medium dilution can control the concentration, resulting in a stable zone boundary, whilst the release is in progress, and where the explosive gas atmosphere does not persist unduly after the release has stopped.

Low Dilution - Low dilution cannot control the concentration whilst release is in progress and/or cannot prevent undue persistence of a flammable atmosphere after release has stopped.

The degree of dilution may be assessed by using the chart from BS EN 60079-10-1:2015.



The availability of ventilation has an influence on the presence or formation of an explosive gas atmosphere and thus also on the type of zone. As availability, or reliability, of the ventilation decreases the type of zone is normally increased.

Three levels of availability of the ventilation should be considered:

- good: ventilation is present virtually continuously;
- fair: ventilation is expected to be present during normal operation. Discontinuities are permitted provided they occur infrequently and for short periods;
- poor: ventilation which does not meet the standard of fair or good, but discontinuities are not expected to occur for long periods.

Ventilation that does not even meet the requirement for poor availability must not be considered to contribute to the ventilation of the area.

The effect of ventilation and dilution on the type of zone can be summarised in the table below:

Grade of release	Effectiveness of Ventilation						
	High Dilution			Medium Dilution			Low Dilution
	Availability of ventilation						
	Good	Fair	Poor	Good	Fair	Poor	Good, fair or poor
Continuous	Non-hazardous (Zone 0 NE) ^a	Zone 2 (Zone 0 NE) ^a	Zone 1 (Zone 0 NE) ^a	Zone 0	Zone 0 + Zone 2	Zone 0 + Zone 1	Zone 0
Primary	Non-hazardous (Zone 1 NE) ^a	Zone 2 (Zone 1 NE) ^a	Zone 2 (Zone 1 NE) ^a	Zone 1	Zone 1 + Zone 2	Zone 1 + Zone 2	Zone 1 or zone 0 ^c
Secondary^b	Non-hazardous (Zone 2 NE) ^a	Non-hazardous (Zone 2 NE) ^a	Zone 2	Zone 2	Zone 2	Zone 2	Zone 1 and even Zone 0 ^c

^a Zone 0 NE, 1 NE or 2 NE indicates a theoretical zone which would be of negligible extent under normal conditions.

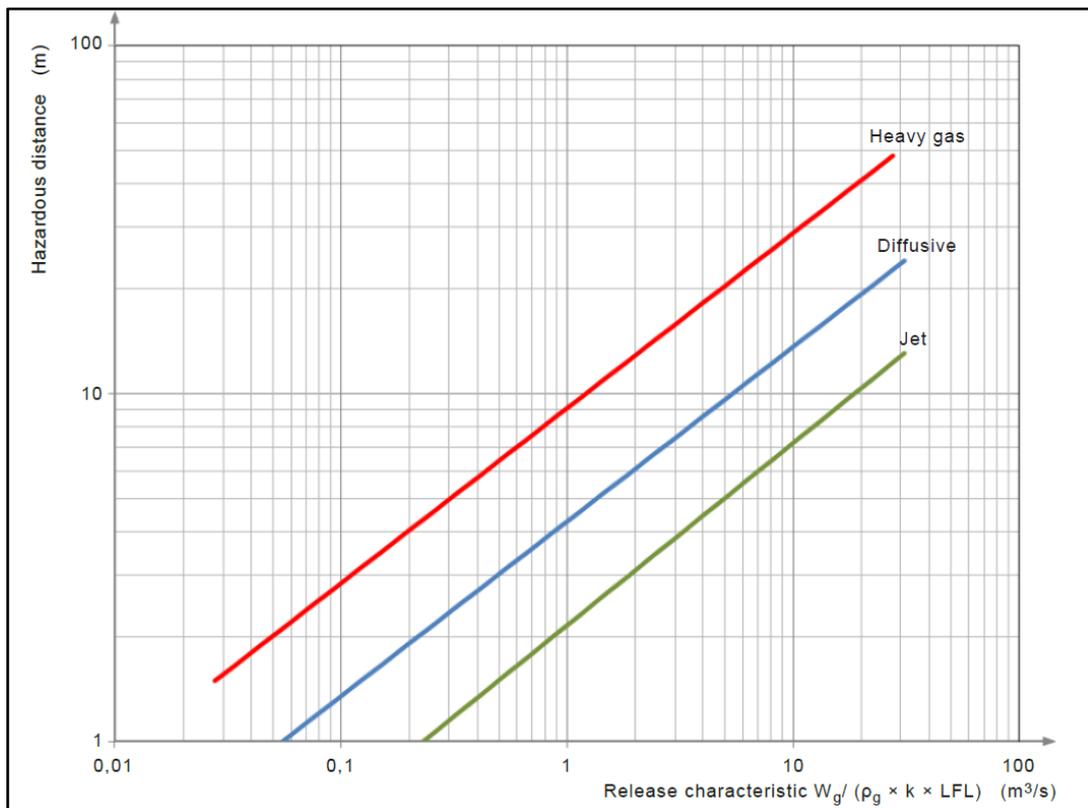
^b The zone 2 area created by a secondary grade of release may exceed that attributable to a primary or continuous grade of release; in this case, the greater distance should be taken.

