DSEAR IMPLEMENTATION

FOR THE WASTE MANAGEMENT INDUSTRY

INDUSTRY CODE OF PRACTICE

ESA ICoP 1, Edition 1: Nov. 2005

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FOREWORD

James Barrett, Head of the Manufacturing Sector of the Health and Safety Executive.

This code has been prepared by the Environmental Services Association in consultation with the Health and Safety Executive and has been endorsed by the Waste Industry Safety and Health (WISH) Forum which represents the interests of the industry.

This Code should not be regarded as an authoritative interpretation of the law, but if you follow the advice set out in it you will normally be doing enough to comply with health and safety law in respect of those specific issues on which the Code gives advice. Similarly, Health and Safety Inspectors seeking to secure compliance with the law may refer to this Guidance as illustrating good practice.

The HSE believes that the contents of this Code demonstrate good practice in the waste management industry and commends its use.

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This Industry Code of Practice was prepared by the following members of the Steering Group representing the waste management industry and external consultants:

Andrew Cox	EnerG Natural Power Limited, EnerG House, Daniel Adamson Road, Salford, Manchester M50 1DT
David Holton	Sira Certification, Eccleston, Chester CH4 9JN
Marian Kelly	Environmental Services Association (ESA)
Peter Murdoch	Sira Certification, Eccleston, Chester CH4 9JN
Paul Rogers	for Biffa Waste Services Limited, Cressex Head Office, Coronation Road, Cressex Business Park, High Wycombe, HP12 3TZ
Neil Taylor	Viridor Waste Management, Great Western House, Station Approach, Taunton, TA1 1QW
Ian Walker	Technical Manager, Sita Power, SITA UK, Packington House, Packington Lane, Little Packington, Meriden, Coventry CV7 7HN

Contributions from the following persons and/or bodies are gratefully acknowledged:

-	ESA Executive Committee
-	ESA Landfill, Pre-Treatment and Logistics Committee
-	Health and Safety Executive
Stuart Hayward-Higham	SITA UK Limited; Chair of ESA Working Group
Chris Parry	Biffa waste Services Limited; ESA Working Group
Dick Turner	Viridor Waste Management; ESA Working Group

In this report, footnotes are indicated with a letter [A] and endnotes (references to documents used) with a number [1].

1 SCOPE OF THIS DOCUMENT

This is a top-level document that introduces in general terms the requirements of DSEAR[1] (see section 2.2). The detailed requirements on how to comply with the more far-reaching regulation are contained in a number of subsidiary documents that are referred to as 'Industry Codes of Practice' (ICoPs). Those regulations that are more straightforward are fully covered in this document – see section 2.5.

The ICoPs are listed in section 2.5 and cover the main operations undertaken by the waste management industry. It is intended that more will be added to include the less commonly-encountered activities.

It is intended that the ICoPs will be sufficiently detailed to enable the Site/Facility Manager on any waste management industry site to undertake an assessment of the site and bring it into compliance with the legislation. The Site/Facility Manager has overall responsibility for compliance, but may decide to delegate responsibility to another person or a team; in some cases, third party assistance may be sought.

2 APPLICABLE LEGISLATION

2.1 The ATEX directives

There are two ATEX Directives. 'ATEX' stands for '<u>AT</u>mosphere <u>EX</u>plosible', so the two ATEX Directives are concerned with explosive atmospheres. These may arise from flammable gases, vapours, mists or dusts mixed with air in a proportion that means they can explode if ignited. Examples include:

- ♦ landfill gas and air;
- ♦ petrol vapour and air;
- ♦ metal dust and air.

The two directives are:

1 ATEX 94/9/EC Directive[2], the ATEX 'Product' Directive, concerned with the manufacture of equipment and protective systems designed for use in potentially explosive atmospheres';

2 ATEX 1999/92/EC Directive[3], the Worker Protection Directive (also known as the 'ATEX 137' Directive), concerned with the "minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres".

2.2 DSEAR

Member States of the European Union were required to implement both ATEX Directives with national regulations by 1 July 2003. In the UK, the ATEX Worker Protection Directive was implemented by means of the Dangerous Substances and Explosive Atmospheres Regulations (DSEAR), which were issued in December 2002 but which became mandatory on 1 July 2003. However, DSEAR includes a transition period, ending 30 June 2006, to enable existing plants to be brought into compliance. New plants must be immediately compliant with DSEAR before they become operational.

The ATEX Worker Protection Directive overlaps with the ATEX Product Directive with respect to the equipment to be installed in new plant. As well as including all the requirements of the ATEX Worker Protection Directive, DSEAR also includes those aspects of the Chemical Agents Directive 98/24/EC that deal with flammable risks.

DSEAR defines a "dangerous substance" as:

- ♦ a substance or preparation which meets the criteria in the approved classification and labelling guide[4] for classification as a substance or preparation which is explosive, oxidising, extremely flammable, highly flammable or flammable, whether or not that substance or preparation is classified under the CHIP Regulations[5];
- ♦ a substance or preparation which because of its physio-chemical or chemical properties and the way it is used or is present in the workplace creates a risk, not being a substance or preparation as defined above;
- ♦ any dust, in the form of solid particles, fibrous materials or otherwise which can form an explosive mixture with air or an explosive atmosphere, not being a substance or preparation as defined above.

It is clear from these definitions that the waste management industry falls under the scope of DSEAR. The primary 'dangerous substance' in the waste management industry is landfill gas, produced by the decomposition of organic matter and often subsequently used to generate power. However, the diversity of the waste management industry means that numerous other flammable materials are handled – in some cases, the identity of the material may not even be known.

2.3 Exclusions from DSEAR

Note that the flammable material must be mixed with air to form a potentially explosive atmosphere. Substances that are technically 'explosives' (such as 'Semtex', nitroglycerine, etc.) do ***not*** come under the definition of a potentially explosive atmosphere, since no air is required for an explosive mixture to occur. Explosives are subject to other legislation and will not be discussed further.

The ATEX Directives are concerned with potentially explosive atmospheres rather than fires. Therefore, materials such as paper, wood, coal, plastic and other solids that can catch fire but cannot give rise to an explosion are not within the scope of DSEAR. There is, however, overlap: for example, a leak of landfill gas from a faulty joint will mix with air and form a potentially explosive atmosphere, but if it is ignited, there will not be an explosion if the leak is outdoors (although in a confined area, an explosion might occur).

There are some aspects of the waste management industry that are specifically excluded from compliance with certain parts of DSEAR. Regulation 3(2) lists these. Because other directives or safe operational procedures apply to such activities, regulations 5(4)(c) (suitable equipment, verification of safety), 7 (area classification, marking with signs and provision of personal protective equipment) and 11 (duty of co-ordination) of DSEAR do not apply to:

(a) areas used directly for and during the medical treatment of patients;

(b) the use of gas appliances burning gaseous fuel (that is to say, any fuel which is in a gaseous state at a temperature of 15°C under a pressure of 1 bar) which:

> (i) are used for cooking, heating, hot water production, refrigeration, lighting or washing; and
>
> (ii) have, where applicable, a normal water temperature not exceeding 105°C including forced draught burners and heating bodies to be equipped with such burners but not including an appliance specifically designed for use in an industrial process carried out on industrial premises;

(c) gas fittings located in domestic premises;

(d) the manufacture, handling, use, storage and transport of explosives or chemically unstable substances;

(e) any activity at a mine;

(f) any activity at a quarry;

(g) any activity at a borehole site[A];

(h) any activity at an offshore installation carried out for the purposes of the offshore installation; and

(i) means of transport, apart from fork-lift trucks.

2.4 Summary of DSEAR

The major duties associated with DSEAR compliance are found in the following regulations

- Regulation 5: risk assessment – see section 5
- Regulation 6: elimination or reduction of risk – see section 6
- Regulation 7: area classification, – see section 7
- Regulation 8: Accidents, incidents and emergencies – see section 8
- Regulation 9: Training and information – see section 9
- Regulation 10: identification of containers and pipes – see section 10
- Regulation 11: duty of co-ordination – see section 11

DSEAR is concerned with protection against risks from fire and explosion arising from dangerous substances used or present in the workplace. A workplace is defined as any premises or part of premises used for or in connection with work. DSEAR thus impacts on many aspects of the waste management industry and must

[A] This exclusion covers the mineral extraction industry, for which other regulations apply; drilling wells is not excluded from DSEAR.

be applied wherever flammable gases, liquids, mists and dusts may be present in such quantities that could cause a risk to workers' health.

The ATEX Worker Protection Directive requires a so-called 'Explosion Protection Document' (EPD) to be produced to bring together in a single document all the various aspects of compliance with the Directive. DSEAR does not specifically make reference to an EPD, but does require that documentation exists to detail significant findings of the explosion risk assessment and to demonstrate organisational arrangements. However, it is recommended that an EPD is produced. This need not, however, repeat risk assessments undertaken under other legislation such as COSHH[6] and the MHSW Regulations[7], but merely reference the appropriate documents. The EPD must be produced before the commencement of work and revised when changes occur in the workplace or organisation of work. For existing activities, the deadline is 30 June 2006.

2.5 Where to go for further guidance

The Health & Safety Executive has produced a number of 'Approved Codes of Practice ('ACoPs). The main ACoP, which includes all aspects of DSEAR compliance, is L138[8]. However, L133[9], L134[10], L135[11], L136[12] and L137[13] amplify certain key aspects and give more detailed information than that contained in L138.

This ICoP provides guidance on

- Regulation 9: information, instruction and training (section 9)
- Regulation 10: identification of hazardous contents of containers and pipes (section 10)
- Regulation 11: duty of co-ordination (section 11)

DSEAR regulations 1 to 4 and 12 to 17 have few or no additional requirements[B].

A range of guidance is currently available or in preparation for waste management and waste management related activities, including:

Activity	Guidance
Landfill gas management: area classification	ESA Industry Code of Practice 2 (ICoP 2): Area classification of landfill gas extraction, utilisation and combustion (November 2005)
Leachate management: area classification	ESA Industry Code of Practice 3 (ICoP 3): Area classification for leachate activities (publication due January 2006)
Drilling activities on landfill	ESA Industry Code of Practice 4 (ICoP 4) - to be developed
Landfill operations	ESA Industry Code of Practice 5 (ICoP 5) - to be developed
Treatment operations	ESA Industry Code of Practice 6 (ICoP 6) - to be developed
Solid waste non-destructive facilities	ESA Industry Code of Practice 7 (ICoP 7) - to be developed

3 OVERVIEW OF OPERATIONS WITHIN THE WASTE MANAGEMENT INDUSTRY

3.1 Landfill

Landfill activities involve the development of land to deposit waste in a environmentally safe manner. The waste is usually deposited in separate cells which are filled with compacted waste materials that are progressively covered and then sealed with a permanent cap. Biodegradable materials degrade to release landfill gas which is mainly composed of methane and carbon dioxide. This landfill gas is increasingly collected for combustion and energy conversion.

Decomposition of waste and the passage of water through the waste gives rise to leachate - a mixture of organic degradation products, liquid wastes and rainwater. Leachate is extremely variable in composition, depending on the nature of the waste in the landfill, the landfill design, etc. Leachate is collected in a network of pipes, removed from the landfill and treated.

B Regulations 1 and 2 are general in nature. Regulation 3 lists the exclusions already covered in section 2.3 of this document. Regulation 4 contains general duties that are further amplified in the regulations that follow. Regulations 12 to 16 have no specific requirements. Regulation 17 contains the provision to allow until 30 June 2006 for full compliance for plant that was already operational on 30 June 2003.

3.2 Thermal treatment

Thermal treatment technologies include incineration (energy from waste plants) and Advanced Conversion Technologies such as anaerobic digestion, gasification and pyrolysis. These technologies use a variety of processes to convert the waste into energy and/or by-product fuels for use in associated power generation activities.

3.3 Civic Amenity sites

Civic Amenity sites are controlled areas where the public delivers waste to directly. The waste accepted varies from site to site but typically includes bulky household items and material for recycling. Civic Amenity sites often also collect hazardous, explosive and flammable materials.

3.4 Transfer stations

Transfer stations are facilities where waste or recyclable materials from separate collection vehicles are combined into loads for transportation to waste treatment or disposal facilities. The waste or recyclable material may be compacted or bulked before transportation.

3.5 Waste support facilities

A number of facilities support waste management operations which may come under the requirements of DSEAR including motor vehicle workshops, spray booths, etc.

4 TIMETABLE FOR THE IMPLEMENTATION OF DSEAR

4.1 Arrangements for workplaces in use on or before 30 June 2003

Requirement	**When**	**Action**
Equipment and protective systems already in use/available at the workplace	By 30 June 2006*	Review equipment/protective systems against risk assessment requirements in regulation 5 of DSEAR. Equipment/protective systems at the workplace can continue to be used provided that the assessment indicates it is safe to do so.
Classification and zoning of hazardous areas	By 30 June 2006*	Classify places into hazardous and non-hazardous places and zone hazardous places in accordance with regulation 7(1) of DSEAR. However, places may need to be classified before this date if equipment available for the first time after 30 June 2003 is to be used there.
Marking hazardous places	By 30 June 2006*	Provide any signs required by regulation 7(3)/Schedule 4 of DSEAR. If the part of the workplace to be marked is modified after 30 June 2003, but before 30 June 2006, regulation 17(3) of DSEAR requires that signs are provided from the date of the modification.
Provision of work clothing	By 30 June 2006*	Provide antistatic work clothing as required by regulation 7(5) of DSEAR. However, if the part of the workplace in which it is to be worn is modified before this date it should be provided from the date of the modification.
Co-ordination of explosion protection measures	By 30 June 2006*	Co-ordinate any measures required by regulation 11 of DSEAR and, as required by regulation 5(4) of DSEAR, record the aim of the co-ordination in the risk assessment. However, if part of the workplace is modified before 30 June 2006, the co-ordination requirements in respect of that part apply from the date of the modification.

* Note that existing UK legislation already covers many aspects relating to running a site where flammable materials are handled and, if an incident were to occur before 30 June 2006, the site operator might be liable under existing legislation if found to be negligent.

4.2 Arrangements for workplaces used for the first time after 30 June 2003

All Regulations should be fully complied with before the workplace is used. In general, all installed electrical and non-electrical equipment should be marked in accordance with the ATEX 'Product' Directive, although there are certain exceptions for non-ATEX equipment that is not new or held in stock. Extensions to existing plant are likewise covered.

5 DSEAR REGULATION 5: RISK ASSESSMENT

DSEAR regulation 5 requires risk assessments that identify: -

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.

The risk assessment requirements of DSEAR should already have been largely met by compliance with the Management of Health & Safety at Work (MHSW) Regulations 1999. Consequently, this requirement applies to existing workplaces with immediate effect. DSEAR also requires that the significant findings of the risk assessment should be communicated to employees.

Risk assessments should be updated if the nature of the activity changes.

For a list of available guidance documents, refer to section 2.5.

6 DSEAR REGULATION 6: ELIMINATION OF RISK

DSEAR requires employers to reduce risk as far as reasonably practicable. Substitution of flammable materials with non-flammable is rarely practical in the waste management industry. Reducing the quantity of flammable material on site is likewise not practical and, in the case of flammable dusts, does not significantly reduce the risk, since the explosion hazards only arise when the dust is transported or used in a process.

6.1 Maintenance work

Maintenance work is frequently when there is the greatest risk of the release of a flammable material. Consequently, potential ignition sources must be very carefully controlled.

6.2 Control of ignition sources

Ignition can be initiated by, for example:

- Unprotected fixed electrical apparatus.
- Spark producing portable equipment.
- Electrostatic discharges.
- Electrical equipment that is overheating or sparking due to a fault.
- Hot surfaces of heating equipment.
- Hot surfaces or sparks from mechanical equipment (by design or failure).
- Smoking.

- Open flames.
- Spontaneous combustion.
- Lightning.

EN 1127-1[14] lists thirteen type of ignition source:

Ignition source	Possible controls[C]
Live flames, e.g. arc welding, smoking	Close supervision by trained personnel, removal of flammable hazard, hot-work permit, no smoking policy on certain areas of the site
Sparks and hot surfaces from electrical equipment	Suitably-protected equipment, designed for hazardous area use, or otherwise assessed as compliant
Electrostatic discharges – equipment. See CLC/TR 50404:2003[15] clause 11.3.1.1.	Earthing normally inherent in the building structural steelwork. Earth bonding is not normally required, but could be required for items mounted on non-conducting supports.
Electrostatic discharges - personnel See CLC/TR 50404:2003 clause 9.3 (footwear) and CLC/TR 50404:2003 clause 9.4 (clothing)	In spite of the fact that modern clothing, made from synthetic textiles, can readily become electrostatically charged it is not, in general, an ignition risk providing that the wearer is earthed by means of suitable footwear and flooring. However, clothing should be as close fitting as is practical and should not be removed or unfastened in areas where there could be flammable atmospheres.
Lightning	Site buildings in hazardous areas may need to be fitted with lightning protection.
Sparks and hot surfaces arising from engineering activities	Sites should operate a permit to work system for such hot work
Chemical reactions	Unexpected exothermic or other potentially violent reactions are unlikely to be carried out in the waste management industry, but this possibility should be considered. HSE guidance will be published in the near future.
Stray electric currents, cathodic corrosion protection	Unlikely to be present
Electromagnetic fields in the frequency range from 9 kHz to 300 GHz	Unlikely to be present
Electromagnetic radiation in the frequency range from 3×10^{11} Hz to 3×10^{15} Hz or wavelength range from 1000 µm to 0.1 µm (optical spectrum)	Unlikely to be present
Ionising radiation	Unlikely to be present
Ultrasonics	Unlikely to be present; if present, unlikely to be at an energy level sufficient to cause an ignition
Adiabatic compression, shock waves, gas flows	Unlikely to be present

For a list of available guidance documents, refer to section 2.5: L136 is particularly relevant.

C This list is for guidance only and is not exhaustive

7 DSEAR REGULATION 7: AREA CLASSIFICATION & SELECTION

7.1 Area classification

It is a legal requirement for area classification to be carried out. In summary, this requires the Site/Facility Manager to identify locations where potentially explosive atmosphere do or could occur and to record this information on suitable drawings.

7.2 Selection of equipment for use in explosive atmospheres

For *existing* electrical equipment, which covers the vast majority of plant, there is no requirement to replace it with ATEX-marked equivalents provided a risk assessment shows that the equipment is suitable for its location. In the case of *certified* electrical equipment, it is easy to justify its continued operation in a hazardous area provided it is in good condition, since its certification assures an appropriate level of protection.

In some cases, *uncertified* equipment is permitted, but only in zone 2 and only when the operator has sufficient knowledge, information and experience to assess the equipment as providing a suitable level of protection. More information is given in APPENDIX 2.

Prior to ATEX, there were no requirements for non-electrical equipment to meet specific constructional requirements and it was left to the site operator to perform a risk assessment as to its suitability for use in a hazardous area. This has changed under ATEX, and now all new non-electrical equipment should be ATEX-marked. However, existing non-electrical equipment may be retained subject to a risk assessment. This will involve an ignition hazard assessment. Further guidance is given in APPENDIX 1.

For *new* plant, DSEAR states that equipment and protective systems (electrical and non-electrical) must be selected on the basis of the requirements set out in ATEX Product Directive, unless the risk assessment finds otherwise. However the DSEAR Approved Code of Practice L138 states that risk assessment cannot be used to justify equipment built to lower standards than that specified by the ATEX Product Directive. Consequently in the UK, new equipment must be appropriately marked dependant on the zone in which it is installed, unless its use is temporary or workers are excluded.

Equipment manufactured against the ATEX Product Directive is marked to indicate its 'Category'. The category is used to select the zone or zones in which it may be used.

ATEX Category	Permitted zones of use	Design requirements
1G	0, 1, 2	safe with two independent faults or safe even when rare malfunctions are considered
1D	20, 21, 22	
2G	1, 2	safe when foreseeable malfunctions are considered
2D	21, 22	
3G	2	safe in normal operation
3D	22	

Definitions of the zones and a fuller treatment of the subject of area classification is contained in the area classification ICoP.

7.2.1 Marking example 1

The marking could include:

Ex II 2G

where 'II' refers to the group, in this case indicating that the equipment is for non-mining use (group I is for mining)
2 refers to the category
'G' refers to the fact that the equipment is suitable for flammable gases and vapours

Putting together the 2G, it can be inferred that the equipment can be used in zones 1 and 2.

7.2.2 Marking example 2

The marking could include:

Ex II 3D

where 3 refers to the category
'D' refers to the fact that the equipment is suitable for flammable dusts

Putting together the 3D, it can be inferred that the equipment can be used in zone 22 only. This equipment is not, therefore, suitable for gas/vapour zones.

7.2.3 Marking example 3

The marking could include:

Ex II 1GD or Ex II 1G
1D (T100°C)

where 1 refers to the category
'G' refers to the fact that the equipment is suitable for flammable gases and vapours
'D' refers to the fact that the equipment is suitable for flammable dusts
T100°C refers to the surface temperature of the equipment.

Putting together the 1G and 1D, it can be inferred that the equipment can be used in all zones. Note that other selection criteria apply: the equipment must also be suitable for the apparatus group and temperature class for gases and vapours or the layer and cloud auto-ignition temperatures for dusts.

7.2.4 Other selection considerations

It is not sufficient to select equipment solely on whether it is suitable for the zone of use. There are at least two more selection criteria, namely:

- ♦ is the equipment compatible with the apparatus group of the flammable material
- ♦ is the equipment compatible with the temperature class of the flammable material

Consideration should also be given to environmental factors, such as the likelihood of corrosion, water ingress, etc.

Equipment should only be specified and installed by suitably qualified persons.

7.2.5 Inspection of equipment

Electrical equipment should be periodically inspected against EN 60079-17 to confirm that its explosion protection is still effective. Non-electrical equipment should be checked against the manufacturer's instruction manual.

For further available guidance, refer to section 2.5.

7.3 Marking of zones

The purpose of signs is to warn of areas where an explosive atmosphere may occur in such a quantity that employees need to be warned of its presence, so that they can take the necessary precautions in relation to the risk. Zoned areas should be marked with the sign shown whenever such marking might make the site safer for workers.

Currently, zoned areas are generally not marked; where needed, this should be done by 30 June 2006.

The sign to be used has black letters on a yellow background with black edging (the yellow part to take up at least 50% of the area of the sign).

7.4 Verification

The purpose of verifying overall explosion safety is to confirm the workplace can operate in accordance with these Regulations. It applies to new or existing plant and equipment but verification of a new plant must be done before the plant becomes operational.

Verification can be carried out through a variety of means, for example by an examination of documents, visual inspection, or physical checks and measurements. Much of the work may be a normal part of the commissioning process. Examples of the work involved could include: -

a) checks that mechanical ventilation systems produce the air flows intended;
b) checking with the manufacturer that suitable explosion mitigation measures have been applied
c) inspection of records showing that process equipment is leak-tight before dangerous substances are introduced for the first time;
d) ensuring that a hazardous area classification drawing has been prepared, and a visual inspection that electrical equipment is of the correct type or category for the zone where it has been installed, has been installed correctly; and
e) ensuring that appropriate information is available about the flammable properties of materials to be handled in the plant.

For new workplaces to be used for the first time after 30 June 2003 there is a requirement for explosion safety to be verified by a person competent in the field of explosion protection as a result of experience and professional training.

7.5 Anti static clothing

The DSEAR ACoP L138 requires that anti-static footwear and clothing should be provided when the risk assessment identifies that it is required. Paragraphs 263 and 264 are particularly relevant and the requirements may be interpreted as follows: anti-static footwear and flooring (e.g. concrete, metal grids) are generally sufficient for areas where there is a flammable gas or vapour risk; anti-static footwear is not generally required for dusts, since they are not easily ignited, but flooring must not be highly insulating. Such a summary must, however, not preclude consideration of specific high-risk gases or activities.

For a list of available guidance documents, refer to section 2.5.

8 DSEAR REGULATION 8: ACCIDENTS, INCIDENTS AND EMERGENCIES

Arrangements must be in place to deal with accidents, incidents and emergencies. The following points should be addressed, amongst others:

- Occupied buildings should have a fire alarm system that is tested regularly
- Evacuation and assembly points should be designated and clearly marked
- Emergency exits should be marked and housekeeping standards are such that exits are unobstructed.
- Fire drills should be held at suitable intervals
- Visitors should be alerted to escape routes and muster points
- Notice boards in every workplace should detail the local emergency arrangements

For a list of available guidance documents, refer to section 2.5.

9 DSEAR REGULATION 9: TRAINING AND INFORMATION

DSEAR requires information on the hazardous properties of substances to be made available. The hazardous properties of all flammable liquids, vapours and dusts should be identified and made available at the workplace where this is practical. Specifically, employees should be made aware of the potentially explosive nature of landfill gas and measures taken to reduce the risk of ignition. Training is required to cover such areas as:

- the no-smoking policy in or near hazardous areas
- the prohibition of the use of uncertified electrical equipment in hazardous areas, such as test equipment, mobile phones, pagers, personal audio equipment, etc.
- the correct use of intrinsically safe test equipment, e.g. oxygen analysers

It is recommended that such persons attend a hazardous area awareness course.

Those installing, maintaining and inspecting electrical and non-electrical equipment in hazardous areas require more detailed training that gives an understanding of the methods of protection of equipment and the corresponding checks and precautions to be applied. It is recommended that such persons attend a training course offering the required level of detail.

10 DSEAR REGULATION 10: IDENTIFICATION OF CONTAINERS AND PIPES

Identification of pipes and containers, particularly those that are visible, alerts employees and others to the presence of a dangerous substance so that they can take the necessary precautions. Identification can also help to avoid confusion over contents and thereby avoid incorrect mixing of contents.

Containers and pipework containing hazardous materials should be marked according to the appropriate regulations[16].

11 DSEAR REGULATION 11: CO-ORDINATION

Where there are two or more employers sharing a workplace, regulation 11 requires the employer responsible for the workplace to co-ordinate the implementation of measures taken under DSEAR to protect employees and others at the workplace from risks from explosive atmospheres.

In the waste management industry, the situation is complicated by the fact that a waste is received from a number of different companies. In many cases on landfill sites, the employees from outside contractors and visitors may be unaware of their responsibilities under DSEAR since there is no widely-held perception of a landfill site as a hazardous area. This situation can be addressed by segregating such persons and their vehicles from zoned areas by careful routing of the access roads sufficiently far away from wells and other locations where landfill gas collects. Suitable warning signs at the entrance to the site and a no-smoking policy may be sufficient.

Where access to zoned areas is part of the work of outside contractors (e.g. drilling, pipe-laying, work within parts of the Gas Management Compound), then contractors must be required to provide risk assessments and method statements and only send in suitably-qualified persons for such work.

Compliance with this regulation may also be achieved by means of a site induction (verbal or audio-visual), a permit-to-work system, accompanying visitors, or other methods deemed appropriate to the level of risk.