^c Will be zone 0 if the ventilation is so weak and the release is such that in practice an explosive gas atmosphere exists virtually continuously (i.e. approaching a 'no ventilation' condition).

'+' signifies 'surrounded by'.

Availability of ventilation in naturally ventilated enclosed spaces shall never be considered as good.

The Zone of extent can be determined by calculation or using calculation or assessment based on reputable sources, e.g. Computational fluid dynamics (CFD). The chart below from BS EN 60079-10-1:2015 may also be used as a guide to determine the extent of hazardous zones for various forms of release.



For low pressure gas releases, the Scottish Water document 'Guidance For The Assessment and Zoning of Hazardous Areas Version 2.1' quotes three possible equations for the extent of the Hazardous Area or Zone as follows:

- for a gas leak under pressure e.g. a pipework flange, valve gland or vent, at pressures up to 500 mbar(g):

$$X = 0.068 \times (A\sqrt{P_1})^{0.55}$$

Where:

A = leak area (mm²)

P_1 = gauge pressure in mbar

X = dispersion distance (m)

- for a gas leak at pressures above 1 bar(g):

$$X = 0.365 [A((P_1 / 1000) + 1)]^{0.55}$$

Where the variables are as above.

- for gas dispersion from a low velocity release:

$$X = \left(\frac{42300 \times Q_g \times f}{M \times E \times w} \right)^{0.55} \times 1.2$$

where:

X = dispersion distance (m)

Q_g = gas flow rate (kg/s)

E = lower explosive limit of flammable gas (%vol)

f = air exchange effectiveness factor

M = molecular weight of gas or vapour

w = wind speed (0.5m/s for a low level point source, 1.0m/s for high level point source)

Notes:

- 1) the above equations only apply when the resulting dispersion distance does not touch the ground or other substantial boundary.
- 2) Calculation of the dispersion distance from ventilation openings is unnecessary for a high degree of ventilation.
- 3) For gas leaks at pressures between 500 mbar(g) and 1 bar(g) the dispersion distance must be interpolated.

These equations consider the Ventilation Influence on Zone Extent and take into account the plant arrangement with respect to the grade of release and ventilation available. They determine the effect of ventilation with respect to the source geometry and release velocity.

A7.4 Dusts

Dusts if mixed with air at the right concentration and ignited could result in a dust explosion.

A dust explosion can only take place if a number of conditions are simultaneously satisfied:

- The dust must be explosible;
- The dust must have a particle size distribution that will allow the propagation of flame;
- The atmosphere into which the dust is dispersed as a cloud or suspension must contain sufficient oxidant to support combustion;
- The dust cloud must have a concentration within the explosible range;
- The dust cloud must be in contact with an ignition source of sufficient energy to cause an ignition.

To quantify the potential of a dust explosion, dusts are tested, and the explosive properties are measured. The following dust flammability properties are required to assess the risk from dust explosions:

- **K_{st}**, this is the rate of pressure rise that may occur in a restricted space explosion e.g. the dust collection bin/duct work.
- **P_{max}**, this the potential maximum pressure that may occur in a restricted space explosion e.g. the dust collection bin/duct work. This will determine if explosion relief/suppression is required to alleviate the likelihood of the vessel disintegrating.
- **The Minimum Ignition Temperature (MIT)**, there are two values associated with dusts: a) dust cloud & b) dust layer. This value is required to identify any potential ignition sources that may initiate ignition e.g. rotating equipment /motors.
- **The Minimum Ignition Energy (MIE)**, is the energy required to ignite a flammable dust cloud e.g. static generated by material transport equipment/mobile radios/clothing.
- **The Minimum Explosive Concentration (MEC)**, is the lowest concentration of dust cloud that will allow combustion.