12 CONCLUSION

The waste management industry has a legal obligation to comply with DSEAR. The first step is to undertake an area classification of the site, without which, the other necessary steps cannot be taken. In summary, these remaining steps are:

1. Conduct risk assessments of activities involving flammable materials and establish whether the existing safe systems of work are adequate; methods of risk reduction should be studied;
2. Record the measures already in place (or required to be implemented) to control ignition sources;
3. Justify the existing electrical and non-electrical equipment in the zoned areas; ensure new equipment (both electrical and non-electrical) is ATEX-marked;
4. Set up an inspection system against EN 60079-17 for electrical equipment and a similar system for non-electrical equipment;
5. Ensure staff are adequately trained; and
6. Ensure hazardous areas are marked where appropriate.

APPENDIX 1: ASSESSMENT OF ALREADY-INSTALLED NON-ELECTRICAL EQUIPMENT

The following appendix is supplied for information only
and is not intended in itself to impart a level of training necessary for a competent person

A1.1 General obligations

Article 9 of the ATEX 1999/92/EC ('Worker Protection') Directive has requirements for electrical and non-electrical equipment already installed when the Directive came into force. Paragraph 4 states:

"Where workplaces which contain places where explosive atmospheres may occur, are already in use before 30 June 2003, they shall comply with the minimum requirements set out in this Directive no later than three years after that date."

Annex II(2)2.5 states:

"All necessary measures must be taken to ensure that the workplace, work equipment and any associated connecting device made available to workers have been designed, constructed, assembled and installed, and are maintained and operated, in such a way as to minimise the risk of an explosion...."

With specific regard to non-electrical equipment, the ATEX manufacturing directive 94/9/EC gives constructional requirements and the ATEX Worker Protection Directive requires non-electrical equipment already installed to be assessed for its ignition capability, although it is not required to meet the constructional requirements of new equipment. The assessment should be completed by 30 June 2006. EN 1127-1 lists thirteen type of ignition source:

1 hot surfaces
2 flames and hot gases
3 non-electrically-generated sparks
4 electrical apparatus
5 stray static currents, cathodic corrosion protection
6 static electricity
7 lightning
8 electromagnetic fields in the frequency range 9 kHz to 300 GHz
9 electromagnetic radiation in the frequency range from 300 GHz to 3000 GHz or wavelength from 100 μm to 0.1 μm (optical spectrum)
10 ionising radiation
11 ultrasonics
12 adiabatic compression, shock waves, gas flows
13 chemical reactions

New non-electrical equipment should be marked as ATEX-compliant. What follows is guidance of how non-electrical equipment that is already installed can be assessed as suitable for continued use. Typical examples that require an assessment are:

- pump
- coupling (e.g. between a motor and the associated pump)
- conveyor belt
- hoist
- solenoid valve
- gearbox
- brake

The ignition hazard assessment for equipment in the following zones will now be discussed:

Gas/vapour zone	Dust zone	Probability of explosive atmosphere	Requirements
2	22	low	Safe in normal operation
1	21	medium	Safe even with 'expected malfunctions'
0	20	high	Safe even with 'rare malfunctions'

A1.2 Non-electrical equipment in zones 2 (flammable gases/vapours) and 22 (flammable dusts)

Zones 2 and 22 are the low risk zones where an explosive atmosphere arises only very occasionally, usually as a result of the failure of plant equipment (e.g. leaking flange or seal) or human error (accidental spill). As such, the requirements for the installed equipment are not excessively onerous and often are easily met by normal well-designed industrial equipment. The requirements for equipment in these zones can be broadly summarised as follows:

in normal operation, the equipment should not spark
and should not have excessively hot surfaces;
its ingress protection should be suitable for the environment

Refer also to the list of 13 possible sources of ignition listed above; however, most or all will not apply to non-electrical equipment in normal operation.

When considering non-electrical equipment, and whether it is acceptable for continued use in zone 2 or 22 a hazardous area, it is usually self-evident whether it sparks or not. With regard to temperature rise, very few of those parts exposed to the flammable gas or dust will exceed even 100°C, which makes the item acceptable for the vast majority of flammable materials[D]. It should be stressed that only normal operation needs be considered for these zones; fault conditions (such as a seized bearing) are not taken into account, due to the low probability of such a fault occurring at exactly the same time as the explosive atmosphere.

For non-electrical equipment, the problem of ingress protection is usually simple to assess, since ingress of water will not cause sparking or a rise in temperature. With regard to dusts (whether flammable or not), the equipment is almost certainly designed to withstand such environmental factors, so seals will be provided to keep dust out of bearings and other moving parts. If this is not the case, then the equipment should not be installed in this location in the first place.

It is important to stress that the above assumes that the equipment is properly maintained.

A1.3 Non-electrical equipment in gas zones 1 and dust zones 21

Unlike in zones 2 and 22, foreseeable malfunctions should be considered when assessing non-electrical equipment in zones 1 and 21. Thus, the situation is somewhat more complicated.

When first considering the issue, the difficulty usually arises as to what constitutes a 'foreseeable malfunction' and whether such should be tolerated in a zone 1/21. Useful guidance on how to do the ignition hazard assessment can be found in EN 13463-1:2001, which is one of a suite of standards giving the constructional requirements for hazardous area non-electrical equipment. It should be stressed that there is no suggestion in the ATEX Directive that existing equipment should either be made to comply with these standards or else replaced, but they can be used for guidance.

A note in EN 13463-5 section 5.1 is included here because it gives guidance that is of general use:

[D] For those flammables with very low auto-ignition temperatures (e.g. carbon disulphide, CS_2), then a more careful approach will be required, possibly involving actual measurement of the surface temperature or contacting the manufacturer. Regarding flammable dusts, be aware that a 75 K safety factor must be applied to the AIT of the dust layer and a 2/3 safety factor to the AIT of a cloud.

"Slow-moving parts with a circumferential speed of less than 1 m/s do not normally require protection against heating by friction and non-electrical sparks".

A1.3.1 Example: ignition hazard assessment of a solenoid valve (reference EN 13463-1 Annex B1)

Normal operation	Expected malfunction
Friction producing heat	Frictional ignition following the breakage of the spring Compression/shock-wave ignition

Normal operation is highly unlikely to produce an ignition for the reasons outlined in the previous sub-section. For malfunctions, some element of judgement is required by a suitably-qualified person to assess the likelihood of these becoming an ignition source in the valve under consideration.

The general approach, which takes care of most of the ignition hazards, is as follows:

ensure that the equipment is maintained in accordance with the manufacturer's guidelines and that all parts with a potential to become ignition sources are replaced at or before the specified interval

A1.3.2 Example: ignition hazard assessment of a conveyor belt (reference EN 13463-1 Annex B2)

A conveyor belt is a more complex example, which includes a number of non-electrical devices. Possible ignition sources are:

Normal operation	Expected malfunction
♦ temperature rise of bearings ♦ frictional heat from moving parts inside the gearbox ♦ frictional heat from the brakes ♦ dust entering the brake housing ♦ frictional heat from the belt idler rollers ♦ dust deposits on the gearbox ♦ static electricity discharge ♦ surface temperature of all moving parts	• bearing failure due to loss of lubrication • belt rubbing on spilled product • ingress of stones or metal fragments to gearbox • unacceptable oil loss from the gearbox • brakes left on too long after the drive motor has started • brake disengagement fails • clutch slippage • belt idler roller seizes and is rubbed by the moving conveyor belt • slippage of conveyor belt on the driving drum due to loss of tension or stalling of the belt • belt driven at overspeed • friction between the belt and fixed parts • moving parts close together, gap filled with dust

Most of these will have been covered by the original design of the conveyor. Again, the general approach outlined above will usually suffice.

Static discharges are, arguably, the commonest cause of unintentional sparking and special attention should be paid to this particular ignition source.

A1.4 Non-electrical equipment in gas zones 0 and dust zones 20

Such equipment is relatively rare, but certain examples will require consideration, e.g.

- grinder in a mill classified as a zone 20
- agitator in a process vessel classified as zone 0

For dust zone 20, it is often not possible to classify the internal non-electrical equipment as safe with rare malfunctions. The grinder in a mill is a prime example: a metal fragment introduced by accident is quite likely to produce a spark when it comes into contact with the grinder wheels. Another problem is that of static build-up produced by the flow of dust itself. The usual approach is to have explosion venting since the probability of an ignition-capable spark cannot be reduced to a sufficiently low level. Assuming this is present and suitably-located and maintained, this is probably sufficient.

For zone 0, the ignition hazard assessment should consider 'rare malfunctions' as well as 'expected malfunctions'. To take the example of an agitator, the mechanical seal protecting the bearings could be in contact with the zone 0. Possible approaches could be:

- monitoring the barrier fluid level or pressure or flow
- an analysis of past failure rates
- periodic vibration or temperature monitoring

As for equipment in lower risk zones, the routine maintenance and scheduled replacement of the bearings should be as recommended by the manufacturer.

An assessment of the agitator blade is also required. Its potential for producing a spark should be assessed, considering such mitigating factors as:

- are the blades always immersed?
- are the blades and shaft made from alloys containing insignificant quantities of 'light' metals such as magnesium, aluminium, zirconium, titanium?
- is the rotation speed less than 1 m/s?

A1.5 Summary

An assessment of non-electrical equipment in zones 2 and 22 is straightforward but a more careful analysis is required for the higher-risk zones. It is not possible to give a detailed approach for all situations, but the application of sound engineering judgement and implementation of reasonable precautions, proportionate to the zone classification, to prevent potential ignition sources becoming active is sufficient to comply with the requirements in the ATEX Worker Protection Directive.

APPENDIX 2: ASSESSMENT OF ALREADY-INSTALLED UNCERTIFIED ELECTRICAL EQUIPMENT

The following appendix is supplied for information only and is not intended in itself to impart a level of training necessary for a competent person.

A2.1 The legal situation

Article 9 of the ATEX 1999/92/EC Directive (Worker Protection Directive, WPD) has mandatory requirements for electrical and non-electrical equipment installed in hazardous areas. This article can be paraphrased as follows:

> (1) Equipment that was already in use on 30 June 2003[E] must comply with the minimum requirements laid down in Annex II Part A of the Directive. The requirements for fitting ATEX-compliant equipment are in Part B, so *there is no requirement to retro-fit ATEX equipment.*
>
> (2) Equipment installed after 30 June 2003 in new or extended plant must comply with Annex II Parts A and B. In effect, this requires it to be ATEX marked by the manufacturer[F] as suitable for the hazardous area into which it is being installed.

Article 9(2) is clear: with very few exceptions, ATEX-marked equipment must be used for new installations. However, Article 9(1) requires further discussion.

For existing equipment, the ATEX WPD requires the equipment (whether electrical or non-electrical) to be assessed for its continued suitability for the zone into which it is installed. It is convenient to divide the equipment into electrical and non-electrical (mechanical); only electrical equipment is dealt with below.

A2.2 Uncertified electrical equipment in zone 2

This section deals with equipment installed in zone 2 before the ATEX directives came into force on 1 July 2003. The requirements for zone 2 were and are considerably more relaxed than for zone 1 and EN 60079-14:2003[17] clause 5.2.3c permitted the use of uncertified equipment in zone 2, provided it is assessed as meeting the requirements of the relevant standard. These requirements can be summarised as follows for the commonest form of Type n equipment ("Ex n non-sparking"):

1 the enclosure is normally required to be IP54 minimum, though protection by location (e.g. indoors) permits a lower level of ingress protection

2 the equipment shall contain no sources of ignition in normal operation, i.e.
- **hot surfaces:** no surfaces hotter than the ignition temperature of the hazard gas
- **sparks:** no normally-sparking components are permitted, e.g. switches, relays unless encapsulated), contactors, circuit-breakers, potentiometers (unless the spark is current-limited) and easily-separated connectors (secure with adhesive if necessary). Such items are acceptable if certified to another concept, e.g. Ex d switches.

It should be stressed that the assessment takes account only of normal operation, and not fault conditions (e.g. a conductor coming loose from a terminal or a fuse blowing), since it is considered a sufficiently low risk that such a fault could occur at exactly the same time as a flammable gas is present in the enclosure. The enclosure is not required to be gas-tight for this method of protection.

There is no upper voltage limit and uncertified terminals are permitted. It is also possible to use test-disconnect terminals (non-sparking in normal operation), fuse terminals and other terminals incorporating components such as diodes. However, it is usual to use test-disconnect and fuse terminals that are *certified* as Ex n/N, since these are readily available.

E 1 July 2003 was the date on which both ATEX Directives came into force; most, if not all, of the equipment on the site was already in use on this date.

F This rule is not absolute and there are a number of exceptions, but, in the interests of clarity, these will not be discussed.

Common examples of uncertified items of equipment that may be thus assessed are:

- A.C. induction motors (paying particular attention to maximum temperature; sometimes a guide is that the limiting temperature for the wiring insulation is stated on the marking plate as a "Class"[G])
- Junction boxes
- Non-purged panels with no sources of ignition
- Panels containing potential ignition sources that are protected by the pressurisation principle

This relaxation in EN 60079-14 clause 5.2.3c does not apply to zone 1: all electrical equipment should be certified.

Note that the ATEX 1999/92/EC Worker Protection Directive requires *new* equipment (electrical and non-electrical) for zone 2 to be marked as ATEX-compliant.

A2.3 Uncertified equipment already installed in dust zones 20, 21 and 22

Before the advent of the ATEX Directives, there was no mechanism for certifying electrical equipment for flammable dust areas and hence no requirement to use certified equipment. The approach used in the UK is found in HSG103[18], which permits equipment that is merely protected against dust.

Zone 21: Paragraph 37 states: ".... in zone 21 .... existing equipment .... with a dust-tight enclosure made to IP6X is still likely to be suitable".

Zone 22: Paragraph 38 states: "In [zone 22]....older equipment made with a dust resistant enclosure to IP5X may remain in service".

Thus, provided the equipment is in good condition and no further ignition hazards are identified, if it meets these fairly modest requirements, it may be considered satisfactory for continued use; it is not necessary to replace it with ATEX-marked equipment.

For equipment in zone 20, BS 7535[19] was applied. The approach can be summarised as follows:

For flammable dust zones, install equipment that is suitable for the equivalent flammable gas zone and is also dust-tight.

Thus, for zone 20, intrinsically safe equipment that is also IP6X may be appropriate for continued use, provided due consideration is given to factors such as the ruggedness of the enclosure, ohmic heating of the dust, etc.

It should be stressed that the definitions of flammable dust zones are concerned only with the presence of flammable clouds of dust and take no account of dust layers. The smouldering risk of the dust layer on the external surfaces of equipment should be addressed separately. Dust layers are significant in zoning if they can be stirred up to form an explosive cloud; such a risk can be removed by good housekeeping.

[G] Class A = 105°C, class E = 120°C, class B = 130°C, class F = 155°C, class H = 180°C, class N = 200°C (values from EASA Electrical Engineering Handbook).

APPENDIX 3 REFERENCES

The following publications were referenced in compiling this report:

1 Dangerous Substances Explosive Atmospheres Regulations:2002 ('DSEAR')

2 ATEX Directive 94/9/EC: Equipment and protective systems for use in potentially explosive atmospheres

3 ATEX Directive 1999/92/EC: Minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres

4 Approved Guide to the Classification and Labelling of Dangerous Substances and Dangerous Preparations, 5th edition, April 2002

5 Chemicals Hazard Information and Packaging for Supply Regulations, 1994

6 Control of Substances Hazardous to Health (COSHH) Regulations, 2002

7 Management of Health & Safety at Work Regulations, 1999

8 L138. Dangerous substances and explosive atmospheres regulations 2002: approved code of practice and guidance. HSE books. ISBN 0 7176 2203 7

9 L133. Dangerous substances and explosive atmospheres regulations 2002: Unloading petrol from road tankers. HSE books. ISBN 0 7176 2197 9

10 L134. Dangerous substances and explosive atmospheres regulations 2002: Design of plant equipment and workplaces. HSE books. ISBN 0 7176 2199 5

11 L135. Dangerous substances and explosive atmospheres regulations 2002: Storage of dangerous substances. HSE books. ISBN 0 7176 2200 2

12 L136. Dangerous substances and explosive atmospheres regulations 2002: Control and mitigation measures. HSE books. ISBN 0 7176 2201 0

13 L137. Dangerous substances and explosive atmospheres regulations 2002: Safe maintenance repair and cleaning procedures. HSE books. ISBN 0 7176 2202 9

14 EN 1127-2:1998: Explosive atmospheres – explosion prevention and protection: Part 1: Basic concepts and methodology

15 PD CLC/TR 50404:2003. Electrostatics - Code of practice for the avoidance of hazards due to static electricity.

16 The Health and Safety (Safety Signs and Signals) Regulations 1996 (S.I. 1996/341)

17 EN 60079-14:2003 - Electrical apparatus for explosive gas atmospheres - Part 14: Electrical installations in hazardous areas (other than mines)

18 HSG103: Safe handling of combustible dusts: precautions against explosions, HSE Books, 2003

19 BS 7535:1992 – Guide to the use of electrical equipment complying with BS 5501 or BS 6941 in the presence of flammable dusts.

AREA CLASSIFICATION FOR

LANDFILL GAS EXTRACTION,

UTILISATION AND COMBUSTION

INDUSTRY CODE OF PRACTICE

ESA ICoP 2, edition 1: Nov. 2005

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FOREWORD
James Barrett, Head of the Manufacturing Sector of the Health and Safety Executive

This code has been prepared by the Environmental Services Association in consultation with the Health and Safety Executive and has been endorsed by the Waste Industry Safety and Health (WISH) Forum which represents the interests of the industry.

This Code should not be regarded as an authoritative interpretation of the law, but if you follow the advice set out in it you will normally be doing enough to comply with health and safety law in respect of those specific issues on which the Code gives advice. Similarly, Health and Safety Inspectors seeking to secure compliance with the law may refer to this Guidance as illustrating good practice.

The HSE believes that the contents of this Code demonstrate good practice in the landfill industry and commends its use.

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Andrew Cox	EnerG Natural Power Limited, EnerG House, Daniel Adamson Road, Salford, Manchester M50 1DT
David Holton	Sira Certification, Eccleston, Chester CH4 9JN
Peter Murdoch	Sira Certification, Eccleston, Chester CH4 9JN
Paul Rogers	for Biffa Waste Services Limited, Cressex Head Office, Coronation Road, Cressex Business Park, High Wycombe, HP12 3TZ
Neil Taylor	Viridor Waste Management, Great Western House, Station Approach, Taunton, TA1 1QW
Ian Walker	Technical Manager, Sita Power, Sita UK, Packington House, Packington Lane, Little Packington, Meriden, Coventry CV7 7HN

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-	ESA Executive Committee
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-	Health and Safety Executive
-	Summerleaze Re-Generation Limited
Julie Brown	Regional EQHS Auditor/Advisor, Biffa Waste Services
Peter Brown	Safety Implementation Manager, Biffa Waste Services
Michelle Conway	Development Manager, Biffa Waste Services
Sergi Cuadrat	Biogas Technology Limited
Paul Ellis	Environmental Control Advisor, Biffa Waste Services
Andrew Goode	Novera Energy
Paul Gough	General Manager, Roxby Landfill Site, Biffa Waste Services
Tim Gunn	Engineer, Environmental Technology, Biffa Waste Services
Stuart Hayward-Higham	Sita UK Limited; Chair of ESA Working Group
Ian Hill	Clarke Energy
Marian Kelly	ESA Working Group
Rafal Lewicki	Biogas Technology Limited
Chris Males	Development Assistant, Biffa Waste Services
Paul McParland	Cleanaway
Tim Otley	Sita UK Limited; ESA Working Group
Chris Parry	Biffa waste Services Limited; ESA Working Group
Dick Turner	Viridor Waste Management; ESA Working Group
Graham Wilkins	Technical Manager, Environmental Technology, Biffa Waste Services
Geoff Winckles	Institution of Gas Engineers and Managers

In this document, footnotes are indicated with number ([1]) and endnotes (references to documents used) with a letter ([A]).

1 INTRODUCTION AND SCOPE

1.1 Executive summary

This document (ESA ICoP 2) is one of a number called up by the primary document (ESA ICoP 1) that, together, advise on how to fulfil the requirements of the Dangerous Substances Explosive Atmospheres Regulations:2002 ('DSEAR')[A] for the waste management industry. ICoP 2 is concerned only with landfill gas; this contains a high proportion of methane and when released into the atmosphere, it mixes with the air and forms a potentially explosive atmosphere. As a result, DSEAR requires that the process of area classification be carried out to identify where such potentially explosive atmospheres could form.

This Landfill Industry Code of Practice for area classification (referred to throughout this document as the Landfill 'ICoP') attempts to apply existing codes of practice (CoPs) to the specific situations found in landfill gas collection and power generation. Although the experience of the industry has been incorporated into this document, very little additional research relating to area classification is available, so this Landfill ICoP aims to apply established area classification methodology to the problem of landfill gas. This ICoP comprises a set of recommendations only and is not mandatory, but is intended to represent good practice. This ICoP is mainly concerned with a site that is up-and-running and not at its start-up phase nor its running-down phase. Site-specific factors should always be considered when applying this ICoP, e.g.

- landfill gas with methane concentrations above 60% v/v[1],
- significant generation of hydrogen or hydrogen sulphide[2],
- parts of the site where a mixture within the flammable range might be present for extended periods within the collection system,
- overpressures above 80 mbarg and 350 mbarg in the collection and generation respectively.

Throughout the ICoP, there are situations covered that may require additional verification of the validity of the assumptions.

It is envisaged that this Edition will be reviewed and re-issued by the end of 2006. Comments from the industry are welcomed and should be sent to ESA (m-kelly@esauk.org) before 1 July 2006.

1.2 Principal codes of practice referenced

The European code of practice on area classification is EN 60079-10:2003[B], which is technically identical to IEC 60079-10:2002. Section 1 of EN 60079-10:2003 contains the following statement:

> "For detailed recommendations regarding the extent of the hazardous areas in specific industries or applications, reference may be made to the codes relating to those industries or applications".

A number of industry CoPs are available that supplement the information in EN 60079-10:2003 and give more specific guidance for certain industries but no CoP exists for the waste management industry. This Landfill ICoP therefore aims to provide a standardised approach to the classification of hazardous areas in the landfill industry, based on the principles of EN 60079-10 but also using guidance from other published CoPs where appropriate. The intention is that as many as possible of the standard situations will be included in this Landfill ICoP to allow the area classification of landfill facilities to be performed in a consistent manner across the industry by suitably-qualified persons.

The main CoP referenced in addition to EN 60079-10 is the Institute of Gas Engineers IGE/SR/25 code[C], since this applies to natural gas, which is similar to landfill gas. However, IGE/SR/25 does not deal specifically with the low pressures encountered in the waste industry, so, although the mass release equations have been adapted from this code, zone extents have been obtained by calculation.

Article 7(1) of the ATEX 94/9/EC Directive[D] (enacted in the UK by means of DSEAR Regulation 7) makes area classification a legal requirement throughout Europe and, on a particular site, it is the Site/Facility Manager who holds the final responsibility to ensure it is complied with. The primary purpose of area classification of hazardous areas is to allow the selection of suitable electrical and non-electrical apparatus as well as

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1 Higher methane concentrations will not affect the zone number, but will slightly increase the zone extents for releases into the surrounding air

2 Hydrogen sulphide is flammable but it is also highly toxic. It is highly unlikely that sufficient hydrogen sulphide can be produced to give a flammable risk – the LEL is 4.3%, which equates to 43,000ppm, so its toxic nature is far more important than its flammable nature.

identifying areas where additional precautions are required as a result of the explosion risk. Within this Landfill ICoP, a 'hazardous area' is one in which a flammable gas/air mixture is, or could be, present.

1.3 Scope

This Landfill ICoP should be applied in the design of new works, the refurbishment of existing works and where no area classification currently exists. This document does **not** consider

- drilling operations, for which a safe system of work is currently being developed in association with the relevant bodies;
- maintenance operations, for which a safe system of work should be applied;
- catastrophic failures, within the meaning EN 60079-10:2003 (see section 4.2.4);
- safety issues associated with toxic, asphyxiant or other hazards associated with landfill gas;
- utilisation systems with a delivery pressure above 350 mbarg;
- landfill site activities concerned with flammable materials other than landfill gas. In some cases, standard guidance is available apart from that already referenced in this Landfill ICoP [E F G H I J K]. However, further work may be required for situations specific to the waste management industry. Such activities include:
    - Leachate storage, treatment and disposal (ESA ICoP 3)
    - Drilling (ESA ICoP 4)
    - Operations (landfill) (ESA ICoP 5)
    - Operations (treatment) (ESA ICoP 6) including liquid treatments/solidification, advanced conversion technologies, aerosol destruction facilities
    - Solid waste non-destructive facilities (ESA ICoP 7), including civic amenity (CA) sites, transfer stations and materials recycling facility (MRF)

2 DEFINITIONS AND TERMS

Some of the definitions below are specific to landfill gas extraction.

Term	Explanation
apparatus group	the part of the certification code (IIA, IIB, IIC or II) that indicates the range of gases and vapours for which the equipment is suitable. Equipment marked IIC or II is suitable for all gases and vapours (provided the temperature class is appropriate). IIB equipment is suitable for IIA and IIB gases. IIA equipment is suitable only for IIA gases.
area classification	the process of zoning the site to delineate between hazardous areas and non-hazardous areas
basal seal	clay liner, plastic membrane or other impermeable material underneath the waste, primarily engineered to prevent leachate from seeping into the ground below the landfill.
category 1G equipment	equipment with a very high level of protection, suitable for installation in zone 0[3]; it may equally be used in zones 1 and 2. Most Category 1G electrical equipment is protected by intrinsic safety.
category 2G equipment	equipment with a high level of protection, suitable for installation in zone 1; it may equally be used in a zone 2.
category 3G equipment	equipment with a standard level of protection, suitable for installation in zone 2.
condensate	the liquid that forms as the landfill gas cools
grades of release	see section 4.2.1
hazardous area	an area where there is a reasonable probability of finding a potentially explosive atmosphere
leachate	water-based liquid that collects in a landfill site, containing numerous contaminants depending on the constituents in the landfill mass
lower explosive limit (LEL)	the minimum amount of flammable gas that, mixed with air, will produce a potentially explosive atmosphere; it is usually expressed as a percentage by volume
negligible extent	where the estimated volume of a potentially explosive atmosphere is small (less than 0.1 m^3, equivalent to a sphere of radius 0.3 m)[4], it is defined as having 'negligible extent' and no zoning applies.
non-hazardous area	an area where there is a negligible or extremely low probability of a potentially explosive atmosphere being present; such an atmosphere may be present under catastrophic[5] failure conditions
potentially explosive atmosphere (PEA)	a mixture of gas and air that is within the flammable range, i.e. between the LEL and UEL
temperature class	Equipment is designated with a temperature class, T1 to T6; T6 equipment is the coolest (below 85°C), whereas T1 equipment is the hottest (below 450°C). Gases and vapours are also assigned temperature classes T1 to T6 to allow suitable equipment to be chosen.
upper explosive limit (UEL)	the maximum amount of flammable gas that, mixed with air, will produce a potentially explosive atmosphere; it is usually expressed as a percentage by volume
zones (0, 1, 2)	see section 4.2.2

[3] Note that equipment should ideally be installed in the non-hazardous area or, if in a hazardous area, in the zone of least risk

[4] Strictly speaking, a 'hypothetical volume' (V_Z) of less than 0.1 m^3 rather than a zone volume is the criterion for being "of negligible extent". EN 60079-10:2003 calculation 4 (conclusion) states that a V_z <0.1 m^3 allows the ventilation to be assessed as degree 'high'. From the definition of degree 'high' in clause B.3.1, a zone of negligible extent results.

[5] See section 4.2.4

3 PROPERTIES OF LANDFILL GAS

The only flammable material addressed in this ICoP is landfill gas, which is produced by the anaerobic decomposition of organic matter. It is a mixture predominantly of methane (CH_4) and carbon dioxide (CO_2). The following description is for area classification only and is not intended to be a COSHH assessment.

Landfill gas is produced by the microbial degradation of biodegradable organic material present within the landfill. The degradation process takes place in five stages. The transition from one stage to the next being dependent upon many characteristics and therefore the time for which each stage is present is difficult to pre-determine. It is however, possible to have different stages of the degradation process taking place at any one time within a landfill site.

The factors that affect the production of landfill gas are typically:

- Waste composition (in particular the amount of readily degradable organic material)
- Density of the emplaced waste
- Moisture content and its distribution through the waste mass
- Acidity/alkalinity (pH) and nutrient availability (to feed the microbes).
- Temperature
- Presence of toxic agents and chemical inhibitors.

Stage 1 of the process, which is aerobic in nature, involves the consumption of any oxygen present within the waste, primarily by aerobic microbial activity. This process results in the main in the evolution of carbon dioxide gas, water and heat. Providing there are no sources of air ingress to the waste to replenish those consumed at this stage, then the concentration of oxygen will reduce. Nitrogen will decay as the gases produced purge it out from the waste mass.

Stage 2 of the degradation process involves the conversion from aerobic to anaerobic conditions within the waste mass, the results of this process being the production of ethanoic acid (acetic acid), ethanoates (acetates), ethanol, ammonia, carbon dioxide, hydrogen, water and heat. The hydrogen and carbon dioxide produced during this process continues to purge the remaining nitrogen from the atmosphere within the body of the waste.

Stage 3 of the degradation process is that where the methanogenesis process commences with methane and carbon dioxide being produced.

Stage 4 is where a period of equilibrium is reached in the degradation process. The conditions present in the body of waste provide a steady state condition during which methane and carbon dioxide are evolved in a ratio of typically 3:2 (60:40%) by volume.

Stage 5 represents the final stage of the degradation process during which the gas composition within the body of waste gradually assumes that of atmospheric air.

The composition of the landfill gas varies from one landfill site to another and within a landfill site, from one cell to another. The make up of the gas composition will change with time, the changes of which can be attributed to[L]

- Differences in waste composition, pre-treatment and storage;
- Changes in the rate and predominant form of microbial activity e.g. aerobic/anaerobic;
- The age of the emplaced waste;
- Gas management regime;
- The hydraulic characteristics of the site;
- The physiochemical properties of waste components;
- The differing properties of the components of landfill gas e.g. solubility;
- Landfill temperature.

Landfill gas has the following properties:

Property	Value	Comments
Constituents	Methane (CH_4)– 60% v/v Carbon dioxide (CO_2)– 40% v/v 35.3% CH_4 by mass	Proportions may vary but these values will be used for calculation purposes (see table below). CO_2 is not flammable.
Molecular mass (M)	27.2 kg/kmol (60% CH_4)	Methane has a molecular mass of 16; carbon dioxide has a molecular mass of 44. Therefore, landfill gas containing 60% methane will have a molecular mass as follows: M = [(60 x 16) + (40 x 44)]/100
Explosive limits[M]	4.4 – 16.5% v/v[6]	Assumed as for pure methane[7] in air
Relative density (air = 1)	0.94	Air has an average molecular mass of 29 kg/kmol
Minimum temperature of landfill gas (for calculation purposes)	10°C	From LFTGN 03[N]
Apparatus group	IIA	As for methane
Auto-ignition temperature	537°C	As for methane
Temperature class	T1	As for methane

Since landfill gas has the least onerous apparatus group and temperature class, all hazardous area equipment is suitable for use with landfill gas provided it has been correctly selected against other criteria, notably the zone.

In preparing this ICoP, the presence of hydrogen as a gas produced in the microbial decomposition of waste has not been considered. In general, as hydrogen is associated with the early stages of the degradation process, it is unlikely that gas extraction for power generation or utilisation (combustion) within a landfill gas flare would be initiated. However, it may be the case where some form of odour control involving gas collection from waste in stages 1 to 3 of the decomposition process is required. Also, monitoring may take place, releasing hydrogen. If this is the case, then a specific risk assessment based on actual measurements and conditions present should be undertaken to identify any risk of a potential explosive atmosphere being present with, where required, suitable and sufficient mitigating measures put in place. Hydrogen is a IIC/T1 gas.

There are many other components associated with the decomposition of waste – refer to LFTGN 04[O] which addresses the health and environmental aspects, but not primarily the flammable risk.

4 THE PRINCIPLES OF AREA CLASSIFICATION

4.1 Safety principles

This sub-section is reproduced unchanged from EN 60079-10:2003 section 3.1.

> Installations in which flammable materials are handled or stored should be designed, operated and maintained so that any releases of flammable material, and consequently the extent of hazardous areas, are kept to a minimum, whether in normal operation or otherwise, with regard to frequency, duration and quantity.
>
> It is important to examine those parts of process equipment and systems from which release of flammable material may arise and to consider modifying the design to minimise the likelihood and frequency of such releases and the quantity and rate of release of material.
>
> These fundamental considerations should be examined at an early stage of the design development of any process plant and should also receive prime attention in carrying out the area classification study. In the case of maintenance activities other than those of normal operation, the extent of the

6 BS EN 61779-1:2000 quotes 4.4% – 17%

7 It is likely that the LEL for landfill gas is higher than that of pure methane, on account of the CO_2 content, but the LEL for pure methane has been used where applicable in calculations.

zone may be affected but it is expected that this would be dealt with by a permit-to-work system[8]. In a situation in which there may be an explosive gas atmosphere, the following steps should be taken:

a) eliminate the likelihood of an explosive gas atmosphere occurring around the source of ignition, or
b) eliminate the source of ignition.

Where this is not possible, protective measures, process equipment, systems and procedures should be selected and prepared so the likelihood of the coincidence of a) and b) is so small as to be acceptable. Such measures may be used singly, if they are recognised as being highly reliable, or in combination to achieve an equivalent level of safety. EN 1127-1:1998[P] may be a useful reference.

4.2 Area classification terminology

4.2.1 Grades of release

Potential releases of flammable materials are assigned 'grades of release', which are defined as follows in EN 60079-10:2003 section 2.7:

Grade of release	**Definition**
Continuous:	a release which is continuous or is expected to occur frequently or for long periods *(typically >1000 hours/year)*
Primary:	a release which can be expected to occur periodically or occasionally during normal operation *(typically between 10 and 1000 hours/year)*
Secondary:	a release which is not expected to occur during normal operation and, if it does occur, is likely to do so only infrequently and for short periods *(typically less than 10 hours/year and for short periods only)*

The text in *italics* is not part of the definitions in EN 60079-10 but is additional guidance found in IP15[Q] section 1.6.4. There is no clear definition of 'short periods' as applied to secondary grade releases, but EN 60079-10 Calculation No. 7 implies that a persistence time of less than one hour is consistent with the definition of a secondary grade release.

4.2.2 Zone definitions

The zone number assigned is based solely on the probability of an explosive atmosphere being present in a given location. Three probabilities are recognised:

High probability	
Zone 0	A place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is present continuously or for long periods or frequently.
Medium probability	
Zone 1	A place in which an explosive atmosphere consisting of a mixture with air or flammable substances in the form of gas, vapour or mist is likely to occur in normal operation occasionally.
Low probability	
Zone 2	A place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is not likely to occur in normal operation but, if it does occur, will persist for a short period only.

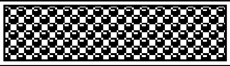
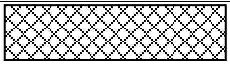
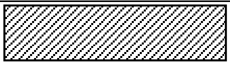
Areas where there is an even lower probability of an explosive atmosphere being present can be classified as non-hazardous but possible catastrophic events[9] leading to the formation of an explosive atmosphere in such areas are subject to a risk assessment.

8 The permit-to-work will include a risk assessment and will also consider procedures for safe systems of work

9 See section 4.2.4

4.2.3 Relationship between grades of release, zones and installed equipment

In unrestricted open-air locations, the following generally apply:

Grade of release	Corresponding gas/vapour zone	Zone designation
Continuous grade release	zone 0	
Primary grade release	zone 1	
Secondary grade release	zone 2	

Equipment manufactured against the ATEX Product Directive is marked to indicate its 'Category'. The category is used to select the zone or zones in which it may be used.

ATEX Category	Permitted zones of use	Design requirements
1G	0, 1, 2	safe with two independent faults or safe even when rare malfunctions are considered
1D	20, 21, 22	
2G	1, 2	safe when foreseeable malfunctions are considered
2D	21, 22	
3G	2	safe in normal operation
3D	22	

A fuller treatment of DSEAR compliance is covered in ESA ICoP 1.

The grade of release and zone are not synonymous. Poor ventilation may result in a more stringent zone (typical of pits, trenches and indoor situations where ventilation is limited). High levels of ventilation (e.g. local extract ventilation) may be used to allow a less stringent zone classification to be defined.

4.2.4 Catastrophic failures

It is important to note that area classification only deals with reasonably foreseeable events and does not consider highly improbable ('catastrophic') events. EN 60079-10 section 1.1(d) defines 'catastrophic' failures as "beyond the concept of abnormality dealt with in the standard" and lists "the rupture of a process vessel or pipeline and events that are not predictable" as examples. Thus, a 'catastrophic' failure may cause an explosive atmosphere to be present in an area defined by area classification as 'non-hazardous' and such situations are subject to a risk assessment by the operator under other legislation. Catastrophic failures are outside the scope of this ICoP.

The *extent* of the zone is dependent on a number of factors, e.g. the properties of the flammable materials, process pressure, leak aperture, ventilation, safety factors applied etc..

The process of area classification, therefore, involves the identification of all flammable materials, the identification and grading of all releases of flammable material, the assessment of the level of ventilation and/or housekeeping and the determination of the resulting types and extents of the zones. The allocation of zones enables the correct equipment, practices and procedures to be applied to protect the health and safety of the workers concerned with the facility.

4.3 Limitations of existing CoPs

The typical pressures involved in the landfill gas industry are very low and, indeed, much of the extraction side is at an underpressure. Where an overpressure is assumed, it is very modest by comparison with the pressures encountered in the process industry in general. Of the CoPs with national coverage, only IGE/SR/25 considers low pressures (down to 0.1 barg = 100 mbarg) and, in the absence of specific guidance for landfill gas, this CoP will be used as the primary source of guidance for mass release rates and zone extents.

4.4 Information needed for area classification

Area classification should be carried out by those who have knowledge of the properties of landfill gas, the process and the equipment, in consultation, as appropriate, with safety, electrical, mechanical and other engineering personnel.

This ICoP gives guidance on the procedure for classifying areas in which there may be an explosive gas atmosphere and on the extent of zones 0, 1 and 2. The area classification should be carried out when the initial process and instrumentation line diagrams and initial layout plans are available and confirmed before plant start-up. Reviews should be carried out during the life of the plant.

An example of a method for recording the area classification is given below. Its use is not mandatory but it may be useful where more unusual situations occur.

Plant:			**Drawing:**						**Flammable material:** landfill gas			
	Release			Operating temp. & press.		Ventilation			Hazardous area			
No	Plant item	Location	Grade	°C	mbar	Type	Degree	Availability	Zone no.	Zone radius (m)		See note #
										Vert.	Horiz	
1	see note A	see note B	see note C	see note D		note E	note F	note G	see note H	see note I		see note J
2												

Notes on the use of this table

A Plant item: this means an item, such as a pin well, manifold, etc. and should include the relevant part of the item, for example “interior”, “exterior around hatch”. A single plant item may have two or more lines.

B Location: where the item is physically located, e.g. “gas compound”, “various locations on gas field”, etc.

C Grade: this refers to the grade of release, i.e. continuous, primary or secondary

D Operating temperature and pressure: the temperature is likely to be “ambient”[10] and the pressure either a modest over- or under-pressure. In this ICoP, landfill gas is assumed to be between 150 mbarg underpressure and 80 mbarg overpressure on the extraction side and typically up to 350 mbar on the delivery side of the gas booster system. The temperature is taken as 10°C.

E Ventilation type: this is natural, artificial or both.

F Ventilation degree: this is high, medium or low. Outdoors, ventilation is ‘medium’ degree, whereas indoors it will be ‘low’ if there is very little ventilation, ‘medium’ with, say, 12 air changes/hour and only ‘high’ where the air flow is so strong as to effectively dilute any release almost immediately to below its LEL, giving rise to a dilution zone of negligible size.

G Ventilation availability: this can be ‘good’, ‘fair’ or ‘poor’. Outdoors, availability is ‘good’; indoors, where forced ventilation is used, it will generally only be 'good’ if there is a standby fan that starts automatically of the duty fan fails.

H Zone number: this can be 0, 1 or 2, as detailed in this ICoP

I Zone extent: the size of the zone, as detailed in this ICoP

J See note #: it is important that this is filled in to give a reference to the part of this (or another) document from which the zoning has been derived; also include any non-standard features and/or reasons for deviations from the ICoP.

10 Landfill gas temperature can be well above ambient but the temperature makes little difference to the calculated zone extent.

4.5 Equations used in this ICoP

4.5.1 Mass flow rate equation

IGE/SR/25 section 5.2.3.2 gives an equation that may be used to calculate the flow rate through an orifice for natural gas. Although this is not the same as landfill gas, it does allow the actual molecular mass to be inputted into the equation and gives a sufficiently accurate value of mass flow rate from a leak for the purposes of area classification. For pressures below 850 mbarg:

$$g = 1500\, C_d\, A\, (MP/T)^{0.5} \qquad \textbf{Equation 1}$$

where g = mass flow rate of landfill gas in kg/s though a leak
C_d = coefficient of discharge of orifice = 0.8 (0.97 for relief valves)
A = cross-sectional area of the orifice in m^2 ($1\ mm^2 = 10^{-6}\ m^2$)
M = molecular mass = 27.2 kg/kmol for landfill gas containing 60% v/v methane
P = gas pressure in bar gauge (barg)
T = absolute temperature of gas upstream of orifice in K (10°C = 283 K^R assumed)

For simplicity, the temperature of release of landfill gas and the ambient temperature of the gas once release have both been taken as 10°C.

The cross-sectional area assumed in this ICoP for a leak from a flange, screwed fitting, joint or valve gland is based on guidance in IGE/SR/25 section 5.2.1.1, i.e. 0.25 mm^2. This applies to 'normal' conditions and is generally applicable because pressures are low and temperature changes are modest. IGE/SR/25 recommends 2.5 mm^2 for an 'adverse' environment, but this value has not been used. If required, the equations in section 4.5 can be used to calculate the zone extent from this larger leak aperture where 'adverse' environments exist.

IGE/SR/25 Table 1 gives a zone radius of 0.5 m for pressures up to 2 barg ('normal' conditions). Since this table does not differentiate between the zone radii at 2 barg and 0.1 barg, the zone radii have been calculated from first principles using the equations in section 4.5, leading to zone extents smaller than those quoted in IGE/SR/25 Table 1.

4.5.2 Volume flow rate equation

EN 60079-10, IGE/SR/25 and IP15 do not give any equations for calculating the zone extent from a release of gas in a freely-ventilated outdoor location. An equation used by Sira Safety Compliance, based on empirical modelling of release rates to zone extents can be used to directly convert a volume release rate to a zone extent.

First, it is necessary to convert the mass release rate calculated from equation 1 to a volume release rate. This can be done using the Ideal Gas Equation found in standard physics text books; landfill gas is at sufficiently low pressure to approximate to ideal behaviour.

$$pV = nRT$$

where p = absolute pressure of the gas in Pa = 101325 Pa at atmospheric pressure
V = volume of the gas in m^3
n = number of moles[11] = (mass in kg)/(molecular mass in kmol) = g/M
R = gas constant = 8314.4 J/kmol/K
T = absolute temperature in K

Note that standard atmospheric pressure (101325 Pa) will be assumed: variations in atmospheric pressure have a very small effect on the calculations.

Thus: $V = nRT/p = gRT/Mp$

$$= (g \times 8314.4 \times T)/(M \times 101325)$$

$$V = 0.0821 gT/M$$

[11] A mole is the molecular mass of a substance expressed in g. Thus, for methane, 1 mole is 16g. The molecular mass is therefore expressed in g/mol, which is numerically the same with units of kg/kmol.

Converting to volume/s and mass/s gives

$$Q_{LG} = 0.0821gT/M$$

where Q = volume flow rate of landfill gas in m^3/s
g = mass flow rate in kg/s
T = absolute temperature of gas in K
M = molecular mass = 27.2 kg/kmol for landfill gas (60% methane)

The constant in this equation (0.0821) has units and is derived by combining the individual constants for known parameters.

Since this ICoP assumes that landfill gas has a maximum of 60% methane by volume, the volume release rate of methane only is:

$$Q_{CH4} = 0.0493gT/M \qquad \textbf{Equation 2}$$

where Q_{CH4} = volume flow rate of methane in m^3/s *assuming 60% methane v/v.*

Note that the molecular mass of *landfill gas* is used, because the calculation is for the volume release rate of landfill gas, which is then multiplied by 0.6 to convert to a *methane* release rate.

For percentages of landfill gas other than 60%, the value of Q_{LG} can be calculated using the values of molecular mass in the table below and then multiplying by the appropriate value to obtain Q_{CH4}.

Table 1: variation of molecular mass with % methane

% methane	30	40	50	60	70	80
M (kg/kmol)	35.6	32.8	30.0	27.2	24.4	21.6

4.5.3 Zone radius equation for outdoor releases

The zone radius can be calculated directly from the following empirical equation:

$$x = (1840Q_{CH4}/kE_{\%})^{0.55} \qquad \textbf{Equation 3}^{S}$$

where x = zone radius (assumed a sphere) in m
1840 = constant of proportionality derived from the empirical formula – this constant is not dimensionless
Q_{CH4} = volume flow rate of methane in m^3/s calculated from equation 2
k = safety factor applied to the LEL
0.5 for secondary grade releases *or*
0.25 for primary grade releases
$E_{\%}$ = lower explosive limit in % v/v

This equation takes account of obstructions caused by proximity to the ground, walls or other objects. It is only applicable to freely-ventilated outdoor locations and assumes a wind-speed sufficient for turbulent diffusion. EN 60079-10 section 4.4.5(a) states that 2 m/s is a minimum for this mechanism, whereas the minimum wind-speed that can be relied upon virtually continuously is only 0.5 m/s. Thus, the wind speed is not always sufficient for equation 3 to be fully applicable, so some ‘layering’ will occur at low wind-speeds. However, in view of the low pressure assumed (350 mbarg) and with the safety factor (k) included, this equation gives an acceptably conservative result for area classification purposes.

The zone radius is measured from the point of release in all directions, and is thus independent of the density of the release.

4.5.4 Worked example 1 to find the zone radius from a leaking flange

This worked example uses equations 1 to 3 to find the zone radius from a leaking flange on pipework containing landfill gas at 350 mbarg and 10°C.

Step 1: use equation 1 to calculate the mass release rate, g

$$g = 1500\ C_d\ A\ (MP/T)^{0.5}$$

where
- g = mass flow rate of landfill gas in kg/s though a leak
- C_d = constant = 0.8 for most releases
- A = cross-sectional area of the orifice in m^2 = 0.25 mm^2
- M = molecular mass = 27.2 kg/kmol for landfill gas
- P = gas pressure in bar gauge (barg) = 0.35 barg
- T = absolute temperature of gas upstream of orifice in K = 283 K

Thus $g = 1500 \times 0.8 \times (0.25 \times 10^{-6}) \times (27.2 \times 0.35/283)^{0.5}$

$= 5.51 \times 10^{-5}$ kg/s (rounding up)

Step 2: use equation 2 to convert g to a volume release rate, Q

$$Q_{CH4} = 0.0493gT/M$$

where
- Q_{CH4} = volume flow rate of methane in m^3/s
- g = mass flow rate in kg/s = 1.95×10^{-5} kg/s as calculated in step 1
- T = absolute temperature of gas in K = 283 K
- M = molecular mass for landfill gas = 27.2 kg/kmol

Thus $Q_{CH4} = 0.0493 \times 5.51 \times 10^{-5} \times 283/27.2 = 2.83 \times 10^{-5}\ m^3/s$

Step 3: use equation 3 to find the zone radius, x

$$x = (1840Q_{CH4}/kE_{\%})^{0.55}$$

where
- x = zone radius in m
- Q_{CH4} = volume flow rate of methane calculated in step 2 = $2.83 \times 10^{-5}\ m^3/s$
- k = safety factor applied to the LEL = 0.5 (for a secondary grade release)
- $E_{\%}$ = lower explosive limit in % v/v = 4.4

Thus $x = (1840 \times 2.83 \times 10^{-5}/[0.5 \times 4.4])^{0.55}$ = 0.127 m, which will be rounded up to **0.2 m**

4.5.5 Worked example 2 to find the zone radius from a gas well venting freely

This worked example assumes that the gas well is not under pressure but is in a steady-state venting situation whereby the entire production, taken as 30 m^3/hour, is venting to atmosphere. This gives the zone radius around a Bentonite seal that has completely failed.

Equations 1 and 2 are not required since the volume release rate (Q_{CH4}) is already known. Using equation 3:

$$x = (1840Q_{CH4}/kE_{\%})^{0.55}$$

where
- x = zone radius in m
- Q_{CH4} = volume flow rate of methane, which is 60% of 30 m^3/h
  = 18 m^3/h = 18/3600 = 0.005 m^3/s
- k = safety factor applied to the LEL = 0.5 (for a secondary grade release)
- $E_{\%}$ = lower explosive limit in % v/v = 4.4

Thus $x = (1840 \times 0.005/[0.5 \times 4.4])^{0.55}$ = 2.197 m, which will be rounded up to **2.2 m**

4.5.6 When to use the calculation method

Zone extents for general situations involving leaks of landfill gas in outdoor locations can most easily be found by combining the equations above in a spreadsheet[12]. Examples where the calculation method is appropriate are:

- ♦ sample points
- ♦ dipping points
- ♦ leaks from Bentonite seals

where the parameters are other than those given in the examples in this ICoP.

Do not use the calculation method for joints and valve glands, since section 5.3 deals with these.

In line with the precedent in IGE/SR/25, the zone extents calculated have been rounded up to the nearest 0.1 m where the value is less than 10 m. However, this does not imply that the accuracy of the method is such that results to ±0.1 m can be obtained.

5 AREA CLASSIFICATION FOR LANDFILL GAS EXTRACTION

5.1 Overview of landfill gas extraction

This part of the Landfill ICoP deals with all aspects of the extraction of landfill gas, up to the booster. Drilling is to be covered in ICoP 4. Once wells have been drilled and connected to the main pipework system, landfill gas is extracted at a small underpressure (up to 150 mbarg), although there are a number of situations when this underpressure cannot be assumed, such as when a well is isolated from the collection pipework for maintenance reasons or when a high oxygen content is detected causing the well to be isolated and no longer subject to extraction.

5.2 Uncapped landfill sites

In sites or parts of sites that are uncapped, landfill gas generated within the waste will find its way to the surface and escape to atmosphere. The release of landfill gas is not uniform over the whole site, since fissures in the ground, underground obstructions, etc. will force the gas to take the route of least resistance to the surface, resulting in an uneven release distribution over the surface of the site.

This natural gassing process is a continuous grade release and could result in a flammable gas/air mixture on reaching the surface, but it is clearly impractical to assign a zone 0 over the entire uncapped mass. Where the landfill gas is escaping into a well-ventilated open location, as is the case over the vast majority of the site, then there is no risk of explosion and an ignition is highly unlikely to have a serious consequence. Higher release rates may be encountered, for example, close to:

- ♦ exposed drainage blankets
- ♦ exposed protection layers
- ♦ zones around leachate extraction structures
- ♦ areas of generally poor compaction

Therefore, although the phenomenon will be recognised, the zone will be assumed to be of negligible extent[13] and will not therefore appear on area classification drawings[14]. Routine FID[15] testing indicates significant concentrations only within a few centimetres of the ground; these are rarely within the flammable range.

The same approach will be used for the disposal of other flammables apart from landfill gas, such as solvents, aerosols, etc. Where these are included in the bulk compacted waste, they can also lead to gas or vapour emissions at the surface, but these will also be considered to give rise to a zone of negligible extent. The environmental issues are outside the scope of this document, which deals exclusively with the area classification implications.

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12 Electronic copies of the spreadsheets may be obtained by contacting ESA.

13 It is possible that a significant release rate could occur in some places (hence a zone of significant extent), but these locations are difficult to predict; experience over many years has shown that such higher-rate releases have not caused injury due to accidental ignition, so such an event can be assessed as presenting an acceptably low risk.

14 Care should be taken, however, to ensure that such gas cannot collect in enclosures on the surface, particularly those with a source of ignition, such as mobile generators (used for electrofusion (EF) welding), lighting, permanent structures.

15 FID = Flame Ionisation Detector

5.3 Zoning around flanges, screwed fittings, joints and valve glands

Guidance in IGE/SR/25 section 5.2.1.3 indicates that, for pressures up to 2 barg, a 0.5 m zone 2 is applicable around all joints and valves located in a freely-ventilated outdoor location and not subject to adverse conditions such as thermal shock, excessive vibration, etc.. This is to take account of unintentional leaks.

However, the actual maximum pressure of landfill gas is 80 mbarg in the collection side and up to 350 mbarg in the power generation side. Smaller zone radii of 0.1 m for all pressures up to 80 mbarg and 0.2 m up to 350 mbarg can be calculated using the equations in section 4.5 assuming a leak aperture of 0.25 mm^2 (the typical leak size from IGE/SR/25 section 5.2.1.1).

These zone radii may be applied where pipework is correctly-installed and regularly inspected. Where adverse conditions may apply (e.g. vibration, corrosion) and pipework is *not* regularly inspected, then the zone 2 radius of 1 m from IGE/SR/25 Table 1 should be used.

An inspection interval of not more than 6 months is recommended based on guidance in IGE/SR/25 Appendix 4, Tables 13 and 15.

Note: due to the potentially corrosive nature of landfill gas, metal pipes are more vulnerable to chemical attack from inside than plastic pipes.

Orifice plates (manufactured, for example, by Perflow) can be treated as a pair of flanges for the purpose of area classification.