Explosive dusts are grouped according to the maximum pressure (P_{max}) and the rate of pressure rise that may occur (K_{st}). The explosive dust classifications are:

Grouping	K _{st} value	Description
ST class 0	0	Not explosible
ST class 1	less than 200 bar m/sec	Slow explosion, but these can still be very destructive - 80% of explosible dusts fall in this group
ST class 2	between 200 and 300 bar m/sec	Medium speed explosion
ST class 3	greater than 300 bar m/sec	Very high speed explosion, this group includes mainly metal dusts

Dust clouds in the explosive region (above the minimum explosible concentration) are categorised into 3 zones, based upon the grade of release:

Zone 20: Continuous release inside a dust containment enclosure gives rise to Zone 20 - a place in which an explosive atmosphere, in the form of a cloud of combustible dust in air, is present continuously, or for long periods or frequently for short periods. For example, a mill.

Zone 21: Primary grade of release gives rise to Zone 21 - a place in which an explosive atmosphere, in the form of a cloud of combustible dust in air, is likely to occur occasionally in normal operation. For example, bagging points and inspection ports that are frequently opened.

Zone 22: Secondary grade of release gives rise to Zone 22 - a place in which an explosive atmosphere, in the form of a cloud of combustible dust in air, is not likely to occur in normal operation but, if it does occur, will persist for a short period only. For example, leaks from incorrectly fitted lids or spillages.

Appendix 8: Applicable Hazardous Area Classification Standards

The standards normally used in the UK for the determination of Hazardous Areas due to flammable liquids, vapours mists are:

- **BS EN 60079-10-1: 2015:** Explosive Atmospheres – Part 10-1; Classification of areas – Explosive Gas Atmospheres.
Supported by **UK HSE ACOP L138 Ed 2**
- **BS EN 60079-20:2010** Electrical apparatus for explosive gas atmospheres – Part 20: Data for flammable gases and vapours, relating to the use of Electrical Apparatus.
- **IGEM/SR/25 Edition 2** (Institution of Gas Engineers and Managers)
- **EI15: 2015 4th Edition:** Energy Institute EI Model Code of Practice Part 15 Area classification for installations handling flammable fluids

The standard normally used in the UK for the determination of Hazardous Areas due to flammable dusts is:

- **BS EN 60079-10-2: 2015:** Explosive Atmospheres – Part 10-1; Classification of areas – Explosive Dust Atmospheres.

Appendix 9: Useful Publications

Other useful publications include:

- BS EN 61241-10-2 Electrical apparatus for use in the presence of combustible dust – Part 10: Classification of areas where combustible dusts are or maybe present.
- HSE Book - Safe Handling of Combustible Dusts (HSG 103): Precautions against explosions.
- CFD Modelling of Low Pressure Jets for Area Classification – HSL/2005/11 – Health and Safety Laboratory.
- HSE Guidance: Hazardous Area Classification and Laboratory Operations – Health and Safety Executive (<http://www.hse.gov.uk/electricity/atex/classification.htm>)
- HSE Technical Measures Document - Hazardous Area Classification and Control of Ignition Sources (<http://www.hse.gov.uk/comah/sragtech/techmeasareaclas.htm>)
- The American National Fire Protection Association (NFPA) practice for the classification of flammable liquids, gases, or vapours of hazardous locations for electrical installations in chemical process areas (NFPA 497).
- API RP 500 Recommended practice for classification of locations for electrical installations at Petroleum facilities.
- HSE Guidance Document: HSG51 (2nd Edition): The storage of flammable liquids in containers
- Thames Water Utilities Limited Document Reference TWUL/E04 entitled 'Standard Practice Document E04, Zoning of Hazardous Areas, and Issue 4.0' dated May 2009.
- Scottish Water Document Reference: SSP-SP-GUI-02000204 entitled 'Guidance for the Assessment and Zoning of Hazardous Areas Version 2.1' dated January 2009.
- Dŵr Cymru Welsh Water DSEAR Handbook Version 19.1 (May 2020)