Electro-fusion (EF) couplings and butt-fusion welded joints are highly reliable and are not considered as a source of release. The installation of pipework using this technique may involve working on 'live' pipes that are blocked using a 'pig'[16] or by squeezing[17] – this and other construction/maintenance activities are outside the scope of this ICoP.

There are some instances where uncertified electrical equipment is already installed within the zone from a flange, e.g. a flow meter or slam-shut valve. The use of uncertified equipment in zoned areas is dealt with more fully in ICoP 1[18]. However, to facilitate the risk assessment of whether uncertified equipment may remain in a zone 2 area, the information below may be useful.

Compared to the IGE/SR/25 code, guidance in IP15 section 5.4.5.1 allows a more relaxed approach to joints and valves in certain circumstances. The relevant extract is quoted below:

> "For both individual flanges and valves, the likelihood of a release from an individual item is very unlikely and may not warrant classification as hazardous. If a risk-based approach is followed, such items may not require a specific hazardous area and only when there are a number of possible leak sources together .... should this area be classified. As a guide, where there are greater than 10 leak sources (from valves and flanges) within close proximity (i.e. where the zone 2 areas overlap), the area should be classified as a zone 2 area."

In the landfill industry, pressures are low and, on the collection side, the gas is usually at an underpressure. Even where the gas is at an overpressure, there are no operations leading to thermal shock or pressure hammer and the pipes are generally well-protected. There is usually low occupancy. Non-classification of joints and valves aligns with the general principle adopted in section 5.2, whereby releases from uncapped areas (which could exceed the release rate from a flange or valve in certain cases) are also not classified. These factors may assist in deciding whether an uncertified item of electrical equipment needs replacing or not.

5.4 Sampling

5.4.1 In-waste gas extraction wells

Sampling is normally performed by opening the sample point (a 3 mm diameter hole) and attaching a flexible tube that allows a small volume of gas to be drawn through a hand-held gas analyser. The flammable gas is then vented to atmosphere. This will produce a zone 1, but of negligible extent.

16 A 'pig' is an inflatable bladder that is inserted into the gas main and inflated forming a gas-tight seal

17 Refer to the relevant safe operating procedure

18 Note, however, that *new* equipment must be ATEX-marked.

Sampling is a normal operation and opening the sample point would normally be classified as a primary grade release, but the underpressure reduces this to a secondary grade release, since sampling is not normally undertaken when an overpressure exists. The sample point may be left open, in which case landfill gas at up to 80 mbarg overpressure can escape through a hole of diameter 3 mm. Calculations based on the equations in section 4.5 give a zone 2 radius of 0.6 m for dilution to 0.5 LEL.

Intrinsically safe gas analysers are used on some but not all sites. Consideration should be given to the risk of using an uncertified gas analyser. Although outside the scope of this document, it is noted that the major risk from an ignition (itself a low risk) is a situation when the gas being sampled is within its explosive range, potentially allowing a flame to burn back into the pipe.

5.4.2 Perimeter monitoring boreholes

Perimeter monitoring boreholes are a special case: see section 5.9.

5.5 Dipping points

These are located on most gas wells and knock-out pots. Typically, a 1" plug is removed and a dipping probe lowered in. The operation takes a few minutes.

As with sampling, dipping is a normal operation and would normally be classified as a primary grade release, but the underpressure reduces this to a secondary grade release, since sampling is not normally undertaken when an overpressure exists. Landfill gas at up to 80 mbarg overpressure can escape through a hole of outside diameter 25 mm/1" (internal diameter 17 mm). Calculations based on the equations in section 4.5 give a zone 2 radius of 3.6 m for dilution to 0.5 LEL for this orifice size. A larger 50 mm/2" plug (internal diameter 34 mm) gives a 5.8 m zone 2.

This zone radius exceeds that calculated for leaks around the Bentonite seal (2.2 m - see section 5.6.2) and will be unacceptably large for certain locations. If the 3.6 m zone is impractical (e.g. there is fixed uncertified electrical equipment encompassed by the potentially explosive atmosphere), there are a number of possible options, for example:

Option 1: wait until the well is at an underpressure before performing the dipping;

Option 2: isolate the nearby fixed electrical equipment;

Option 3: perform a risk assessment (by a qualified person) to determine whether it is acceptable to allow the nearby fixed electrical equipment to remain energised.

Where dipping does extend the 2.2 m zone 2, it can be justified by being performed under a safe operating procedure that ensures potential ignition sources (e.g. vehicles) are excluded from the larger zone while dipping is in progress.

5.6 Vertical gas well and wellhead

5.6.1 Description of operation

The gas well is the primary point of landfill gas extraction from the waste. It consists of two sections:
1 a vertical perforated well liner
2 the wellhead
as shown in Figure 1 below.

The lower section of the well liner consists of a perforated polyethylene (or similar) pipe surrounded by gravel. The upper section is constructed from solid pipe and is sealed into the landfill cap with an inorganic clay-type material (e.g. 'Bentonite' or similar).

The wellhead consists of an interface fabrication and regulating valve. The valve may be a butterfly type fixed between flanges or a ball or gate type with threaded connections. Flexible joints are usually fitted where the wellhead enters the liner and between the wellhead and the gas collection pipe.

Where 'dipping' is required, the wellhead is terminated in a blank flange that is fitted with a screwed 1" (25 mm) BSP plug – this can be removed for dipping the gas well – see section 5.5.

In normal operation, the gas well is operated under a suction not exceeding 30 mbar. Air ingress cannot be reliably prevented and the presence of air in the landfill gas must be considered as part of normal operation, even though inadvisable. Air ingress is more likely in older landfill sites or on uncapped areas of active sites. Air ingress may be via the waste, the Bentonite seal, the mechanical joints or the sample taps (which may be damaged or inadvertently left open).

An overpressure is possible under foreseeable abnormal conditions, which may occur relatively frequently. This can be caused by an operator noticing a high oxygen content and closing the valve connecting the gas well to the collection pipework. An overpressure slowly builds up as the landfill gas is generated within the waste. A typical overpressure will not exceed 10 mbarg, with a maximum value of 80 mbarg recorded (excluding 'catastrophic' conditions). 80 mbarg has been used in calculations.

Since an overpressure is a relatively common malfunction, the area classification of the areas surrounding the well will assume that an overpressure exists for more than 10 hours a year.

5.6.2 Zoning

The following releases are identified:

Continuous grade releases:
- none

Primary grade releases:
- air ingress into the landfill gas[19] via the waste mass or otherwise resulting in a mixture within the flammable range

Secondary grade releases (leak outwards only when an overpressure exists):
- Bentonite seal – leaks due to drying out and poor compaction
- sample taps – opening for sampling**
- flanged cover – leaking gasket*
- valve flange – leaking gasket*
- valve stem – leaking seal*
- joints on flexible hose (clips)*
- threaded pipe connections used on temporary gas collection systems*

** For sampling, see section 5.4.
* For leaking gaskets, valves and other connections, see section 5.3.

A well sunk in new waste is likely to contain a potentially explosive atmosphere. Once in production, the inside of the gas well is designated a hazardous area because ingress of air into the gas well is not uncommon and this could result in a potentially explosive atmosphere. Ingress results from a poor Bentonite seal or air being drawn in via the landfill. In addition, older gas wells may have significantly higher oxygen levels than fully productive wells. For this reason, the interior is designated a zone 1. A zone 2 is not appropriate since an explosive atmosphere could occur for more than 10 h/yr.

The gas well is usually under suction, so emissions of landfill gas will not normally occur even if there is a leak path. However, if the landfill gas is too rich in oxygen, the well may be isolated, in which case the pressure of landfill gas builds up inside and can leak out.

Of the secondary grade releases, leaks from the Bentonite seal or sample points give the largest mass release rates. However, the probabilities of these two events are different.

Leaks from Bentonite seal: such a release requires two abnormal conditions: the well being at overpressure and failure of the seal. Area classification does not normally consider two independent abnormal events, but a well at overpressure is unlikely though possible in normal operation. Therefore, leaks from the seal will be considered.

[19] Normally, a primary grade release implies the fuel gas leaking into the air. However, the landfill gas is at a lower pressure than the air, so leaking of air into the landfill gas is, technically, a "release". It is primary grade because, although unwanted, it occurs relatively frequently.

Quantifying the leak aperture is difficult. A foreseeable failure mode would be the opening of a fissure, the size of which cannot be realistically estimated. The worst case would entail the entire well production to be lost via the seal.

A steady-state situation will be assumed, whereby the entire well production leaks out (estimated at a maximum of 30 m^3/h). This volume flow rate equates to a mass flow rate of 0.0094 kg/s. A zone radius calculation based on equations in section 4.5 gives a zone 2 of 2.2 m in all directions from the point of release. This zone 2 encompasses smaller zones from sampling and leaks. [A maximum leak rate of 25 m^3/h gives a zone radius of 2 m.].

Some gas wells have different maximum yield rates. Provided the worst-case yield can be reliably predicted based on experience and/or measurement, then the zone 2 around the gas well has the radius shown in Table 2 below. Note that the lower values generally apply to pin wells rather than gas wells.

Table 2: zone radii around wells due to failure of the Bentonite seal

Release rate of well (m^3/h)	**Radius of zone 2 (x metres)** (rounded up to 0.1m)
1	0.4
2	0.5
3	0.7
4	0.8
5	0.9
10	1.3
15	1.6
20	1.8
25	2.0
30	2.2
40	2.6
50	3.0

Note that dipping may increase the zone extent beyond that from the Bentonite seal where smaller values from the above table are taken.

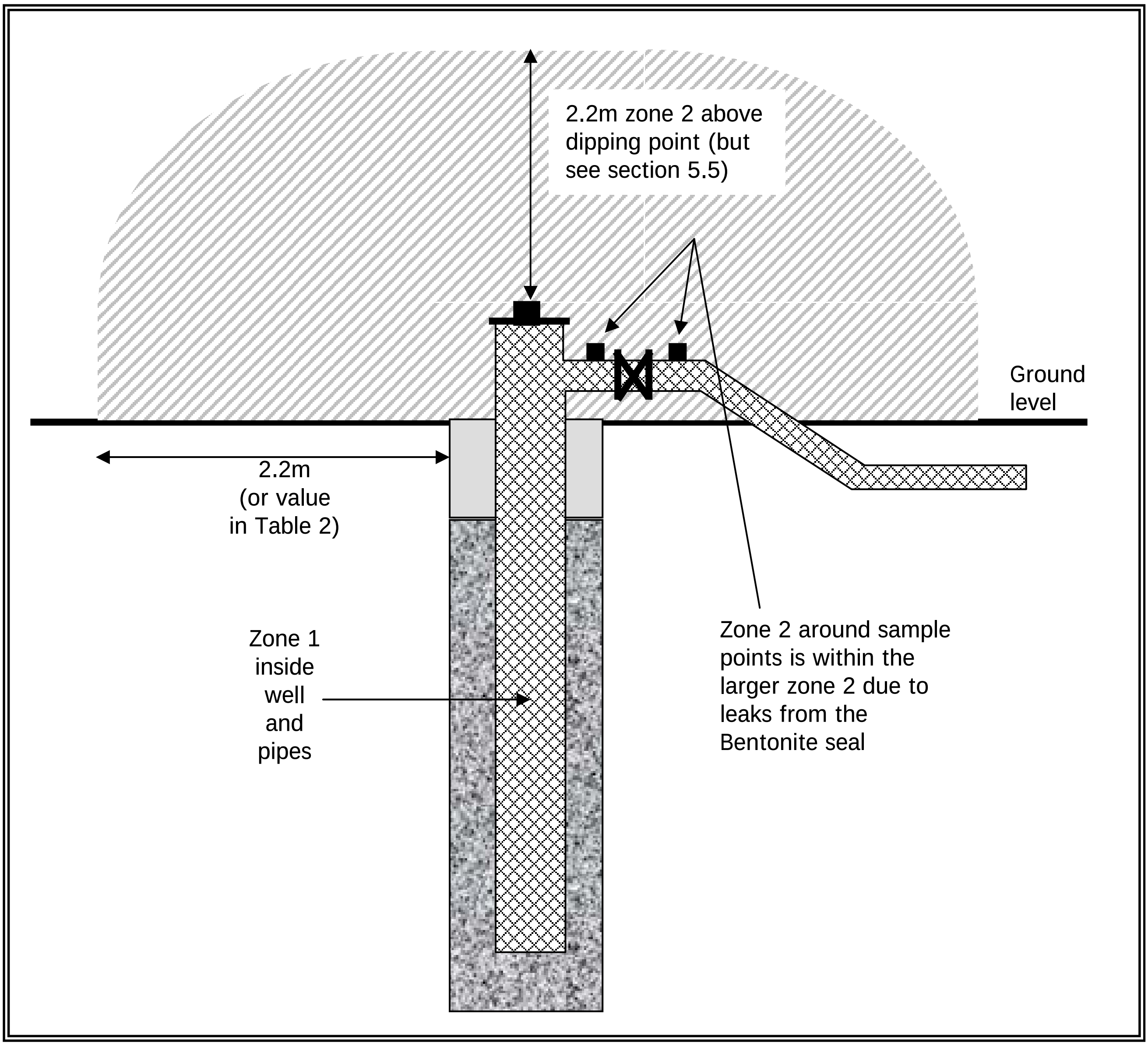
Where the Bentonite seal is assessed as *not* subject to complete failure (e.g. increased depth, stable waste), a smaller zone may be assigned, equal to that of a flange. However, other releases (e.g. sampling, dipping) should still be considered.

Not all gas wells use a Bentonite seal. In some cases, a well is drilled through the plastic membrane (typically medium density polyethylene, MDPE), and the hole 'repaired' by being stitched to a collar on the well itself, providing a gas-tight seal.

Yet another method is using a geosynthetic clay liner (GCL), comprising a hessian-based mat that can seal holes caused by movement of the gas well.

These are relatively new technologies, so it is not possible to determine whether failure of these types of seal should be treated as a secondary grade release (leading to a zone 2, as for Bentonite) or as 'catastrophic' (i.e. highly improbable), leading to a non-hazardous area around the seal.

Figure 1: zoning for an exposed vertical gas well at up to 13 mbarg



5.7 Pin wells

5.7.1 Pin wells in uncapped areas

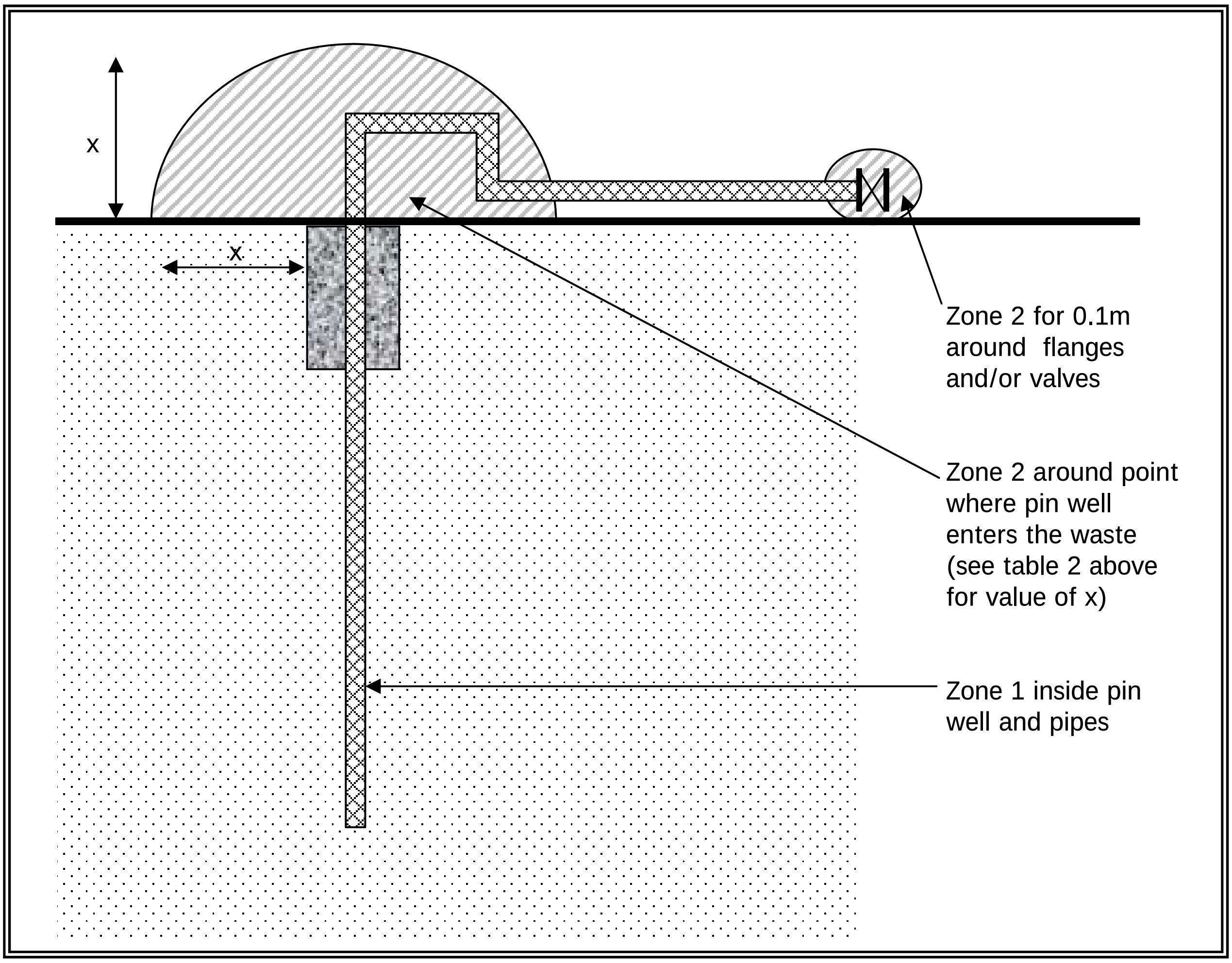
Refer to Figure 2. A pin well is constructed by piling a metal spike (typically 6 m in length) into the waste, then withdrawn and a section of pipe inserted. Bentonite is sometimes used to seal around the hole, or they may be punched through the waste without further sealing. The pipe is slotted or perforated for the bottom 4-5 m and on the surface is connected to a valve. Like the gas well, it should be classified as zone 1 internally. They are generally temporary or sacrificial and may eventually be covered over as the filling depth increases; they are as little as 8 m from each other.

There are no external continuous or primary grade releases. The two secondary grade releases associated with pin wells are:

- valve seal
- leaks through the Bentonite seal

A small zone 2 is required around the valve seal – see section 5.3. The yield from a pin well is likely to be much less than from a gas well: a value of 5 m^3/h is taken as a maximum. If this leaks out around the side of the pipe, the zone radii from Table 2 above can be applied, depending on the release rate of the pin well. Refer to section 3 for a discussion of hydrogen generation.

Figure 2: zoning for a pin well



5.7.2 Pin wells in capped areas

Pin wells in capped areas are treated as gas wells (see section 5.6), i.e. a zone 2 for 2.2 m horizontally and vertically around the seal.

Since pin well installation is usually undertaken by outside contractors, this activity is currently outside the scope of this ICoP but is being dealt with in conjunction with the relevant bodies.

5.8 Gas Scavenger Pipes (horizontal gas wells)

The area classification of gas scavenger pipes is as for gas wells.

5.8.1 Description

Gas scavenger pipes are generally used as `sacrificial' or temporary landfill gas collection systems and are the horizontal equivalent of a pin well. They are normally installed in temporary/uncapped active areas of the landfill, or as secondary/back-up landfill gas collection systems.

Scavenger pipes generally consist of fusion-welded pipes laid horizontally and perforated by drilling holes. Scavenger pipes are spaced according to the site-specific conditions – this may be typically from 5 to 20 metres. A length of solid pipe is used at the point where it leaves the waste mass to prevent air being drawn into the pipe. A seal is then formed between the waste mass and the pipework using either Bentonite (or equivalent) or an HDPE (or similar) sleeve-type coupling (known in the industry as a 'top hat').

Scavenger pipes normally terminate in a valved connection in a collection manifold chamber (see section 5.12).

In normal operation, due to the relatively high risk of air ingress through the waste, suction on scavenger pipes is likely to be less than 10 mbarg, although site-specific applications may dictate the use of higher levels of suction. In a fault situation, where gas extraction is lost, pressure within the scavenger pipe may rise typically to 80 mbar above atmospheric. In this situation leakage may occur at the rubber coupling or where the pipe exits the ground. There is also likely to be leakage through the uncapped waste above.

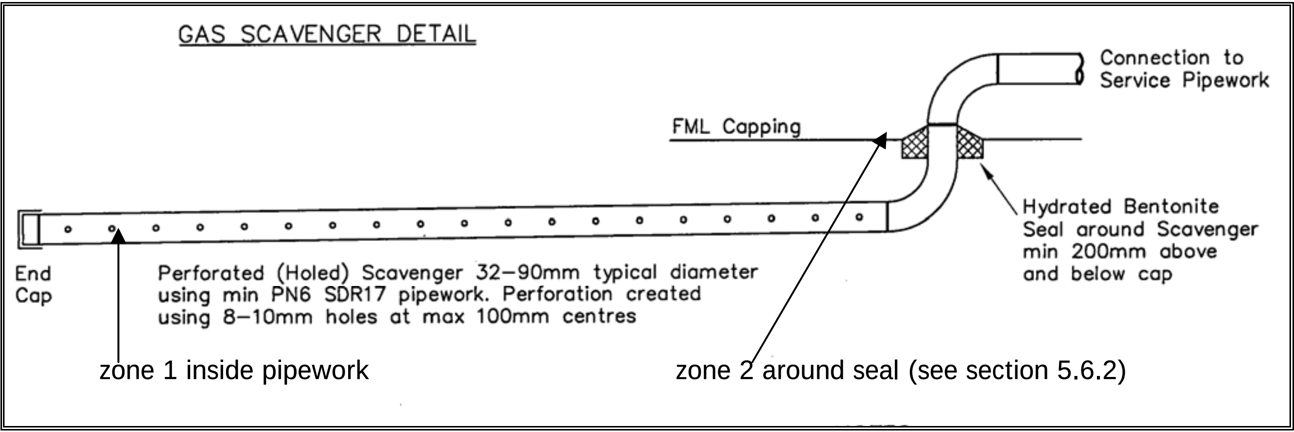
Gas scavenger pipes are normally very low maintenance. Operations may consist of taking gas samples, although this will more often be carried out at the gas collection manifold. Maintenance operations may include the connection and disconnection of scavenger pipes or repairs to any pipework damage.

Note that some scavenger pipes (or wells) are installed then covered with more waste, in which case the situation outside the pipe is similar to an uncapped landfill area – see section 5.2.

5.8.2 Zoning

Internally, the scavenger pipework is zone 1, for the same reason as the gas well. A zone 2 occurs where the scavenger pipe comes through the lining for connection to the main gas collection pipework. The radius of the zone 2 is the same as for the Bentonite seal of a gas well, i.e. 2.2 m (see section 5.6).

Figure 3: zoning for a typical gas scavenger pipe



5.9 Perimeter boreholes

These are outside the waste boundary and are used to measure potential landfill gas migration. They are not usually connected to the extraction system but are capped. There are other potential sources of methane apart from that derived from waste, e.g. mines gas, peat gas or marsh gas. On some sites, there may be waste adjoining the controlled area that has been previously tipped.

The landfill gas may be above the LEL but only a small volume is contained in the borehole itself. On older or less well-engineered sites, the pressure within the borehole may be influenced by the gas extraction taking place in the adjacent cell. In this case, the borehole may be at an underpressure. On newer or better-engineered sites, the boreholes are unlikely to be influenced by the extraction of the landfill gas from the waste and hence at a slight overpressure.

Where individual perimeter boreholes are known to have a history of consistent or frequent elevated levels of landfill gas above the LEL, a zone 1 should be applied internally. Otherwise, a zone 2 applies.

A 3 mm orifice is typical for manual sampling. There are also systems with continuous automatic sampling.

The overpressure is much less than the peak of 80 mbarg assumed for gas wells. The external zone caused by opening the sample point are dependant on the overpressure and can be taken as 0.3 m up to 6 mbarg. Perimeter boreholes may also be opened for water sampling or extraction – a different-sized zone applies for this and should be calculated on a site-specific basis.

5.10 Leachate extraction points

5.10.1 Description

Leachate extraction points are primarily designed to remove liquid (leachate) from the base of the engineered 'cell' (a subsection of the whole landfill void). However, landfill gas is also harvested. They are generally installed along the slope of the wall of the cell or as vertical chambers within the waste mass; they key into the leachate drainage blanket.

There are various orientations: horizontal, side slope risers and vertical. The various types are identical to each other in terms of the area classification, and also similar to gas wells. What follows is a typical example, the principles of which can be applied to other types of leachate extraction systems.

The pipe is commonly a wide-diameter jointed pipe with no flanged joints between the top and the leachate collection chamber, which is a horizontal section of pipe, extending a number of metres, with perforations in the pipe. Inside this is a leachate pumping main.

A pump[20] is located in the leachate chamber, in addition to a trigger device[21]. The trigger device is used to monitor the levels of leachate at that point. An alternative to this method is to have a separate pipe placed next to the side riser pipe in which the trigger device may be located. At a pre-set level, the pump automatically switches on and pumps the leachate up the internal pipe. Once it reaches a pre-determined lower level, the pump will automatically switch off.

The control system for the pump is located above ground, usually in the vicinity of the leachate extraction point.

Internal pressures are variable but in normal operation the system would be under vacuum, typically 40 mbarg. When no gas extraction is taking place, positive pressures up to 80 mbarg could be present.

5.10.2 Zoning

Refer to Figure 4. This assembly resembles a gas well and the same area classification generally applies, with a zone 1 above the liquid level and a zone 2 below. There is an external zone 2 of 2.2 m around the seal – see section 5.6. As for the gas well, removal of the dipping cap when the leachate riser is at an overpressure gives an unacceptably large potentially explosive atmosphere with a radius of tens of metres, so the cap should only be removed under a maintenance procedure. Refer to section 5.5 for the possible options.

Below the water level is zone 2 by default. However, if the control system[22] to prevent the pump from becoming unsubmerged is considered to be of a high reliability type, then the region below the liquid level may be classified as non-hazardous. Alternatively, if a top-fill pump is used and suitable measures[23] are taken to ensure it does not fall over when lowered into the well and pump itself dry (thereby becoming a potential ignition source), the region below the liquid level may also be classified as non-hazardous.

Leachate is water-based but it is possible it could contain flammable liquids if such liquids have seeped down through the waste. However, compared to the volume of landfill gas evolved, any potentially explosive atmosphere from leachate vapour is likely to be within the zones defined for landfill gas[24].

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20 Electric, air-driven or other pumps may be used.

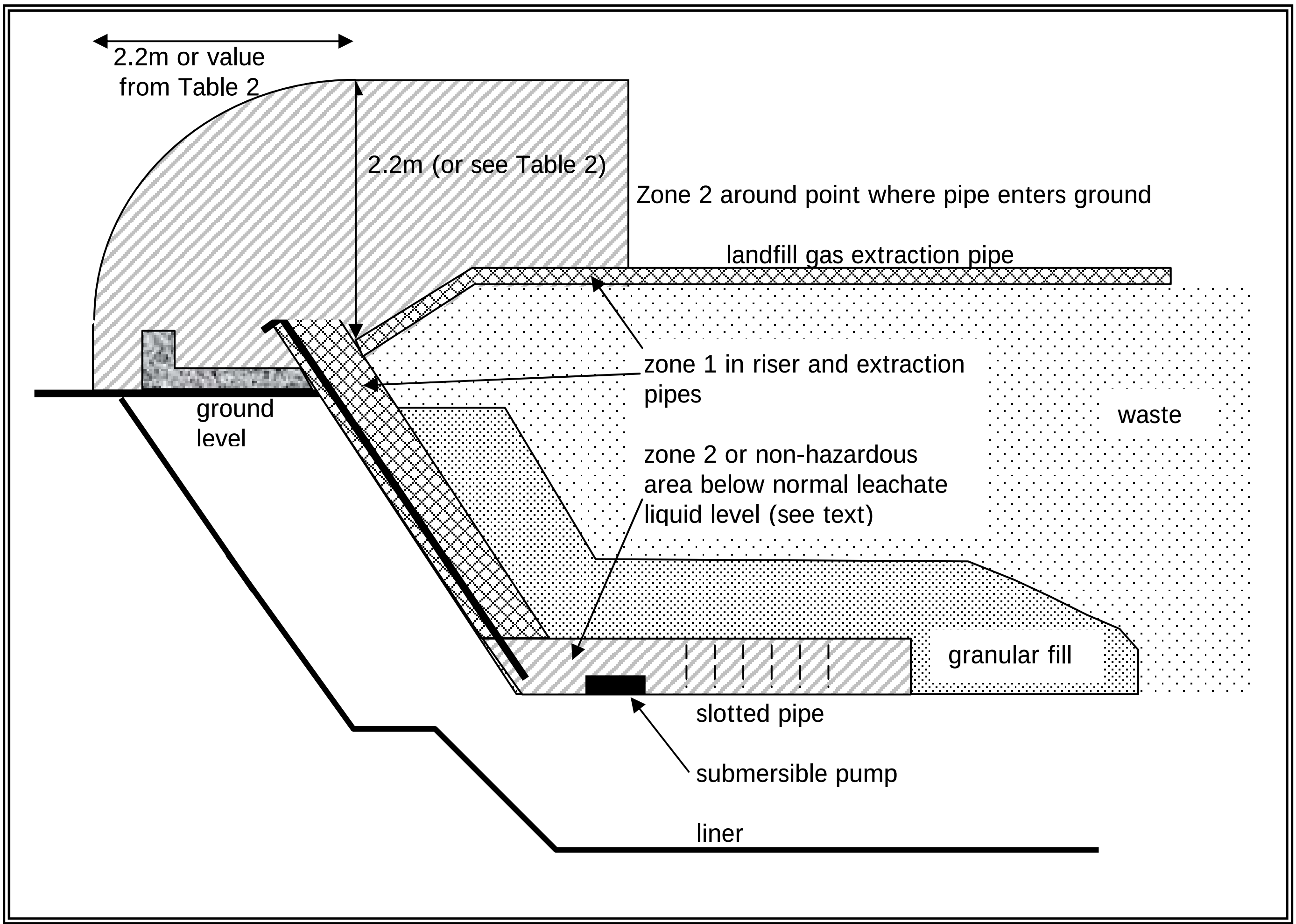
21 The trigger device could be a transducer, float switch, etc.

22 An appropriately-certified transducers or another means (e.g. undercurrent protection.) of detecting the 'pumping dry' situation are also appropriate if assessed as sufficiently reliable.

23 Such measures might be, for example, securing the pump on a 'sledge' prior to being offered into the opening of the leachate extraction point; the pump is secured in such a way that it cannot turn over when presented and located in the side riser. For vertical wells, the pump could be supported at the top until it reaches the bottom of the well and therefore cannot turn over.

24 The presence of low flashpoint liquids in the leachate at high ambient temperatures could lead to a vapour/air mixture that exceeds the zone defined for landfill gas. Refer to the relevant ICoP for leachate extraction and treatment.

Figure 4: zoning for a leachate riser



5.11 Leachate recirculation injection

This facility involves penetrating the capping so, as in the case of gas wells and leachate extraction wells, there is the possibility of leaks around the seal. A zone 2 typically of radius 2.2 m applies – see section 5.6.

5.12 Gas collection manifold

5.12.1 Description

The gas collection manifold is of HDPE (or similar) or steel fabrication and is the point where the collection pipes from individual or groups of gas wells are joined together prior to connection to the main gas collector pipeline. Gas quality can be regulated and flow rate adjusted by a valve on each individual pipeline joining the collection manifold. A further regulating valve is located at the exit pipe to the manifold. Generally, sampling valves are fitted to each individual gas pipe entering and exiting the collection manifold.

There are two basic variations:

1 open design, used for above-ground manifolds that do not require protection from unauthorised access

2 enclosed design used for above-ground manifolds that require protection and also below ground manifolds

The enclosed manifold is located within a chamber constructed of plastic or steel sheet. The chamber is normally fitted with a solid cover or lid. Whilst this type of cover does not offer a good degree of ventilation, open mesh or ventilated covers tend to allow flooding or silting up of the manifold chamber.

In normal operation, the manifold is under suction, up to 150 mbarg. Fault conditions such as damage to a main collection pipe or loss of the gas extraction system may result in the gas pressure within the collection manifold rising to above atmospheric (maximum 80 mbarg). However, an overpressure within the manifold pipework is a much rarer event than in an individual gas well.

5.12.2 Zoning

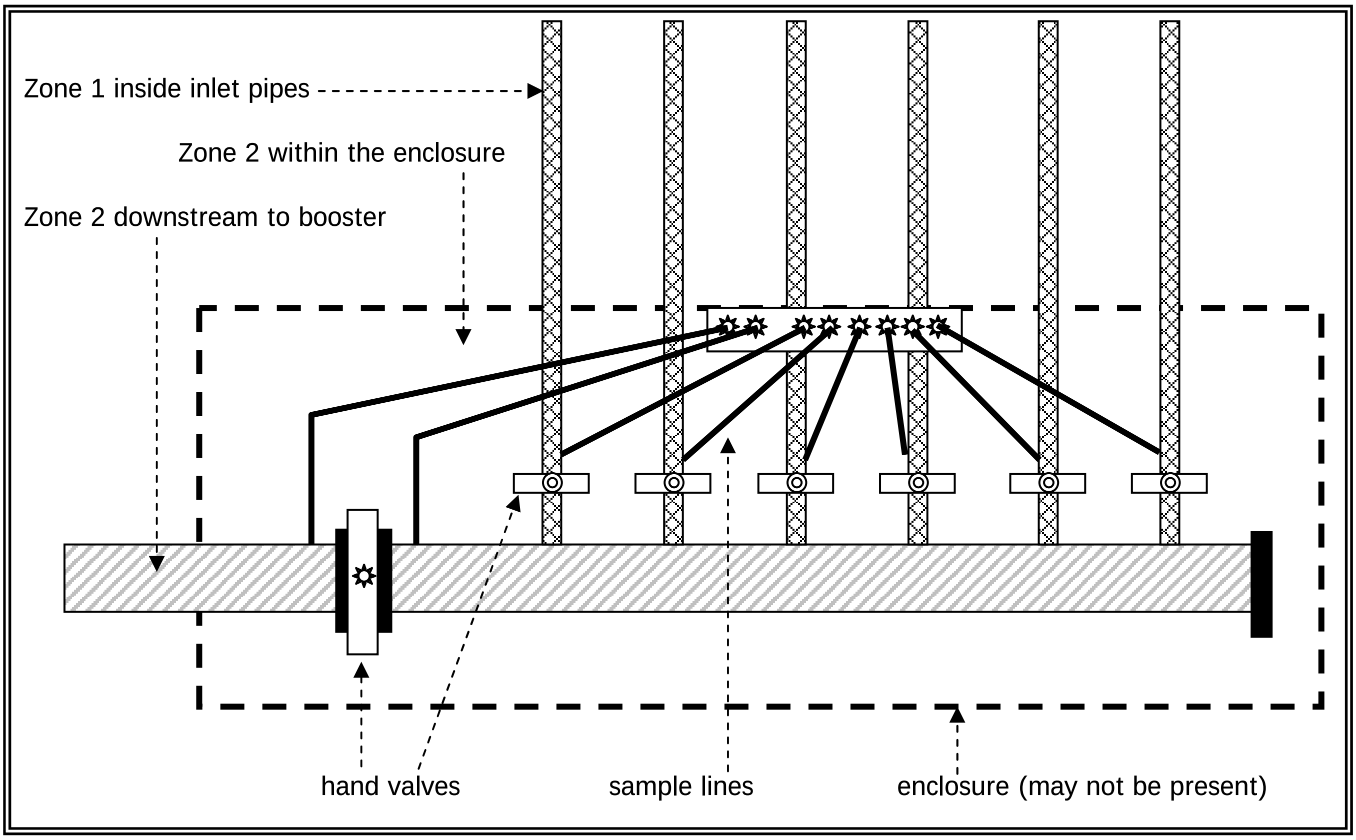
Refer to Figure 5. For reasons already explained, the pipework in the gas wells is designated as a zone 1 internally due to the possible ingress of air. However, at each point where the output from two or more wells is combined, the probability of the mixture being within the explosive range falls. At some point in the collection pipework, a less onerous zone is appropriate. It is convenient to designate the manifold as the point at which this change of zone takes place, so the interior of pipework from the manifold valve downstream all the way to the booster should be designated as a zone 2. However, the zone 1 extends from this manifold to the carrier main if the manifold only has one active pipe or because flammable concentrations are detected relatively frequently, e.g. in old sites with lean gas.

Externally, the potential releases are secondary grade:

- flanges
- gas sampling valve stems
- condensate drainage plugs
- sample points
- flow monitoring points

As stated above, an overpressure within the manifold pipework is a much rarer event than in an individual gas well, and, for a release to occur, a failure of the containment is also required. Therefore, no zone is applicable around flanges and valves. Removal of the drainage plug, opening of the sample point and flow monitoring point should not be done if the system is at an overpressure, so, again, no external zone is required. In spite of this, the enclosure, if it exists, will be designated a zone 2, since the ventilation is poor and any release would dissipate very slowly[25].

Figure 5: zoning for a pipework manifold



[25] Due to the possibility of a dangerous level of landfill gas in the enclosure, there should be limited personnel access, which should only by under a permit-to-work.

5.13 Pipework from manifold to booster

The pipework internally from the manifold (typically) to the booster is classified as zone 2. There are, however, situations on a small number of plants (typically just after a shut-down) in which it is not possible to state with certainty that an explosive mixture within the pipe does not exceed 10 hours a year. Therefore, in a limited number of cases, it will be necessary for the operator to confirm (for example by means of methane monitoring) that instances of feed gas within the explosive range are sufficiently rare to justify a zone 2 designation internally.

It should be noted that, once the booster is switched on, the time during which it is exposed to a 'slug' of explosive gas/air is relatively short, even though this mixture could have been resident in the pipe for a much longer time. Therefore, it is unlikely that the booster will need to be rated for better than a zone 2 application.

5.14 Knock-out pots

Description

The pot is constructed from polyethylene (or similar) and acts as an in-line condensate collection vessel, which is located typically at low points within the main gas service carrier. During normal operation, the pot will be under suction ranging from 40 – 150 mbarg. An overpressure up to 80 mbarg is possible under abnormal conditions.

There are three basic variations, which are identical from an area classification perspective:

1 pumped KO pot
2 vacuumless KO pot
3 barometric drain KO pot

The condensate is not considered to be a source of release due to the low solubility of methane in water. It is collected in the pot and is pumped out. Typically, the pump is automatically-activated when the condensate level reaches a certain level and switches off when the liquid is at the required low level. The pump remains submerged except under abnormal conditions. There may be control systems in the KO pot.

Dependant upon the design, there may be a balance pipe between the main body and the inner sleeve to maintain equal pressures in both areas.

The top of the knock out pot is housed within an enclosure with an opening lid.

Zoning

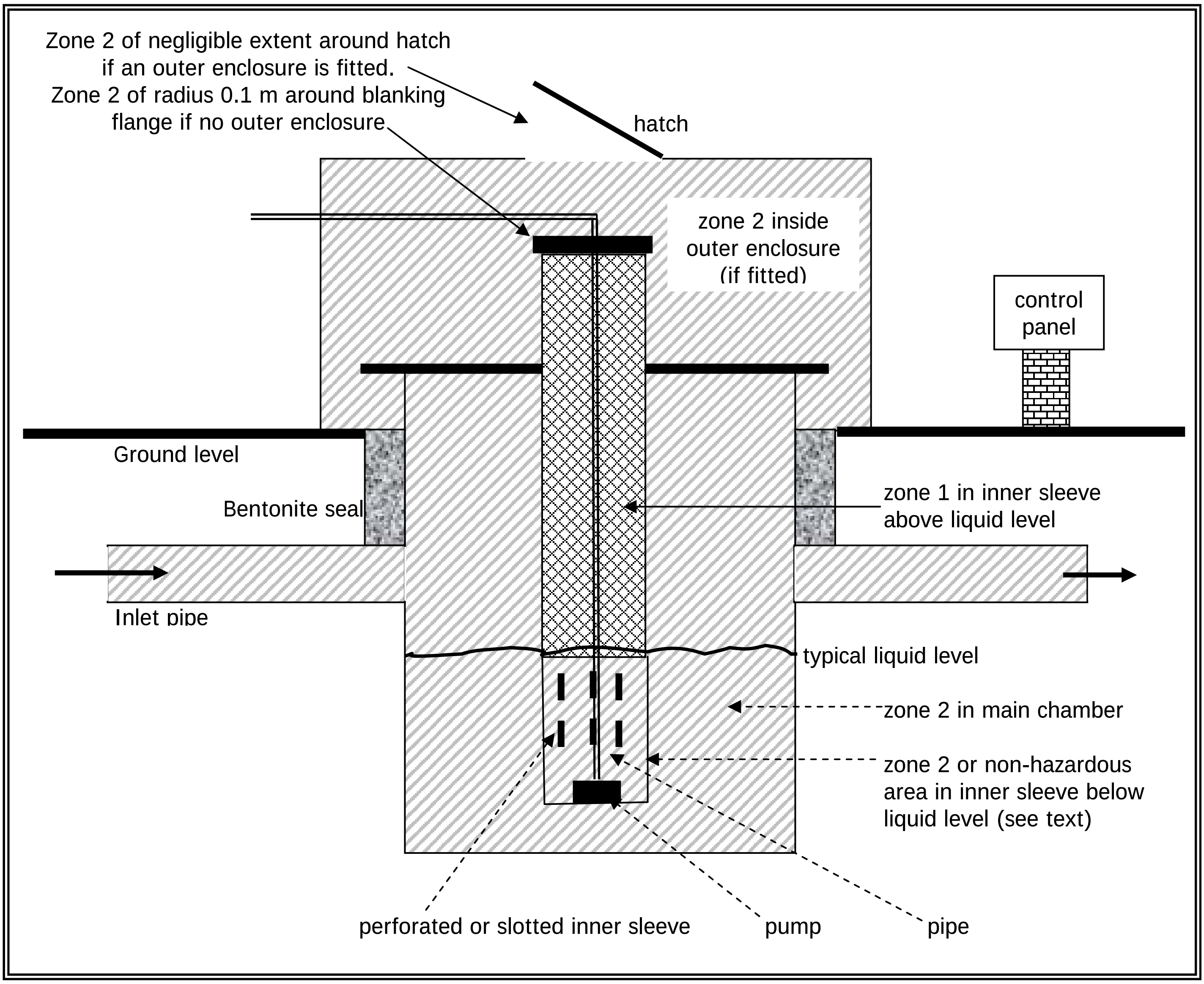
Refer to Figure 6. For reasons explained in section 5.13, the pipework at this part of the system is a zone 2. Therefore the main chamber of the knock-out pot is also zone 2. The zoning of a typical knock-out pot is shown below.

The inner sleeve (if it exists) usually contains air. However, if the condensate is pumped out to below the level of the perforations, then landfill gas can enter the inner sleeve and, if the level of condensate rises again, it will be trapped along with the air. This mixture could be within the explosive range and cannot readily dissipate, so will persist. Thus, a zone 1 rather than a zone 2 applies for the inner sleeve above the liquid level, zone 2 below. However, if a top-fill (as opposed to a bottom-fill) pump is installed below the liquid level and there is further protection against the pump becoming unsubmerged by means of a level transducer, then the area below the liquid level is a non-hazardous area. Refer to section 5.10.2 for further information.

Leaks into the outer enclosure over the knock-out pot (via imperfectly-sealed cable entries or other routes) are unlikely because the gas underneath is normally at an underpressure (main section) or ambient pressure (inner sleeve). Two faults are required (gas pipe at an overpressure and failure of the seal) for this enclosure to have an explosive atmosphere in it but the ventilation is poor and, as a precaution, a zone 2 will be designated, with a further zone 2 of negligible extent around the hatch.

Note that some knock-out pots are sunk into waste, in which case there is a zone around the Bentonite seal – see section 5.6.2.

Figure 6: zoning for a typical pumped knock-out pot



5.15 Passive vents

Modern installations do not include vents but some existing sites have these, typically using 150 mm (6") pipe. The vent is a static or aspiromatic (rotating) cowl and normally has a flame arrestor fitted. The discharge height is typically between 1 m and 3 m. Vents are only installed in relatively unproductive areas where the gas quality is low, so flow rates are low and pressure is limited. The flow rate is unlikely to exceed 5 m^3/h. Based on this value and the equations in section 4.5, a zone of extent 1.3 m radius is applicable for dilution to 0.25 LEL. This will be a zone 0, since gas emission is a continuous grade release.

5.16 Drilling operations

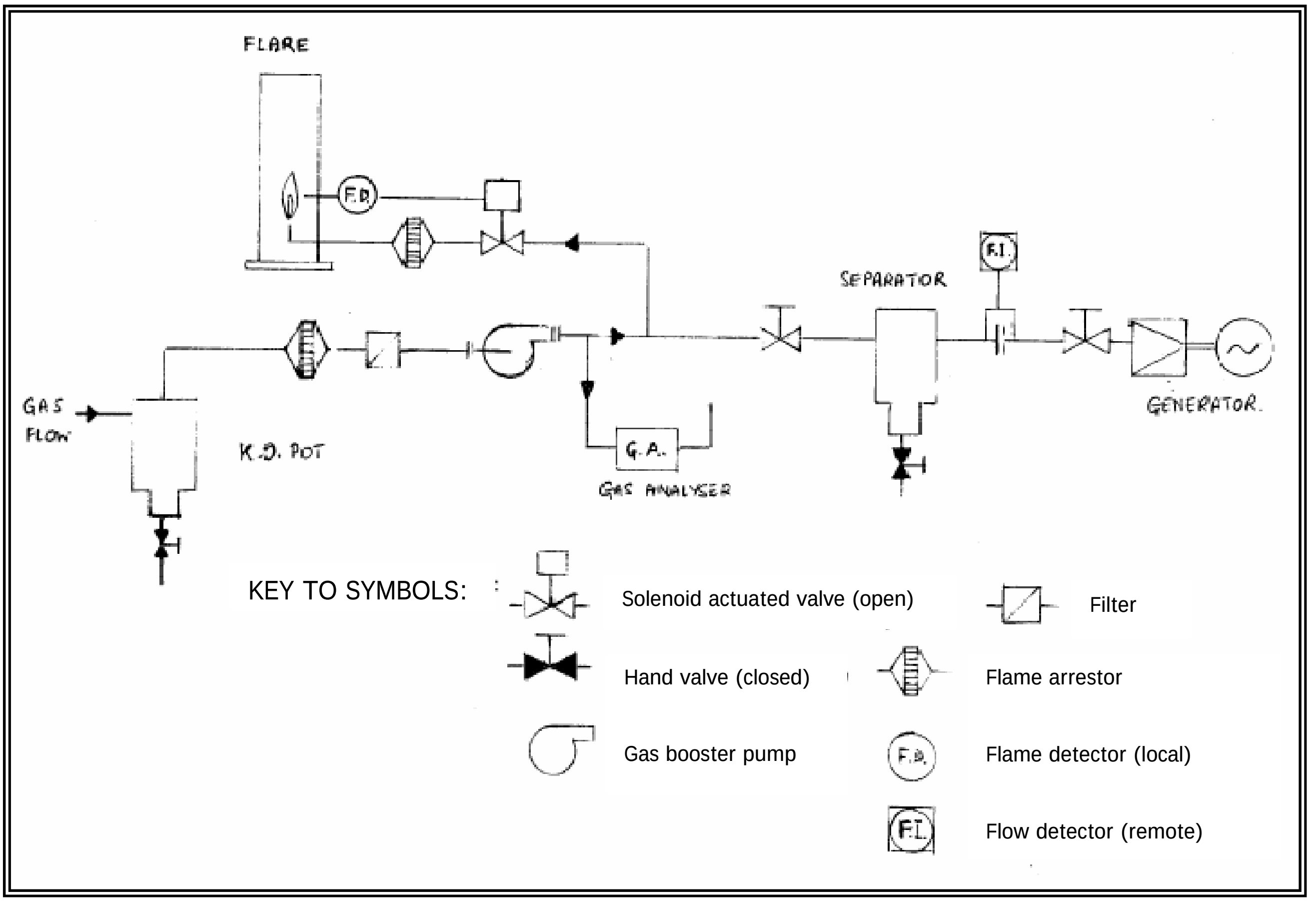
Since drilling operations are usually undertaken by outside contactors, this activity is currently outside the scope of this ICoP but is being dealt with in conjunction with the relevant bodies. An ICoP covering this

6 AREA CLASSIFICATION FOR LANDFILL GAS UTILISATION AND COMBUSTION

6.1 Overview of power generation from landfill gas

The following section of this Landfill ICoP deals with all aspects of the landfill gas from the booster onwards. Landfill gas is extracted at a small underpressure (up to 150 mbarg) supplied by the booster, which then generates an overpressure (up to 350 mbarg) for reciprocating engines. Reference section 6.10 for higher pressure systems. This may be regulated to a lower pressure (typically 150 mbarg) for the Landfill Gas Generation Sets (LFGs) used to generate electricity. Power generation from landfill gas typically takes place in a fenced 'Gas Management Compound'. A typical process flow is as follows.

Figure 7: typical process flow in a gas generating compound



If the feedstock becomes contaminated with oxygen up to a pre-determined level (or the level of methane falls too low for whatever reason), the mix to the engine becomes too lean and generation stops[26], usually diverting the feedstock to a flare. Due to the large number of feeder wells to a particular booster, it is highly improbable that the feedstock will actually contain enough oxygen to be within the flammable range, but, for the reasons given in section 5.13, the interior of the pipe to the booster is classified as a zone 2. For this reason, flame arrestors are fitted.

This is a relatively new industry and the majority of plants have been installed since the mid-nineties. Consequently, the equipment is modern and generally follows the latest thinking with regard to ventilation and the installation of explosion-protected equipment where necessary. Older plant may need to be up-graded.

26 The gas below certain calorific value cannot be utilised in the engine, so either low methane or high oxygen (air) content could trigger sending landfill gas to the flare or vent it if it is not possible to flare it safely (<25% CH4)

Consideration should be given to gas generating compounds built on former landfill sites since the possibility of landfill gas migrating into areas classified as non-hazardous (e.g. switch rooms) has been known to cause an ignition in at least one case.

6.2 Manual sampling

Manual sampling is normally performed by opening the sample point (a 3 mm diameter hole) and connecting a flexible tube that allows a small volume of gas to be drawn through a hand-held gas analyser. The flammable gas is then vented to atmosphere.

Sampling is a normal operation and is classified as a primary grade release, leading to a zone 1. The sample point may be left open, in which case landfill gas at up to 350 mbarg overpressure can escape through a hole of diameter 3 mm. IP15 Table C9(a) gives a 1 m zone for a 4 barg release of gas from a 5 mm hole – the release of landfill gas will be less than this so this value is conservative.

6.3 Continuous gas monitoring

Continuous Gas Monitoring Analysers, where installed, typically have a permanent connection of a 3 mm pipe to the gas main. The analyser is usually located in a small GRP enclosure in the open air. A pump on the analyser pulls through the gas to be sampled, which is then vented to atmosphere via a high-level vent, typically via a flame trap. The inside of the analyser compartment should be classified as a zone 2, with a zone 0 of radius 1.2 m around the vent. To take account of different types of analyser, this zone radius is based on the worst-case assumption of a 350 mbarg pressure via a 3 mm diameter outlet and dilution to 0.25 LEL).

Note: the gas analyser should not be located in an non-hazardous area, such as the control compartment of the engine enclosure. If it is, leakage from the pipework needs to be assessed and a zone extent estimated based on the available ventilation.

6.4 Gas booster – freely-ventilated

The inlet pipe is at an underpressure, so leaks of landfill gas are not considered, thus there is no external zone. Internally, the composition of the gas is such that it is above its upper explosive limit. Very occasionally, it is possible that air can be drawn into the pipe from the waste site, so, to take account of this possibility, the pipework is classified as zone 2 internally. Flame arrestors[27] are typically fitted immediately downstream of the booster.

The only potential releases from the booster itself are flanges (see section 5.3) and shaft seals, both potential secondary grade releases. Shaft seal leaks are especially difficult to quantify, since there are many designs and levels of integrity, ranging from basic to highly sophisticated sealing arrangements. The failure of a 'basic' seal can lead to a significant release of gas whereas, at the other end of the spectrum, a high-integrity seal need not be considered as a source of release. It is therefore recommended that the manufacturer is consulted where necessary to obtain a leak aperture and the zone extent calculated from first principles using the equations in section 4.5. In some cases, a decision can be made that the seal is of sufficient integrity such that failure can be considered 'catastrophic' within the definition in EN 60079-10, i.e. a significant leak[28] (i.e. one leading to a zone of larger than 0.3 m) is highly improbable.

IGE/SR/25 does not deal with seals of this type, but IP15 Table C6 quotes leak diameters the commonest ("Level I"), less common ("Level II") and rare ("Level III") failure modes of different types of pump seal. The 'levels' take account of the fact that there is no single failure mode for seals. IP15 should be consulted for fuller details on how these levels relate to the 'risk-based approach'.

The values in IP15 may be used *where leak diameter information from the manufacturer is not available*. The zone extents calculated for larger shaft diameters are unrealistic. Taking as an example a booster with a single seal with a throttle bush (or an equivalent level of integrity), IP15 gives a leak diameter of 0.1SD for a 'Level I' failure (SD = shaft diameter).

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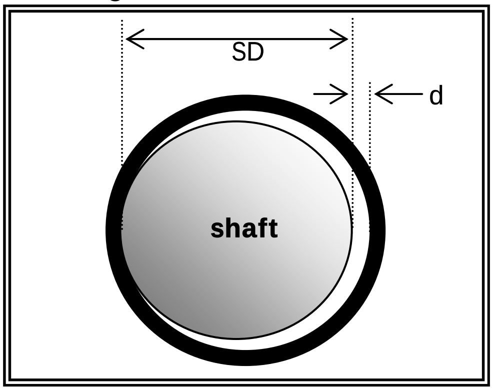
27 Since these devices are required to halt an incipient explosion, they are classed as 'safety devices' under the ATEX 94/9/EC (Product) Directive; future installations should make use of flame arrestors that are ATEX-marked but retro-fitting of ATEX-marked arrestors is not required for existing facilities (installed before 1 July 2003) provided the existing flame arrestor is fit for purpose, correctly installed and appropriately maintained.

28 EN 60079-10:2003 calculation 4 states that a V_z <0.1 m^3 (i.e. a sphere of radius 0.3 m) allows the ventilation to be assessed as degree 'high'. From the definition of degree 'high' in clause B.3.1, a zone of negligible extent results.

Figure 8: shaft leak diameter



The mass flow rate (g) from a failed seal requires the value of the cross-sectional area of the leak (A), where

$$A = \pi ([SD+d]/2)^2 - \pi (SD/2)^2$$

IP15 does not give zone extents at such low pressures, so the zone extents for dilution to 0.5 LEL are calculated from the equations used in section 4.5 of this ICoP. It can be seen from the leak area in Table 3 below that these are unrealistically high, particularly for larger shaft diameters, leading to zone radii that are also unrealistically high.

Table 3: Booster pump at 150mbarg – level I leak (shaft diameters 10 to 100 mm)							
Shaft diameter (mm)	10	15	25	40	50	80	100
Leak area (mm^2)	16.5	37.1	103	264	412	1056	1649
Zone 2 radius (m)	1.1	1.6	2.8	4.7	6.0	10	13

Table 4: Booster pump at 200mbarg – level I leak (shaft diameters 10 to 100 mm)							
Shaft diameter (mm)	10	15	25	40	50	80	100
Zone 2 radius (m)	1.1	1.8	3.0	5.1	6.5	11	14

Table 5: Booster pump at 250mbarg – level I leak (shaft diameters 10 to 100 mm)							
Shaft diameter (mm)	10	15	25	40	50	80	100
Zone 2 radius (m)	1.2	1.9	3.2	5.4	6.9	11	15

Table 6: Booster pump at 300mbarg – level I leak (shaft diameters 10 to 100 mm)							
Shaft diameter (mm)	10	15	25	40	50	80	100
Zone 2 radius (m)	1.3	2.0	3.4	5.7	7.2	12	15

Table 7: Booster pump at 350mbarg – level I leak (shaft diameters 10 to 100 mm)							
Shaft diameter (mm)	10	15	25	40	50	80	100
Zone 2 radius (m)	1.3	2.0	3.5	5.9	7.5	13	16

6.5 Gas booster – enclosed

Where the gas booster is inside an enclosure (typically an acoustic enclosure), there is the additional hazard of an explosion if a gas/air mixture is ignited. This event shall be made sufficiently improbable by supplying a suitable level of ventilation to the enclosure. Releases are secondary grade and therefore, by definition, improbable; ventilation failure is also improbable. Area classification does not normally consider two improbable events happening at the same time, so it is not necessary to consider a leak when the ventilation has failed provided the ventilation is reliable.

To ensure that secondary grade releases do not persist in excess of the time allowed for a zone 2 to be appropriate, IP15 section 6.3.1 requires 12 air changes/hour. This may be produced by forced ventilation or by adequate openings in the structure to allow a sufficient air change rate by natural ventilation. Rather than calculate the extent of the zone within the enclosure, it is simplest to designate a zone 2 throughout the enclosure, with no external extent (since forced or outdoor natural ventilation will rapidly dilute landfill gas from a small leak). A more rigorous approach is to use the equations in EN 60079-10:2003 section B.4.2, which may be used to calculate the hypothetical volume (V_z); if this is negligible[29] (less than 0.1 m^3), then no zone is required.

6.6 Flame arrestor

Flame arrestors can be considered as flanges for area classification purposes – see section 5.3.

6.7 Separator / knock-out vessel

Description

This is typically the last vessel prior to entry into the engine compartment. It is designed to remove the last traces of condensate from the feedstock and should be located outdoors. There are various designs. Condensate is removed either by a manual drain or by a float-operated valve.

The manual drain allows liquid to be removed, but this is usually followed by a small release of landfill gas, which tells the operator that the liquid has all been drained. The tap is closed at this point.

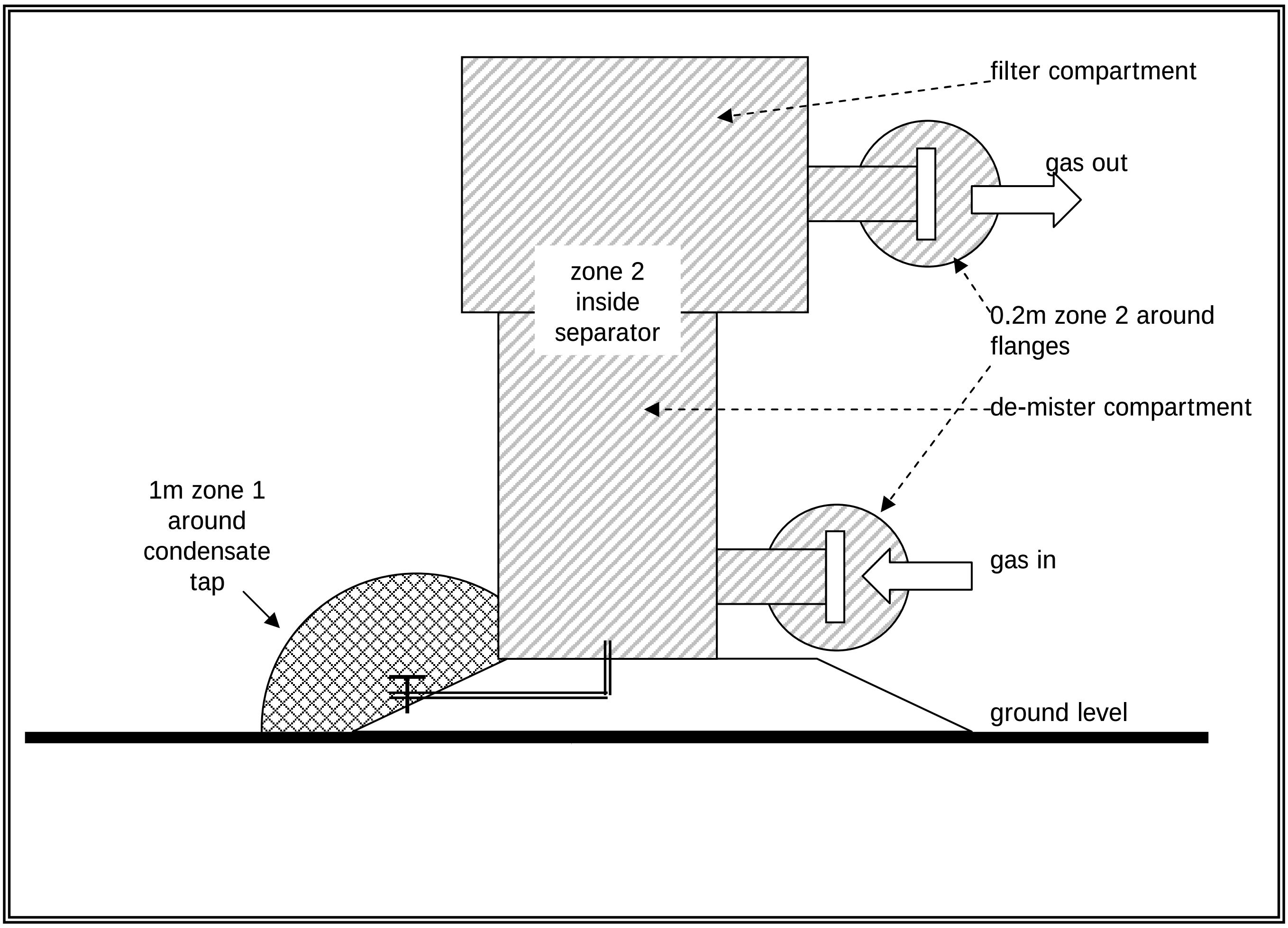
The float-operated valve opens to allow condensate out when the liquid level rises to a certain point. It closes again when the liquid level falls.

29 EN 60079-10:2003 calculation 4, conclusion states that a V_z <0.1 m^3 (i.e. a sphere of radius 0.3 m) allows the ventilation to be assessed as degree 'high'. From the definition of degree 'high' in clause B.3.1, a zone of negligible extent results.

Zoning: manual drain type

Refer to Figure 9. For reasons explained in section 6.4, the pipework at this part of the system is a zone 2. Therefore the main chamber of the separator is also zone 2. A zone 1 radius 1 m is assigned[30] around the drain point to take account of the primary grade release of a small volume of landfill gas. Note that this zone should not impinge on the engine enclosure.

Figure 9: zoning for separator / knock-out vessel with manual drain



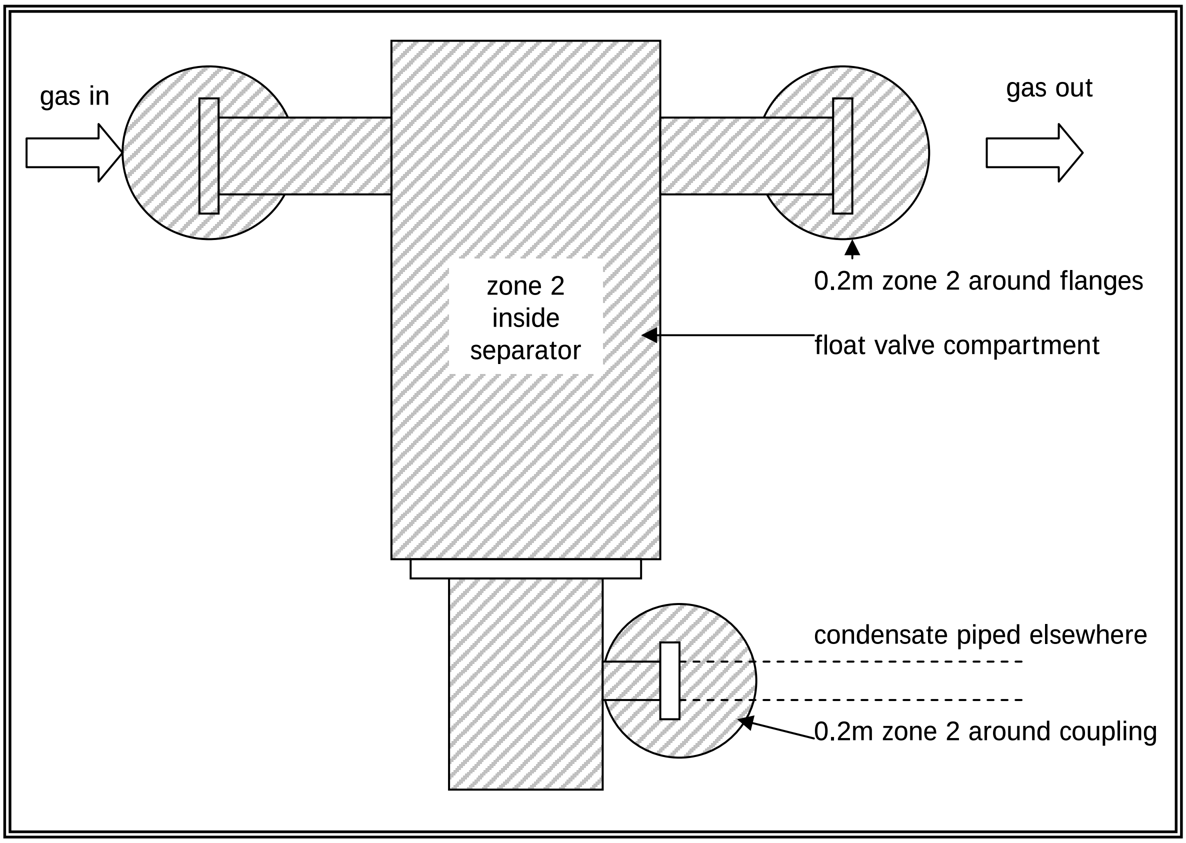
30 IP15 Table C9(a) gives a 1 m zone for a 4 barg release of gas from a 5 mm hole – the release of landfill gas will be less than this so this value is conservative.

Zoning: float-operated valve type

Refer to Figure 10. The separator is a zone 2 internally. This is a sealed system and the only releases are secondary grade around flanges, for which a zone radius of 0.2 m applies (see section 5.3).

The usual failure mode is for the valve to jam shut. It is feasible that the valve can jam open, in which case landfill gas will be released when all the liquid has been drained out. This will be treated as a secondary grade release. The seal may fail to bed properly and give a slow release, so will be treated as a primary grade release and assigned a 0.3 m zone 1. However, these releases do not occur around the separator itself, but should be considered where the condensate pipe ends.

Figure 10: zoning for float-operated valve type separator



6.8 Condensate cyclone/separator

The area classification is the same as for separators.

6.9 In line gas filter systems

An in-line filter comprises a fabricated or cast housing, with a lid and a drain point, and flanged connections to the pipe. Internally, the pipework is zone 2 for the reasons given in section 6.4. All leaks are secondary grade releases and are dealt with in section 5.3.

The lid is removed at intervals (rarely more than annually), but this activity will be performed under a maintenance procedure, so is outside the scope of area classification.

6.10 Gas receivers (pressurised systems, gas compressors)

These items involve gas pressures up to 4 barg and are outside the scope of this ICoP. However, reference may be made to

- HSE Guidance Note PM84[T] – Gas turbines used for power generation
- HSE Information document 482/7[U] - safety of small gas turbines used for power generation.
- IGE/UP/6 – Gas compressors
- IGE/SR/23 – Venting natural gas
- IGE/SR/25 – Hazardous area classification

For general guidance, the zone radii in freely-ventilated outdoor locations for typical leak apertures calculated using the equations in section 4.5 are given in the table below. A pressure of 4 barg and a temperature of 10°C is assumed.

Table 8: zone radii from releases at 4 barg

	Leak aperture (mm²)		
	0.1	**0.25**	**2.5**
	(leak from high integrity joint)	(typical flange or valve-stem leak)	(major flange or valve-stem leak)
zone radius (m) for gas at 4 barg	0.2	0.3	0.9

6.11 Engine enclosures

Engine enclosure fall into three categories:

1 Engine Containers
2 Compartmentalised Engine Halls
3 Open Engine Halls

All new gas engine systems should comply with IGE UP/3. This ICoP deals with all three types provided that:

- Control rooms are separate from the engine compartment and cables passing through dividing walls are appropriately sealed.
- Connecting doors are normally shut (except for access) when the engines are running and landfill gas may be present in the engine compartment.
- They have forced draft or convection ventilation; care should be taken that the inlet for this ventilation should not be located within a zone 2 created by other sources. This ventilation can also be used to supply engine combustion air or this may be sourced independently from a location external to the container.
- Ventilation for the control room is independent of engine hall ventilation and generally is for electrical cooling and personal comfort purposes.
- Engine housings are fitted with appropriately installed and maintained explosive gas detection.

6.11.1 Engine Containers

Typically, this is a metal container with two compartments, one for the control equipment and a larger compartment housing the engine.

6.11.2 Compartmentalised Engine Halls

This is a large engine hall with multiple engine sets. Each set is housed within a separate enclosure with no free air movement between them and other areas. Control units are either located in a common passageway connecting the engine compartments or in a separate control room.

6.11.3 Open Engine Hall

This consists of a large hall containing multiple engine units without any permanent gas tight divisions between engines. Each engine is fed independently with landfill gas, but usually ventilation, air supply and other systems are common. Control rooms and other areas are connected to the engine hall.

6.11.4 Zoning

The larger compartment housing the Landfill Gas Generation Set will have numerous secondary grade releases from joints and seals. There should be no primary or continuous grade releases. Although zoning should be considered, boiler rooms (to which this is similar) have historically not been zoned. As a result, uncertified electrical equipment may be installed. The relevant standard in the UK is BS 5885[V], which states that, "Because of the very low risk of presence of flammable gases in the vicinity of burner pipework and control equipment installed in accordance with this standard and other recognised codes, unless a hazard can exist from some extraneous source then the area may be declared non-hazardous".

6.11.5 Ventilation

To ensure an adequate degree of ventilation, IP15 section 6.3.1 recommends 12 air changes/hour. Every part of the enclosure that contains potential releases should have this level of ventilation, so the total air change rate may exceed 12/h. This is not usually sufficient to reduce the zones to negligible extent. Therefore, where the integrity of the pipework/equipment is in doubt and a risk assessment shows that there is a significant risk to personnel (e.g. where workers are frequently in or around the enclosure), a mitigating measure might be to install gas detection equipment. However, the number and location of detectors is critical, as is the routine calibration and testing. Excessive reliance should not be placed on a system of gas detection without ensuring that it can reliably detect leaks from all the potential leak sources.

6.11.6 Further guidance

The following guidance is outside the scope of area classification but is provided for information.

Most engines take their air from inside the compartment, thus improving the ventilation. However, one of the most likely times for a leak to occur is just after a maintenance operation involving breaking a pipe joint. When the pipework is pressurised again, the engine may not be running and the additional ventilation will not be available. Maintenance procedures should rigorously ensure that there is a suitable level of ventilation during all phases of operation, including maintenance.

Many engine compartments contain the slam-shut valve, so it is possible that a leak from a joint upstream of the valve could release landfill gas into the engine compartment even when the supply is apparently isolated. This should be considered when assessing the ventilation. Ideally, such valves should be located outside the compartment where this is practicable.[31]

6.12 Multi-engine facilities

6.12.1 Open engine halls

The ventilation characteristics of open engine halls are likely to be less well defined compared to bespoke engine enclosures described in the previous section. They should, however, be treated in the same way, i.e. not zoned provided the ventilation is assessed as adequate.

6.12.2 Individual enclosures

As for open engine halls.

6.13 Flares and associated pipework

This section applies to flares without a venting facility. For flares with the facility for venting large volumes of unburnt gas, see section 6.14. There are many designs of flare – the information in this section is for guidance only and a site-specific evaluation will always be required.

Joints and valves associated with a flare will be outdoors and are dealt with in section 5.3. The area classification implications of the flare itself require consideration of possible fault conditions. The pilot is lit by a spark from the igniter. If this does not occur, the system activates the igniter a further number of

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31 Note: on gas engine generating sets with a gas input of 1200 kW (approx. 400 kW electric output), a valve proving system is necessary (IGE UP/3 – Gas Engines). If this check takes place on shut down, the possibility of the upstream valve not fully closing is also protected. Consideration should also be given to items between the proving system and the up stream manual valve. e.g. filters.

times and then shuts down if the pilot does not light. Some systems use permanently-lit pilots (using landfill gas or propane). The unburnt pilot gas is released inside the flare stack, so no zoning is required for this level of flow, since it is in a region usually containing a flame. Only when the pilot is lit is a large flow of gas possible.

If the flame fails, a slam-shut valve operates. Some systems will then automatically go through further ignition cycles, whereas for others this is manually initiated.

For there to be a significant release of unburnt gas, a number of failures are required, so such a situation will be treated as a 'catastrophic' failure[32] of the flare control system and therefore outside the level of probability dealt with in area classification. A risk assessment, however, is required.

There is, consequently, no zone around the top of the flare stack unless the flare control system is so rudimentary that major releases are considered reasonably foreseeable.

6.14 Vents

Various vents occur in landfill gas power generation operations:

1 purge points are used to blow the gas down newly-installed pipe.

2 relief valve vents associated with pumps that do not vent back into the suction side

Venting of new pipework should be carried out to IGE UP/1[W]. Purge points should be sized to suit the IGE UP/1 procedures. Ideally, all purge points should be valved *and* capped or plugged, which avoids the hazardous area consideration in normal plant operation.

Venting of new or re-commissioned pipework is an infrequent, controlled procedure and should be carried out with its own risk assessment (sometimes involving with permit to work procedures). If carried out to the IGE procedure, the activity has a short purge time (a few minutes). The extent of the potentially explosive atmosphere should be monitored and therefore there should be no ignition sources present (e.g. by ensuring that engines, boosters and electrical equipment are all switched off).

For a properly-designed vent, the vented gas will be unimpeded and directed upwards. The main consideration is the possible extent of any 'downward dispersion'[33], since this may affect operations at ground level. IGE/SR/25 quantifies downward dispersion for various pipe diameters and vent heights, but is independent of the maximum release rate, since downward dispersion mainly occurs at low release rates.

Vent pipes with an internal diameter of under 15 mm are not covered in IGE/SR/25.

Table 9: downward dispersion of potentially explosive atmospheres from outdoor venting

Internal diameter of pipe (mm)	**Height of vent (m)**			
	≥1	**≥2**	**≥3**	
	Downward dispersion below vent tip (m)			
	vertically (0.4h + 3d)*			**horizontally** (IGE/SR/25 table 7)
15	1.1	1.1	1.3	0.75
25	1.1	1.1	1.3	1
40	1.2	1.2	1.4	2
50	1.2	1.2	1.4	3

* h = height of vent tip above ground in m; d = internal vent tip diameter in m.

32 See section 4.2.4

33 'Downward dispersion' is the extent of the zone below the source of release for a vent pointing vertically upwards.

APPENDIX 1 REFERENCES

The following publications were referenced in compiling this document:

A Dangerous Substances Explosive Atmospheres Regulations:2002 ('DSEAR') regulation 7 requires area classification to be undertaken

B EN 60079-10:2003 - Electrical apparatus for explosive gas atmospheres - Part 10: Classification of hazardous areas (technically identical to IEC 60079-10:2002)

C Institution of Gas Engineers: IGE/SR/25: Hazardous Area Classification of Natural Gas Installations, 2000

D ATEX Directive 1999/92/EC: Minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres – also known as the 'ATEX 137 Directive' or 'ATEX Worker Protection Directive'

E A. McMillan: Electrical installations in hazardous areas, Butterworth Heinemann, 1998.

F BS 6133:1995 – Code of Practice for the safe operation of lead-acid stationary batteries

G British Compressed Gas Association – numerous codes and guidance notes

H EN61241-10:2004: Electrical apparatus for use in the presence of flammable dust – Part 10: Classification of areas where combustible dusts are or may be present

I HSG51: The storage of flammable liquids in containers, 2nd Edition, 1998

J HS(G)113:Lift trucks in potentially flammable atmospheres, 1996

K HSG103: Safe handling of combustible dusts: precautions against explosions, HSE Books, 2003

L Environment Agency Landfill Directive LFTGN03, Guidance on the Management of Landfill Gas, sec. 6.3.3.

M Environment Agency publication LFTGN03: Guidance on the management of landfill gas, page 53, section 6.2.3, downloaded August 2005.

N Guidance on the Management of Landfill gas, document LFTGN 03, September 2004, Environment Agency

O Guidance for monitoring trace components in landfill gas, document LFTGN 04, September 2004, Environment Agency

P BS EN 1127-1:1998 – Explosive atmospheres – explosion prevention and protection: Part 1: basic concepts and methodology

Q Area Classification Code for Petroleum Installations, Part 15, Third Edition, 2005, Institute of Petroleum (IP15)

R Environment Agency Landfill Directive LFTGN03, Guidance on the Management of Landfill Gas, sec. 6.3.3.

S Sira Area Classification Manual, 2005, chapter 4

T HSE Guidance Document PM84: Control of safety risks at gas turbines used for power generation. June 2000

U HSE Information document 482/7 "Control of health and safety risks from small gas turbines used for power generation

V BS 5885-1:1988: Automatic gas burners. Specification for burners with input rating 60 kW and above (partially replaced by BS EN 676:1997)

W IGE UP/1 Ed 2: Strength testing, tightness testing and direct purging of industrial and commercial gas installations

AREA CLASSIFICATION FOR

LEACHATE EXTRACTION, TREATMENT & DISPOSAL

INDUSTRY CODE OF PRACTICE

ESA ICoP 03, edition 1: May 2006

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FOREWORD

James Barrett, Head of the Manufacturing Sector of the Health and Safety Executive

This code has been prepared by the Environmental Services Association in consultation with the Health and Safety Executive and has been endorsed by the Waste Industry Safety and Health (WISH) Forum which represents the interests of the industry.

This Code should not be regarded as an authoritative interpretation of the law, but if you follow the advice set out in it you will normally be doing enough to comply with health and safety law in respect of those specific issues on which the Code gives advice. Similarly, Health and Safety Inspectors seeking to secure compliance with the law may refer to this Guidance as illustrating good practice.

The HSE believes that the contents of this Code demonstrate good practice in the waste management industry and commends its use.

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-	ESA Health & Safety Working Group
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Marian Kelly	ESA Working Group
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Mark Scanlon	Energy Institute
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In this report, footnotes are indicated with number ([1])
and endnotes (references to documents used) with a letter ([A]).

1 INTRODUCTION AND SCOPE

1.1 Executive summary

This document (ESA ICoP 3) is one of a number called up by the primary document (ESA ICoP 01 – see section 1.3) that, together, advise on how to fulfil the requirements of the Dangerous Substances and Explosive Atmospheres Regulations:2002 ('DSEAR')[A] for the waste management industry. This document is concerned only with leachate, which is a water-based liquid by-product from landfill sites. Depending on the constituents of the landfill mass, leachate may contain sufficient dissolved landfill gas (containing methane) to be able to generate a potentially explosive atmosphere when stored in confined spaces. As a result, DSEAR requires that the process of area classification be carried out to identify where potentially explosive atmospheres could form in leachate extraction, transport, storage, treatment and disposal.

This waste management industry Code of Practice for area classification (referred to throughout this document as ICoP 3) attempts to apply existing codes of practice (CoPs) to the specific situations found in leachate handling. Although the experience of the industry has been incorporated into this document, very little additional research relating to area classification has been done by the industry, so this ICoP 3 aims to apply established area classification methodology to the problem of leachate. This ICoP comprises a set of recommendations only and is not mandatory, but is intended to represent good practice.

Since leachate extraction is frequently associated with landfill gas on landfill sites, this ICoP 3 should be read in conjunction with ESA ICoP 02 (see section 1.3) where appropriate, which deals with the area classification implications of landfill gas itself.

Throughout this ICoP, there are situations covered that may require additional verification of the validity of the assumptions. Site-specific factors should always be considered when applying ICoP 3, e.g.

- ♦ locations where leachate is significantly contaminated with immiscible low-flashpoint liquids;
- ♦ storage facilities for flammable liquids and gases not covered by section 10.

It is envisaged that this Edition will be reviewed and re-issued by the end of 2006. Comments from the industry are welcomed and should be sent to ESA (m-kelly@esauk.org) before 1 July 2006.

1.2 Principal codes of practice referenced

The European code of practice on area classification is EN 60079-10:2003[B], which is technically identical to IEC 60079-10:2002. Section 1 of EN 60079-10:2003 contains the following statement:

> "For detailed recommendations regarding the extent of the hazardous areas in specific industries or applications, reference may be made to the codes relating to those industries or applications".

A number of industry CoPs are available that supplement the information in EN 60079-10:2003 and give more specific guidance for certain industries but no CoP exists specifically for the waste management industry. ICoP 3 therefore aims to provide a standardised approach to the classification of hazardous areas where leachate is handled, based on the principles of EN 60079-10 but also using guidance from other published CoPs where appropriate. The intention is that as many as possible of the standard situations will be included in this ICoP to allow the area classification of leachate facilities to be performed in a consistent manner across the industry by suitably-qualified persons.

The main CoP referenced in addition to EN 60079-10 is the Area classification code for installations handling flammable fluids, Part 15, Third Edition, 2005 ('IP15')[C]. Some of its content is reproduced with permission from the Energy Institute.

Article 7(1) of the ATEX 94/9/EC Directive[D] (enacted in the UK by means of DSEAR Regulation 7) makes area classification a legal requirement throughout Europe and, on a particular site, it is the Site/Facility Manager who holds the final responsibility to ensure it is complied with. The primary purpose of area classification of hazardous areas is to allow the selection of suitable electrical and non-electrical apparatus as well as identifying areas where additional precautions are required as a result of the explosion risk. Within this ICoP, a 'hazardous area' is one in which a flammable gas/air or vapour/air mixture is, or could be, present.

1.3 Scope

ICoP 3 should be applied in the design of new works, the refurbishment of existing works and where no area classification currently exists. This document does **not** consider

- ♦ construction operations
- ♦ drilling operations, for which a safe system of work is currently being developed in association with the relevant bodies;
- ♦ maintenance operations, for which a safe system of work should be applied;
- ♦ catastrophic failures, within the meaning EN 60079-10:2003 (see section 4.2.4);
- ♦ safety issues associated with toxic, asphyxiant or other hazards associated with leachate and the associated gases;
- ♦ activities concerned with flammable materials other than leachate extraction, treatment and disposal;
- ♦ where leachate has significant contamination by low-flashpoint VOCs (as discussed in detail in section 3.2)

In some cases, standard guidance is available apart from that already referenced in this ICoP [E F G H I J K]. Industry guidance has also been produce on general DSEAR compliance (ESA ICoP 1) and area classification on landfill gas abstraction, utilisation and combustion (ESA ICoP 2). However, further guidance is required for situations specific to the waste management industry. Such activities include:

- ❑ Drilling (ESA ICoP 4)
- ❑ Landfill Operations ICoP (ESA ICoP 5) – publication due April 2006
- ❑ Treatment Operations ICoP (ESA ICoP 6) including liquid treatments/solidification, advanced conversion technologies, aerosol destruction facilities
- ❑ Solid waste non-destructive facilities (ICoP 7), including civic amenity (CA) sites, transfer stations and materials recycling facility (MRF)

1.4 Limitations of this ICoP and summary of the approach used

The only flammable material considered in leachate is methane, which can be present in concentrations up to 50 mg/litre[1] (see section 3.1). At such concentrations, small leaks of leachate will not produce enough methane to form a potentially explosive atmosphere of significant size. Therefore, leaks of leachate from seals (e.g. pumps, valves) and pipework joints (e.g. flanges, screwed joints) will be treated as producing a zone of negligible extent, even where the potential leak is indoors. This is because, even in an indoor location, any amount of ventilation, however small, will be sufficient to disperse the very tiny amounts of methane liberated.

Likewise, where large volumes of leachate are stored in an open tank or lagoon, the total amount of dissolved methane may be very large, but methane is only able to escape from leachate at the surface. Therefore, the *rate* of methane release is slow as it is limited by the ability of methane-richer leachate to diffuse to the surface. Thus *no zone will be applied* because the ventilation is sufficient to disperse the methane liberated at the surface. This is true even where the level of liquid in an open tank is well below the rim: the ventilation will be restricted but adequate.

Zoning *is* necessary, however, where methane is liberated from a large volume of leachate in situations of very low levels of ventilation, such as would apply in a closed tank without forced ventilation. The tank is likely to have a vent, but fortuitous air exchange through the vent is not likely to be sufficient to guarantee an adequate degree of ventilation. Where forced ventilation is supplied (as in methane stripping or aerobic biodegradation processes), this does not necessarily remove the requirement for a zone, but the zone will be less onerous (typically a zone 2), to take account of interruptions in the supply of ventilation.

Where the zone extent calculated is excessively large, consideration should be given to further engineering or other methods to reduce the size of the zone.

[1] In theory, concentrations might exceed 50 mg/l of dissolved methane, but since landfill atmospheres typically contain only up to 60% methane gas by volume, dissolved concentrations recorded are usually up to 10 - 15 mg/l of dissolved methane. See http://www.methane-stripping.com/introduction.html and http://www.methane-stripping.com/html/solubility_curve.html

2 GLOSSARY OF TERMS

Term	Explanation
anaerobic reaction	a chemical reaction or a microbial reaction that does not require the presence of air or oxygen
anoxic	without the presence of oxygen
apparatus group	the part of the certification code (IIA, IIB, IIC or II) that indicates the range of gases and vapours for which the equipment is suitable. Equipment marked IIC or II is suitable for all gases and vapours (provided the temperature class is appropriate). IIB equipment is suitable for IIA and IIB gases. IIA equipment is suitable only for IIA gases.
area classification	the process of zoning the site to delineate between hazardous areas and non-hazardous areas
basal seal	clay liner, plastic membrane or other impermeable material underneath the waste, primarily engineered to prevent leachate from seeping into the ground below the landfill.
category 1D	dust-protected equipment that is suitable for installation in zone 20[2]; it may equally be used in zones 21 and 22.
category 2D	dust-protected equipment that is suitable for installation in zone 21; it may equally be used in a zone 22.
category 3D	dust-protected equipment that is suitable for installation in zone 22.
category 1G	equipment with a very high level of protection, suitable for installation in zone 0[3]; it may equally be used in zones 1 and 2. Most Category 1G electrical equipment is protected by intrinsic safety.
category 2G	equipment with a high level of protection, suitable for installation in zone 1; it may equally be used in a zone 2.
category 3G	equipment with a standard level of protection, suitable for installation in zone 2.
condensate	the liquid that forms as landfill gas cools
equivalent diameter D_{eq}^{L}, equivalent release hole diameter	the diameter of the actual release hole assuming it is reduced to an equivalent circular cross section (This concept is used in IP15).
grades of release	see section 4.2.1
flashpoint	the minimum temperature, under standard conditions, at which a flammable liquid produces sufficient vapour to form a potentially explosive atmosphere above the liquid
hazardous area	an area where there is a reasonable probability of finding a potentially explosive atmosphere
immiscible	a liquid that does not mix with another liquid, e.g. water and gasoline are immiscible
leachate	water-based liquid that collects in a landfill site, containing dissolved landfill gas and numerous other contaminants depending on the constituents in the landfill mass
lower explosive limit (LEL)	the minimum amount of flammable gas that, mixed with air, will produce a potentially explosive atmosphere; it is usually expressed as a percentage by volume
miscible liquid	a liquid that mixes with another liquid, e.g. water and ethanol are miscible
negligible extent	where the estimated volume of a potentially explosive atmosphere is small (less than 0.1 m^3, equivalent to a sphere of radius 0.3 m)[4], it is defined as having 'negligible extent' and no zoning applies.
non-hazardous area	an area where there is a negligible or extremely low probability of a potentially explosive atmosphere being present; such an atmosphere may be present under catastrophic[5] failure conditions
potentially explosive atmosphere	a mixture of gas and air that is within the flammable range, i.e. between the LEL and UEL

2 Note that equipment should ideally be installed in the non-hazardous area or, if in a hazardous area, in the zone of least risk

3 Note that equipment should ideally be installed in the non-hazardous area or, if in a hazardous area, in the zone of least risk

4 Strictly speaking, a 'hypothetical volume' (V_Z) of less than 0.1 m^3 rather than a zone volume is the criterion for being "of negligible extent". EN 60079-10:2003 calculation 4 (conclusion) states that a V_z <0.1 m^3 allows the ventilation to be assessed as degree 'high'. From the definition of degree 'high' in clause B.3.1, a zone of negligible extent results.

5 See section 4.2.4.

Term	Explanation
temperature class	Equipment is designated with a temperature class, T1 to T6; T6 equipment is the coolest (below 85°C), whereas T1 equipment is the hottest (below 450°C). Gases and vapours are also assigned temperature classes T1 to T6 to allow suitable equipment to be chosen.
upper explosive limit (UEL)	the maximum amount of flammable gas that, mixed with air, will produce a potentially explosive atmosphere; it is usually expressed as a percentage by volume
zones	see section 4.2.2

3 PROPERTIES OF LEACHATE

3.1 Landfill gas in leachate

Leachate is formed when liquid seeps through a landfill and, in so doing, extracts substances from the deposited wastes containing numerous contaminants depending on the constituents in the landfill mass.

Leachate itself is not a flammable liquid. However, the flammable material most likely to be associated with leachate is landfill gas, which is produced by the anaerobic decomposition of organic matter. Landfill gas is a mixture predominantly of methane (CH_4) and carbon dioxide (CO_2) and the methane content makes it flammable. Methane has a fairly low solubility in water, so leachate that contains water as the only solvent will not contain large quantities of dissolved or entrained methane. The presence of organic materials within the water may increase the solubility of methane. Although present in small quantities, methane will tend to be liberated from leachate, the rate of release increased when the temperature is increased or the pressure is reduced. Where methane is released into an unventilated space (such as inside a closed holding tank), it must be assumed that a potentially explosive atmosphere of methane and air could exist above the liquid level unless otherwise proved.

Water industry research has indicated that 1.4 mg/litre[M] of methane dissolved in leachate is sufficient to form a flammable methane/air mixture above the liquid. A factor of safety of 10 has generally been imposed by the water industry[6], so leachate with concentrations above 0.14 mg/litre[7] should be considered as presenting a flammable risk.

Measurements within the waste management industry indicate that concentrations up to 50 mg/litre[N] can occur, although this is very rare. The solubility of pure methane in water without organic contaminants is approximately 22mg/litre[8], depending on conditions. However, when leachate is in contact with landfill gas, the maximum measured level of dissolved methane is approximately 15mg/l, since landfill gas is not pure methane. Leachate that is discharged under consent into (foul) sewers is generally required by water companies to have a methane concentration below 0.14 mg/litre. In order to achieve this, leachate may need to be treated – a process known as 'methane stripping'. Other treatment processes may also be required before the leachate can safely be released and these may also reduce methane concentration, so, if the methane concentration is adequately reduced, methane stripping will not be required as a separate process.

3.2 Other flammables in leachate

Leachate could pose a flammable risk where volatile organic compounds (VOCs) such as petrol or solvents have been disposed of in the landfill mass rather than to a specialist disposal facility. However, since July 2004, the disposal of liquid wastes has been prohibited to all landfill sites (non-hazardous and hazardous). Nevertheless, many (co-disposal) landfills had accepted liquid wastes before this date. The principle of co-disposal was that the liquid wastes were applied to wastes that contained sufficient unsaturated capacity to adsorb these liquids. In studies carried out on large numbers of samples[O P], no problems in respect to flammable contamination in leachate was found at any site monitored. Thus, it can be deduced that these liquids will have been be completely absorbed in all UK landfills, and furthermore, anaerobic decomposition within the mass of waste will have taken place during the intervening period. Even if, in small pockets of waste, this has not been achieved, evidence suggests that negligible amounts of flammable liquid collect in

6 The same safety factor has been applied by the mining industry, partly due to the flammable risk, but also due to the toxic risk to miners working for long periods in enclosed environments

7 Thames Water, for example, currently require less than 0.1 mg/litre; other thresholds may apply with other water authorities.

8 SRC PHYSPROP database, 2004

UK leachates. Evidence within the industry[9] indicates that leachate samples from municipal solid waste do not exceed permissible concentrations normally set in sewer discharge consents due the presence of oils and greases.

It has been concluded that the presence of significant quantities of solvents is not typical and therefore this code of practice ***will not consider leachate that is contaminated in this way***. Nevertheless, on old sites where drums of VOCs may have been disposed of in the landfill mass in the past, this possibility should be considered and the risk assessed on a site-specific basis by reference to any available site records and the knowledge of those still operating the site. Thus, in this ICoP, the only flammable material considered in leachate is methane from dissolved landfill gas.

3.3 Properties of flammable liquids and gases encountered in leachate handling

Table 1. flammable gases and liquids[10]

Name	**Mol. mass**	**LEL[11] (% v/v)**	**Flash point (°C)**	**Boiling point (°C)**	**Density at stp (kg/m^3)**	**SVP[12] at 32°C (kPa)**	**Apparatus. group**	**T-class (AIT[13])**
butane*	58	1.9	gas	gas	2.4	gas	IIA	T1 (450°C)
diesel fuel[14]	282[15]	0.5	55	>180	820	low	IIA[Q]	T3 (250°C)
landfill gas (60% methane)	27.2	4.4	gas	gas	1.1	gas	IIA	T1 (537°C)
methanol	32	5.5	11	65	791	13.2@20°C 25.0@32°C[16]	IIA	T2 (464°C)
natural gas (assumed methane)[17]	16	4.4	gas	gas	0.66	gas	IIA	T1 (537°C)
propane*	48	1.7	gas	gas	2.0	gas	IIA	T1 (455°C)

* LPG is a mixture containing various proportions of, predominantly, butane and propane.

Where landfill gas is the only flammable hazard, all hazardous area equipment is suitable since landfill gas has the least onerous apparatus group and temperature class. Note, however, that equipment must be correctly selected against other criteria, notably the zone and environmental conditions such as ingress protection requirements.

There are numerous components associated with the decomposition of waste – refer to LFTGN 04[R] which addresses the health and environmental aspects, but not primarily the flammable risk. . However, as this ICoP is concerned only with the flammable risk, the health and environmental aspects are beyond the scope of this ICoP.

3.4 Properties of activated carbon dust

Activated carbon dust (referenced in section 8.5) is explosive at concentrations above approximately 0.14 mg per litre of air[18]. It has a K_{ST} index of 1, indicating a relatively low rate of explosion pressure rise[19].

9 Enviros have carried out extensive monitoring

10 Data from BS EN 61779-1:2000 except where indicated otherwise

11 LEL = lower explosive limit

12 SVP = saturated vapour pressure

13 AIT = auto-ignition temperature

14 Data from Conoco-Phillips MSDS for auto diesel/DERV

15 Diesel fuel oil is typically a mixture of C10 to C28 hydrocarbons; the estimated molecular mass is based on $C_{20}H_{42}$

16 SVP for methanol from www.s-ohe.com/methanol.html

17 Natural gas is a mixture containing (approx.) methane 88%, ethane 5.3%, higher alkanes 2.7%, nitrogen 3.0%, CO_2 1.5%

18 Data from J T Baker MSDS

19 Data from Cabot Corporation MSDS; the K_{ST} index scale runs from 0 (non-explosible) to 3 (strongly explosible).

4 THE PRINCIPLES OF AREA CLASSIFICATION

4.1 Safety principles

This sub-section is reproduced unchanged from EN 60079-10:2003 section 3.1.

> Installations in which flammable materials are handled or stored should be designed, operated and maintained so that any releases of flammable material, and consequently the extent of hazardous areas, are kept to a minimum, whether in normal operation or otherwise, with regard to frequency, duration and quantity.
>
> It is important to examine those parts of process equipment and systems from which release of flammable material may arise and to consider modifying the design to minimise the likelihood and frequency of such releases and the quantity and rate of release of material.
>
> These fundamental considerations should be examined at an early stage of the design development of any process plant and should also receive prime attention in carrying out the area classification study. In the case of maintenance activities other than those of normal operation, the extent of the zone may be affected but it is expected that this would be dealt with by a permit-to-work system[20]. In a situation in which there may be an explosive gas atmosphere, the following steps should be taken:
>
> a) eliminate the likelihood of an explosive gas atmosphere occurring around the source of ignition, or
> b) eliminate the source of ignition.
>
> Where this is not possible, protective measures, process equipment, systems and procedures should be selected and prepared so the likelihood of the coincidence of a) and b) is so small as to be acceptable. Such measures may be used singly, if they are recognised as being highly reliable, or in combination to achieve an equivalent level of safety. EN 1127-1:1998[S] may be a useful reference.

4.2 Area classification terminology

4.2.1 Grades of release

Potential releases of flammable materials are assigned 'grades of release', which are defined in EN 60079-10:2003 section 2.7 as shown in Table 2:

Table 2: definitions of grades of release

Grade of release	Definition
Continuous:	a release which is continuous or is expected to occur frequently or for long periods *(typically >1000 hours/year)*
Primary:	a release which can be expected to occur periodically or occasionally during normal operation *(typically between 10 and 1000 hours/year)*
Secondary:	a release which is not expected to occur during normal operation and, if it does occur, is likely to do so only infrequently and for short periods *(typically less than 10 hours/year and for short periods only)*

The text in *italics* is not part of the definitions in EN 60079-10 but is additional guidance found in IP15 section 1.6.4. There is no clear definition of 'short periods' as applied to secondary grade releases, but EN 60079-10 Calculation No. 7 implies that a persistence time of less than one hour is consistent with the definition of a secondary grade release.

20 The permit-to-work will include a risk assessment and will also consider procedures for safe systems of work

4.2.2 Zone definitions

The zone number assigned is based solely on the probability of an explosive atmosphere being present in a given location. Three probabilities are recognised as defined in Table 3 below:

Table 3: Zone definitions

High probability	
Zone 0	A place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is present continuously or for long periods or frequently.
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.
Medium probability	
Zone 1	A place in which an explosive atmosphere consisting of a mixture with air or flammable substances in the form of gas, vapour or mist is likely to occur in normal operation occasionally.
Zone 21	A place in which an explosive atmosphere in the form of a cloud of combustible dust in air is likely to occur in normal operation occasionally.
Low probability	
Zone 2	A place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is not likely to occur in normal operation but, if it does occur, will persist for a short period only.
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.

Areas where there is an even lower probability of an explosive atmosphere being present can be classified as non-hazardous but possible catastrophic events[21] leading to the formation of an explosive atmosphere in such areas are subject to a risk assessment.

4.2.3 Relationship between grades of release, zones and installed equipment

In unrestricted open-air locations, the relationship between grades and zones generally apply as shown in Table 4:

Table 4: grade or release / zone relationship

Grade of release	Corresponding gas / vapour zone	Corresponding dust zone
Continuous grade release	zone 0	20
Primary grade release	zone 1	21
Secondary grade release	zone 2	22

21 See section 4.2.4

Equipment manufactured against the ATEX Product Directive is marked to indicate its 'Category'. The category is used to select the zone or zones in which it may be used as shown in Table 5:

Table 5: ATEX category/zone relationship

ATEX Category	Permitted zones of use	Design requirements
1G	0, 1, 2	safe with two independent faults or safe even when rare malfunctions are considered
1D	20, 21, 22	
2G	1, 2	safe when foreseeable malfunctions are considered
2D	21, 22	
3G	2	safe in normal operation
3D	22	

A fuller treatment of DSEAR compliance is covered in ESA ICoP 01.

The grade of release and zone are not synonymous. Poor ventilation may result in a more stringent zone (typical of pits, trenches and indoor situations where ventilation is limited). High levels of ventilation (e.g. local extract ventilation) may be used to allow a less stringent zone classification to be defined.

4.2.4 Catastrophic failures

It is important to note that area classification only deals with reasonably foreseeable events and does not consider highly improbable ('catastrophic') events. EN 60079-10 section 1.1(d) defines 'catastrophic' failures as "beyond the concept of abnormality dealt with in the standard" and lists "the rupture of a process vessel or pipeline and events that are not predictable" as examples. Thus, a 'catastrophic' failure may cause an explosive atmosphere to be present in an area defined by area classification as 'non-hazardous' and such situations are subject to a risk assessment by the operator under other legislation. Catastrophic failures are outside the scope of this ICoP.

Forced ventilation failure is not normally regarded as 'catastrophic', since it is a reasonably foreseeable event. However, the concept of catastrophic failure could be applied to ventilation that is highly reliable (e.g. where a standby fan cuts in if the duty fan fails). In this case, the area classification process need not consider ventilation failure.

Another example of where the concept of 'catastrophic' failure is used in area classification is where two independent abnormal events are required for a potentially explosive atmosphere to exist. Secondary grade releases are, by definition, abnormal. Therefore, failure of the local extraction system at the same time as a leak from, say, a faulty gasket need not be considered.

The *extent* of the zone is dependent on a number of factors, e.g. the properties of the flammable materials, process pressure, leak aperture, ventilation, safety factors applied etc..

The process of area classification, therefore, involves the identification of all flammable materials, the identification and grading of all releases of flammable material, the assessment of the level of ventilation and/or housekeeping and the determination of the resulting types and extents of the zones. The allocation of zones enables the correct equipment, practices and procedures to be applied to protect the health and safety of the workers concerned with the facility.

4.3 Information needed for area classification

Area classification should be carried out by those who have knowledge of the properties of leachate, the process and the equipment, in consultation, as appropriate, with safety, electrical, mechanical and other engineering personnel.

This ICoP gives guidance on the procedure for classifying areas in which there may be an explosive gas atmosphere and on the extent of zones 0, 1 and 2. The area classification should be carried out when the initial process and instrumentation line diagrams and initial layout plans are available and confirmed before plant start-up. Reviews should be carried out during the life of the plant.

An example of a method for recording the area classification is given below in Table 6. Its use is not mandatory but it may be useful where more unusual situations occur.

Table 6: example of table for recording area classification

Plant:						**Drawing:**				**Flammable material:** landfill gas		
	Release			Operating temp. & press.		Ventilation			Hazardous area			
No	Plant item	Location	Grade	°C	mbar	Type	Degree	Availability	Zone no.	Zone radius (m)		See note #
										Vert.	Horiz	
1	see note A	see note B	see note C	see note D		note E	note F	note G	see note H	see note I		see note J
2												

Notes on the use of this table

A Plant item: this means an item, such as a leachate riser, closed tank, etc. and should include the relevant part of the item, for example “interior”, “exterior around hatch”. A single plant item may have two or more lines.

B Location: where the item is physically located, e.g. “gas compound”

C Grade: this refers to the grade of release, i.e. continuous, primary or secondary

D Operating temperature and pressure: the temperature and pressure are likely to be “ambient”.

E Ventilation type: this is natural, artificial or both.

F Ventilation degree: this is high, medium or low. Outdoors, ventilation is ‘medium’ degree, whereas indoors it will be ‘low’ if there is very little ventilation, ‘medium’ with, say, 12 air changes/hour and only ‘high’ where the air flow is so strong as to effectively dilute any release almost immediately to below its LEL, giving rise to a dilution zone of negligible size.

G Ventilation availability: this can be ‘good’, ‘fair’ or ‘poor’. Outdoors, availability is ‘good’; indoors, where forced ventilation is used, it will generally only be 'good’ if there is a standby fan that starts automatically if the duty fan fails.

H Zone number: this can be 0, 1 or 2, as detailed in this ICoP

I Zone extent: the size of the zone, as detailed in this ICoP

J It is important that this is filled in to give a reference to the part of this (or another) document from which the zoning has been derived; also include any non-standard features and/or reasons for deviations from the ICoP.

5 AREA CLASSIFICATION FOR LEACHATE EXTRACTION

5.1 Leachate extraction points

5.1.1 Description

Leachate extraction points are primarily designed to remove leachate from the base of the engineered 'cell' (a subsection of the whole landfill void). However, landfill gas can also be harvested. They are generally installed along the slope of the wall of the cell or as vertical chambers or boreholes within the waste mass.

Most leachate extraction points which were raised with the waste, or installed before waste infilling commenced connect into the leachate drainage system. Most retrofitted bored extraction wells do not connect with the leachate drainage system, and rely entirely on percolation through the waste materials to collect leachate.

There are various orientations: horizontal, side slope risers and vertical. The various types are identical to each other in terms of the area classification, and also similar to gas wells. What follows is a typical example, the principles of which can be applied to other types of leachate extraction systems.

The pipe is commonly a wide-diameter jointed pipe with no flanged joints between the top and the leachate collection chamber, which is a horizontal section of pipe, extending a number of metres, with perforations in the pipe. Inside this is a leachate pumping main.

The common types of leachate extraction systems are pneumatic and electrical. Another type, rarely used since the 1990s, is hydraulic, as in eductors. The following description applies to pneumatic and most electric pump systems. Eductor systems do not possess trigger devices, but are otherwise similar and the sections that follow apply equally.

A pump[22] is located in the leachate chamber and a trigger device[23] is also often installed. The trigger device is used to monitor the levels of leachate at that point. An alternative to this method is to have a separate pipe placed next to the side riser pipe in which the trigger device may be located. At a pre-set level, the pump automatically switches on and delivers the leachate up the internal pipe. Once it reaches a pre-determined lower level, the pump will automatically switch off. The control system for the pump is located above ground, usually in the vicinity of the leachate extraction point.

Internal pressures are variable, but where gas extraction is operative the system would be under vacuum, typically 40 mbarg. When no gas extraction is taking place, positive pressures up to 80 mbarg could be present.

5.1.2 Zoning

Refer to Figure 1 and Table 7 below, both of which deal with the zoning resulting from landfill gas. A fuller explanation of the area classification approach is found in ESA ICoP 2. In summary, the assumption made is that the entire yield may leak out of the well via the Bentonite seal under fault conditions. A maximum yield of 30 m^3/h of landfill gas has been taken as an upper limit for almost all leachate risers, but other yields are possible and Table 7 gives the corresponding zone extents.

A leachate riser resembles a gas well and the same area classification generally applies, with a zone 1 above the liquid level and a zone 2 below. There is an external zone 2 around the seal and a smaller zone 2 around the sample point. However, removal of the dipping cap when the leachate riser is at an overpressure allows the well to depressurise quickly and gives a potentially explosive atmosphere that is short-lived but could be larger than that given in Table 7. Since dipping will often be required on a monthly (or more frequent) basis, it will be necessary in practice to remove the cap even when an overpressure is detected. In this case, a maintenance procedure[24] will be required to ensure that the ventilated gas does not come in contact with a potential ignition source. This can be done by such measures as isolating fixed electrical equipment, the exclusion of unsuitable mobile equipment, venting the gas elsewhere, etc..

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22 Electric, air-driven or other pumps may be used.

23 The trigger device could be a transducer, float switch, etc.

24 A 'maintenance procedure' may be known as a 'method guidance' or another similar term

Below the water level can usually be classified as a non-hazardous area. This is the case if the control system[25] preventing the pump from becoming unsubmerged is considered to be of a high reliability type. Alternatively, if a top-fill pump is used and suitable measures[26] are taken to ensure it does not fall over when lowered into the well and pump itself dry (thereby becoming a potential ignition source), the region below the liquid level may also be classified as non-hazardous. If these measures are not in place and there is a reasonable probability of the pump becoming unsubmerged, then the region below the water level should be classified as a zone 2. ESA ICoP 5 should be referenced for a more detailed treatment of the subject of choosing pumps and whether electrical or air-driven are preferred.

Compared to the volume of landfill gas evolved, any potentially explosive atmosphere from leachate will be well within the zones defined for landfill gas.

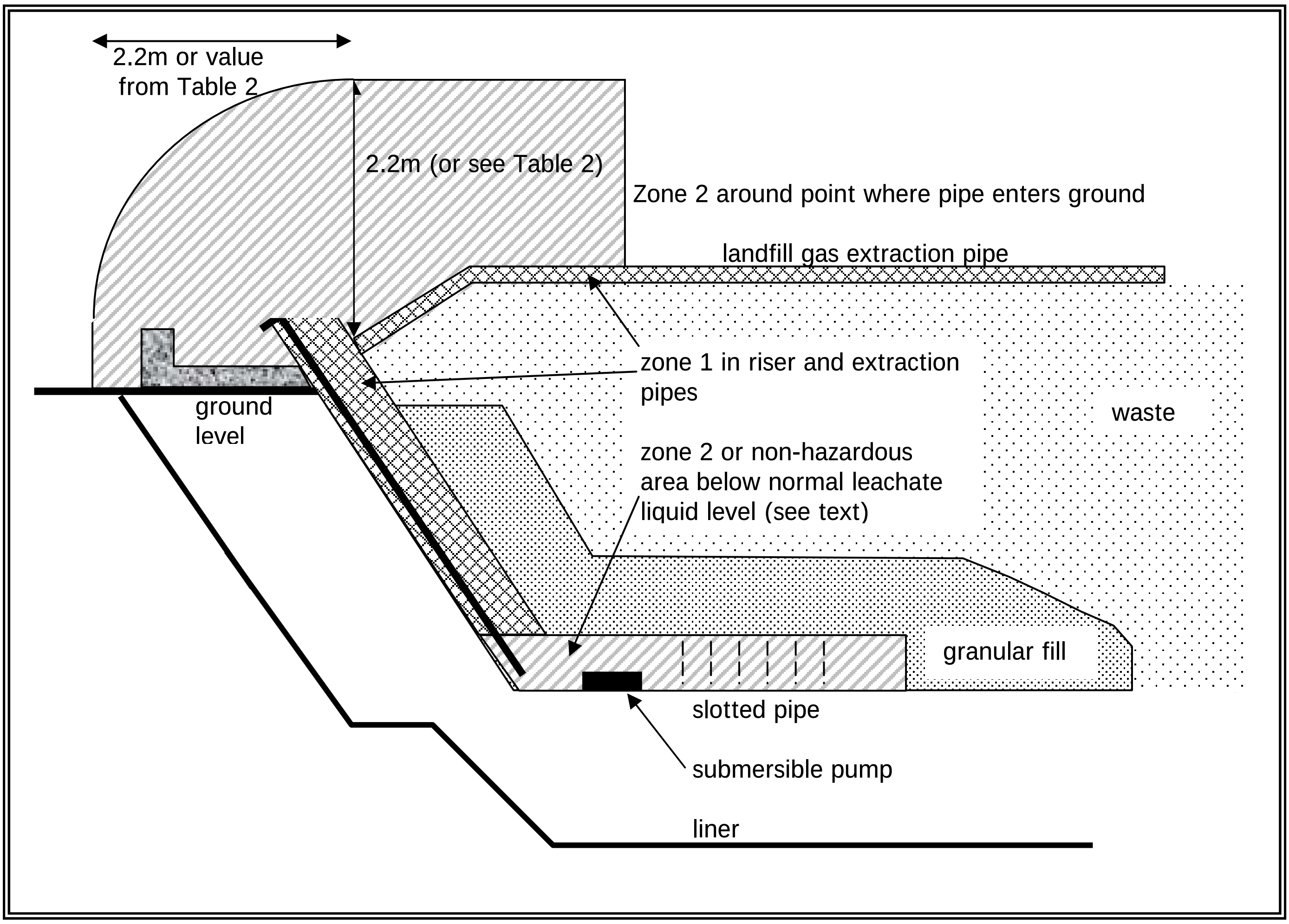
Table 7: zone radii around wells due to failure of the Bentonite seal

Landfill gas release rate of well (m^3/h)	**Radius of zone 2 (x metres)** (rounded up to 0.1m)
1	0.4
2	0.5
3	0.7
4	0.8
5	0.9
10	1.3
15	1.6
20	1.8
25	2.0
30	2.2
40	2.6
50	3.0

25 An appropriately-certified transducer or other means of detecting the 'pumping dry' situation are also appropriate if assessed as sufficiently reliable. Over/undercurrent protection is often used, but care should be taken that, when a pump is replaced, the protection remains appropriate. For example, cavity pumps require overcurrent protection whereas centrifugal require undercurrent protection.

26 Such measures might be, for example, securing the pump on a 'sledge' prior to being offered into the opening of the leachate extraction point; the pump is secured in such a way that it cannot turn over when presented and located in the side riser. For vertical wells, the pump could be supported at the top until it reaches the bottom of the well and therefore cannot turn over.

Figure 1: zoning for a leachate riser (elevation)



5.2 Leachate recirculation injection

This facility involves penetrating the capping so, as in the case of gas wells and leachate extraction wells, there is the possibility of leaks around the seal. A zone 2 applies – see Table 7 above for the extent of the zone.

5.3 Gravitational extraction

In gravitational extraction, leachate runs under gravity to storage without being first brought to the surface. The zoning in the pipe is the same as for pipes on the downhill side of break tanks (see Figure 2), i.e. zone 2.

Some old landfills may discharge by gravity drains into public sewers and some inadvertently may discharge to surface water drains. All landfill gas pathways into sewers or other pipework require investigation and appropriate zoning under such circumstances as a partly full leachate drain presents a significant risk of gas migration into such a sewer or drain system.

6 AREA CLASSIFICATION FOR LEACHATE TRANSMISSION

6.1 Pipework

Leachate may be pumped or gravity-fed, or a combination of the two. Leaks from the containment system are secondary grade releases, but, for the reasons given in section 1.4, no zone is required around such potential release points (flanges, screwed joints, valves, seals, etc.) since the release of a small amount of leachate will give rise to a negligible release of methane.

Where leachate is gravity-fed, it is possible that air could enter the pipe at the top of the rise, via a break tank or other opening in the pipe. Therefore, in these locations, the pipework should be classified as zone 2 internally, because, if an air space occurs, methane could accumulate in flammable concentration with the air – refer to Figure 2. Where air spaces cannot form, the pipe may be classified as non-hazardous.

While assessing risks associated with leachate pipelines, care should be taken to ensure that granular pipe bedding and surround materials are discontinuous where leachate pipework then passes through the landfill cap. This is usually achieved by omitting the normal stone pipe bedding and surround materials for a short distance, and then compacting clay around the pipe (i.e. providing a clay 'stank' within the pipe trench). This ensures that landfill gas migration does not occur through the pipe bedding and surround.

Some long leachate pipelines may possess air release valves. In the case of pumped or gravitating leachate, the air released may contain methane, so a zone 0 is appropriate internally. The release of the air is infrequent, so the area around the valve should be classified as a zone 1. A zone radius of 3 m, as for the passively-ventilated storage tank in Figure 3, applies (although this radius is conservative).

Note: the main equipment likely to be affected by the zoning of pipework is the pump. Since it is highly unlikely that a flammable methane/air mixture could form within the pump, the pump need not be protected for use in a hazardous area. However, if the pump is being used within a zone resulting from releases of landfill gas other than from the leachate (e.g. at the well head), then the pump will need to be appropriate for the zone. ESA ICoP 1 gives more information on the selection of suitable equipment for zoned areas; existing equipment in zones 2 need not necessarily be certified.

6.2 Break tanks

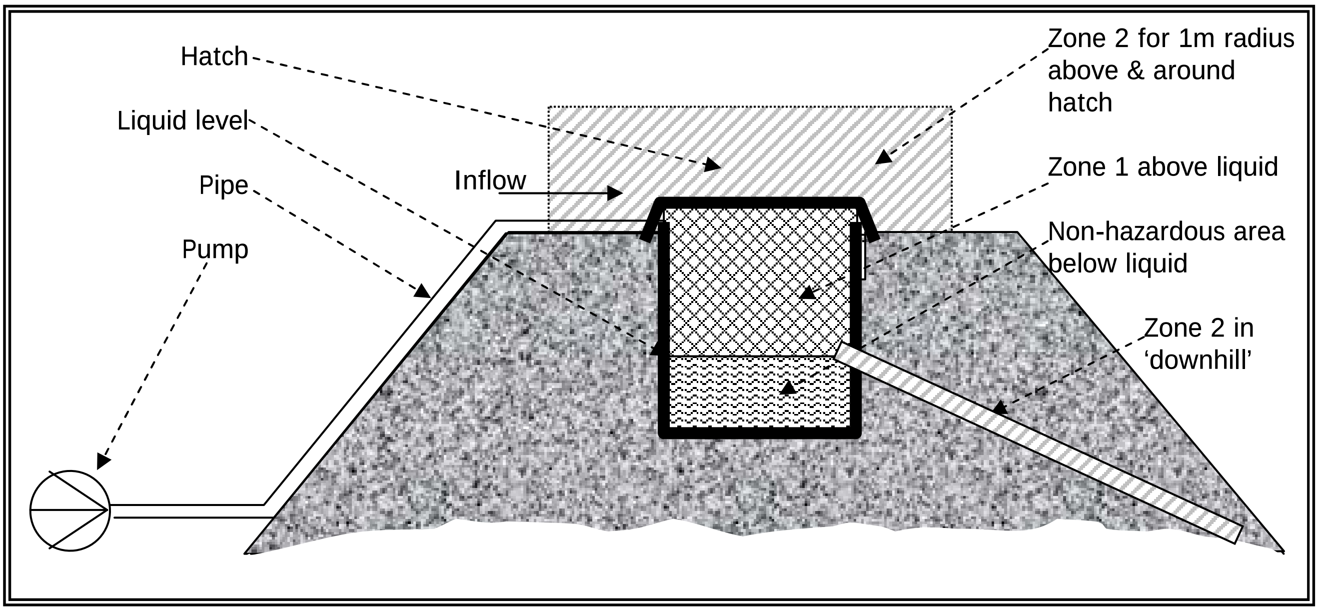
Refer to Figure 2. A break tank is sometimes located at the highest point of a pipe run. If this is the case, air will enter because the hatch is not completely sealed. Methane is likely to build up in this space, so it is classified as zone 1 above the liquid level (i.e. above the outflow pipe).

The hatch may not be closely-fitting but, when closed, any external potentially explosive atmosphere will be a zone 1 of negligible extent. However, it may be opened while a potentially explosive atmosphere exists within the tank, so the zone 2 around the hatch is to take account of this. The main mechanism for methane to rise out of the tank is its buoyancy, but the total inventory is small, so a zone 2 radius of 1 m may be assigned[27].

Below the liquid level will be a non-hazardous area since there is no reasonably foreseeable mechanism by which the tank could become emptied of leachate. Damage or corrosion to the tank is considered to be 'catastrophic' and outside the scope of area classification.

27 Based on IP15 Figure 3.29 (oil-water separator vent)

Figure 2: zoning of a break tank at the high point of a pipe run (elevation)



Break tanks that are used as collection tanks will have the same classification if there is an unventilated air space internally.

6.3 Methane migration through ducts

The use of ducts (or pipes) to provide cable routes between hazard zoned areas (wet wells etc) and cable termination points (e.g. local panels, kiosks, control rooms, etc.) is to be avoided wherever possible unless essential to maintain functionality. Where ducts are considered essential, they may be used to provide cable route from electric-pumped or trigger-instrumented leachate wet wells into control panels and control rooms. Reliance on sealing and re-sealing these ducts immediately after maintenance is not considered to be adequate. An air-gap with free air circulation should be provided in addition to sealing and no electrical equipment should be placed close to exit of the duct in case landfill gas is emitted. The local panels, kiosks, control rooms, etc. can then be considered as non-hazardous areas.

7 AREA CLASSIFICATION FOR LEACHATE STORAGE

7.1 Open tanks/lagoons

Leachate releases methane at a relatively slow rate into the air above the liquid. The rate is determined by the concentration of methane, surface area, agitation, turbulence, temperature and pressure. In an open tank or lagoon, the natural ventilation is sufficient to prevent the formation of methane in explosive concentrations, so no zone is required above the liquid.

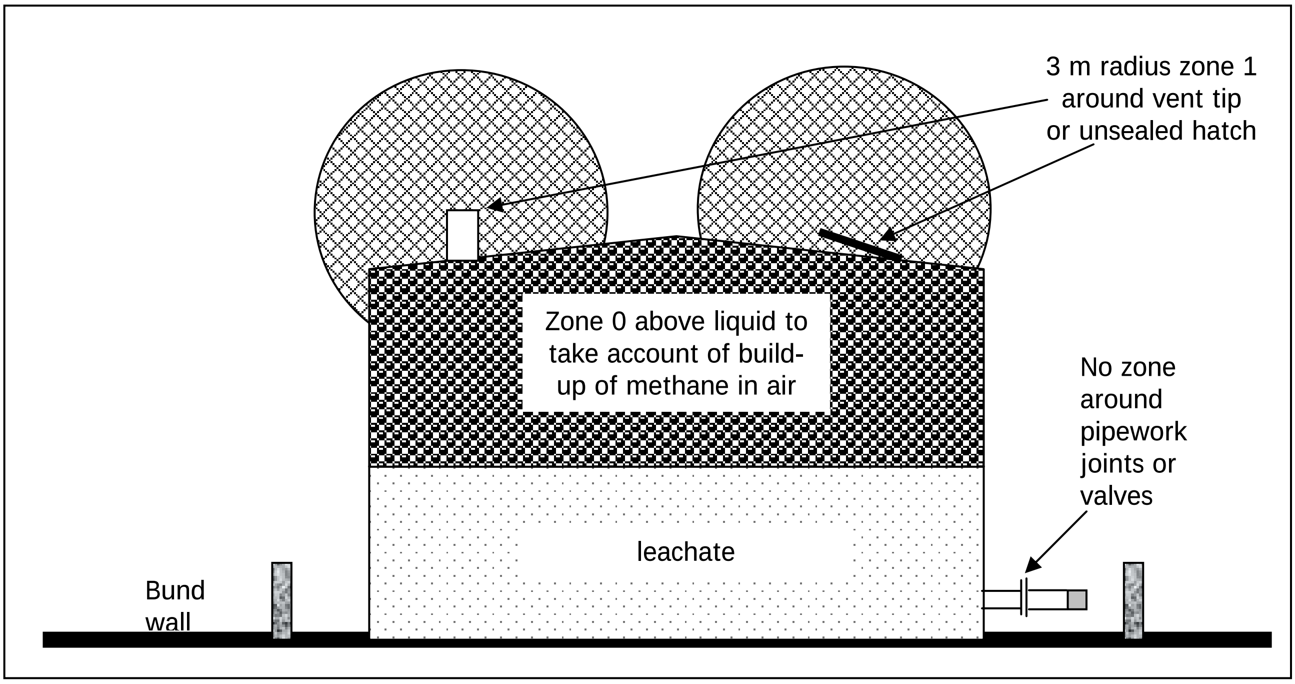
7.2 Closed tanks (passive ventilation)

In a closed tank without significant ventilation, the concentration of methane will rise over time and, if the right conditions persist, it is possible for a potentially explosive methane/air mixture to develop. If the ventilation is low enough to allow it to form, once formed it will persist. It is difficult to establish a minimum provision of natural ventilation that will reliably prevent the formation of a potentially explosive atmosphere, since the effectiveness of natural ventilation is dependant on variables such as wind speed. Therefore, to adopt a conservative approach, all closed tanks with passive ventilation only should be classified as zone 0 internally above the minimum liquid level.

The zoning for a closed tank is as shown in Figure 3 below. All closed tanks will have one or more vent. The maximum release rate of a potentially explosive atmosphere occurs when the tank is being filled, displacing the gas mixture above the liquid. EN 60079-10:2003 example 8 deals with a tank containing a flammable liquid with a vapour denser than air, but this example can be extended to gas/air mixtures. This example recommends a zone 1 with a radius of 3 m.

Some tanks may have a submersible pump. The working level of the tank varies from the maximum capacity down to the level determined by the pump. Provided the pump is reliably prevented from pumping itself dry[28], below this lower liquid level can be classified as a non-hazardous area.

Figure 3: zoning of a closed tank with passive ventilation (elevation)

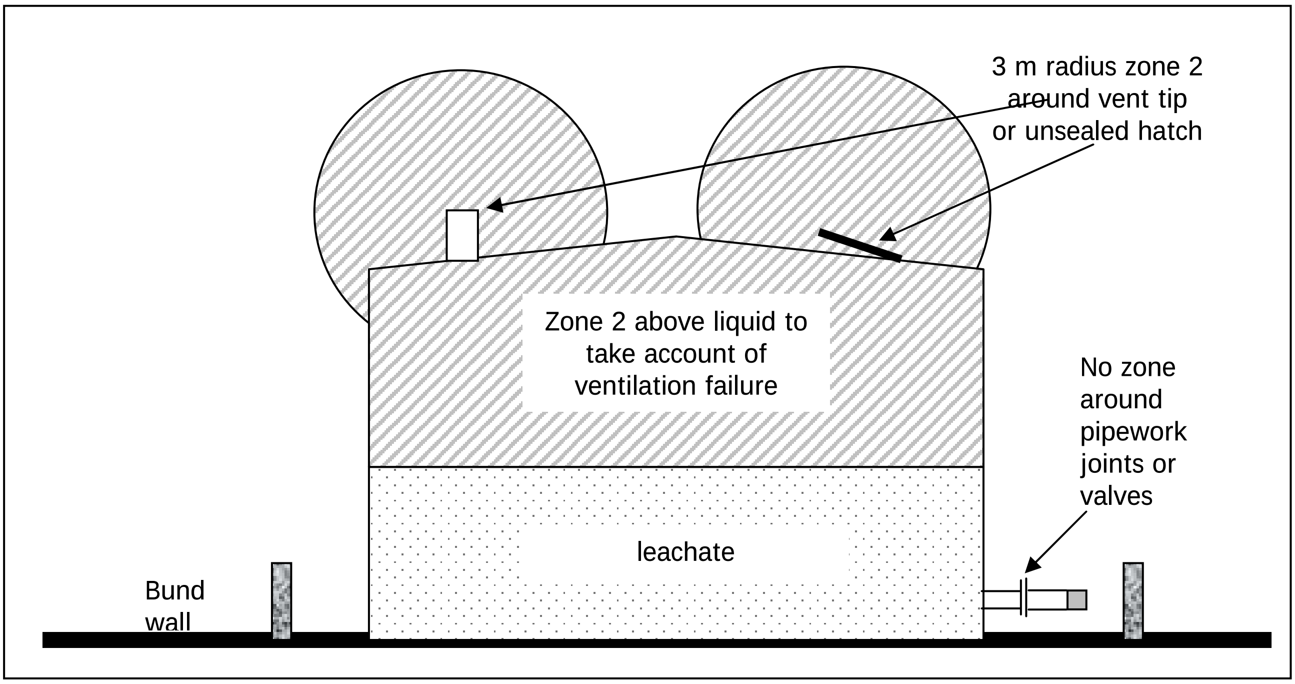


[28] Some pumps are inherently incapable by design of pumping themselves dry, whereas others may need further control measures such as a level switch. This subject is dealt with more fully in ICoP 2.

7.3 Closed tanks (active ventilation)

Active ventilation in this context implies forced (mechanical) ventilation that is sufficient to reliably prevent the formation of a potentially explosive atmosphere. This requires methane to be diluted to less than ¼ LEL. In normal operation, therefore, there is no potentially explosive atmosphere within the tank. However, if it is reasonably foreseeable that the ventilation could fail, or operating conditions require the ventilation to be turned off for a length of time sufficient for the methane concentration to rise to the LEL, then the interior of the tank should be classified as a zone 2, with corresponding zones around vents and unsealed hatches. Refer to Figure 4 below.

Figure 4: zoning of a closed tank with active ventilation (elevation)



The zones 2 can only be changed to non-hazardous if standby ventilation automatically cuts in should the main ventilation fail.

7.4 Bowsers and tankers

Bowsers and tankers are mobile versions of the fixed tanks described above; the area classification is as shown in Figure 5.

8 AREA CLASSIFICATION FOR LEACHATE TREATMENT

8.1 Methane Stripping – closed tanks

Methane stripping involves bubbling air through the leachate. The methane concentration in leachate is monitored at various points in the process. If required, methane stripping is performed using a series of tanks (or separate chambers within one tank), each of which further reduces the methane concentration. Methane stripping is usually done as a continuous process and is necessary to reduce the methane concentration to below the limit of 0.14mg/litre imposed by the water authorities[29]. This limit is a factor of 10 below the LEL to provide a factor of safety (see Appendix 1). Once leachate has been treated in this way, it may be discounted from further area classification considerations.

In normal operation, the air above the liquid is removed at a rate that prevents the formation of a potentially flammable atmosphere by the action of the air being bubbled through the leachate. Thus, the only time when a potentially flammable atmosphere can form is if the passive ventilation fails or when the aeration is de-energised, for whatever reason. Clearly, a potentially explosive atmosphere can only form if the tank is still charged with leachate at above 1.4 mg/l dissolved methane. Some plants may be designed not to de-energise while the plant is still charged with unstripped leachate. However, the failure of the aeration system is a foreseeable event, so must be considered for area classification purposes. Therefore, the tanks will be classified as zone 2 as for a closed tank with active ventilation – see section 7.3 and Figure 4.

8.2 Methane stripping – open tanks

These tanks may be above or below ground level. The interior of the tank is not classified as a hazardous area for the reasons given in section 7.1.

8.3 Aerobic biodegradation

This process uses micro-organisms that oxidise pollutants in the presence of oxygen. In most methods, as in the methane stripping process, air is bubbled up through the leachate. However, in order to provide a suitable environment for the micro-organisms in the sludge, to achieve treatment by aerobic biodegradation the quality of the liquor is always kept close to the discharge quality and only small amounts of raw leachate are discharged into such tanks or lagoons at any time. The result is that the contents of the tank must always be maintained in a highly aerobic condition in order for a biological aeration to work successfully. These aerobic conditions are not compatible with the production or discharge of methane gas. Any methane gas which is introduced in the raw leachate feed will therefore be very rapidly mixed and oxidised in the liquid in any aeration tank. No methane hazard exists and zoning is not therefore necessary for both covered and open tanks.[30]

Open tanks and lagoons, with or without aeration, do not require zoning for the reasons given in section 7.1.

Aerobic biodegradation works best within a temperature envelope of 15°C to 30°C, with 20°C to 25°C being ideal. If the temperature drops much below the minimum, then external heating may be required. Possible methods to achieve this are:

- propane;
- diesel;
- landfill gas;
- natural gas;
- waste heat from the gas engine, tapped off from the exhaust or the flare.

The zoning associated with these various fuels is covered in section 10.

The tanks are heated by means of a heat exchanger to produce hot water, which runs through heating elements in the tank itself.

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29 Not all Water Authorities place a set limit on methane discharges, in which case levels of methane above 0.14mg/litre are permissible in the discharge. However, all discharges must comply with the Public Health Act 1936, which prohibits the discharge of anything flammable into sewers (ie >1.4mg/l in this case).

30 Even if treatment stops for a period of weeks on end (which is not part of normal operation as even dry in summer and low leachate availability, some aeration would normally be undertaken), the high concentration of nitrate ions, NO_3^-, (which provide large amounts of combined oxygen) will prevent spontaneous generation of methane. All of this combined oxygen is available for utilisation before the contents go anaerobic and start to generate methane in the presence of methanogenesis organisms. Nitrate-rich treated leachate effluent is known to actually keep the sewage "sweet" when discharged into a sewer during its passage to the sewage works. The nitrate prevents anaerobic conditions, without which strong "septic" odours and potentially methane would develop.

8.4 Denitrification (anoxic biodegradation)

Denitrification may be a process requirement for leachate treatment where total nitrogen removal is required. Denitrification is an oxidative process in which bacteria use nitrate as the terminal electron acceptor in place of dissolved oxygen, hence the anoxic (no oxygen) zone requirements. Nitrate is reduced to form water and nitrogen gas. No flammable materials are produced.

Leachates are predominantly low in available carbon, which the bacteria require for their metabolism. To ensure stable denitrification is achieved, it is often necessary to provide an additional source of readily available carbon. To feed the micro-organisms, methanol (or a non-flammable material such as molasses) may be added.

Over-dosing is possible, but, since methanol is miscible with water and the amount of methanol is very small compared to the amount of water, the vapour pressure above the mixture would be insufficient to form a potentially explosive atmosphere.

The methanol is broken down by the micro-organisms in the leachate so it can be assumed that the methanol is at a negligible level when the leachate is discharged. Methanol is dealt with in section 10.5.

The space above the liquid will contain oxygen from the air, even though the micro-organisms will slowly remove it. Methane may be liberated from the untreated leachate, so, if the tank is unventilated, it should be classified as shown in Figure 3. If the tank is ventilated, it should be classified as shown in Figure 4.

Some denitrification tanks may not necessarily comprise a methane risk and require a hazard zoning. The zoning proposed above should be a presumed requirement, unless site specific tests are used to demonstrate otherwise.

8.5 Powdered activated carbon (PAC) systems

PAC can form a potentially explosive atmosphere. It is used in a small number of reactors to improve the performance by scavenging for toxic materials (adsorbable organic halogens, AOX) and also provide a high surface area for micro-organisms to establish. It is stored in silos, big bags or 200 litre drums. Transfer is by air or screw feeder to a blending tank, from which it is pumped to the reactor.

Granulated Activated Carbon (GAC) rather than the powder form may be used, for example in filters. Although it must be considered as a fire risk, granulated carbon is outside the scope of area classification, since this only deals with dust *clouds* within the flammable range. It is, however, possible that the granulated carbon contains sufficient fines such that it can produce a potentially explosive atmosphere when handled.

PAC is already in powder form, so is more likely to generate a potentially explosive atmosphere. Once in the blending tank and mixed with water, its flammable properties can be ignored.

The likely transport and storage facilities will be addressed in general terms below, but a site-specific survey will be required. In addition to the guidance given below, reference to the applicable CoP for dust classification (EN 61241-10[T]) is essential.

8.5.1 Screw conveyors

Where these are handling granulated carbon, it is unlikely that a potentially explosive atmosphere will form, so, typically, a zone 22 applies inside. For PAC, a zone 21 or even 20 is more appropriate. In both cases, the fire risk from internal friction should be considered.

8.5.2 Air transfer systems

A potentially explosive atmosphere is highly likely in air transfer systems and the interior should be classified as zone 20 unless there is clear evidence that the dust concentration does not exceed the LEL in normal operation[31], in which case a zone 22 applies.

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31 In practice, it is usually very difficult to make this judgement, so the 'default' is a zone 20.

8.5.3 Dust extraction filter

This is normally classified as a zone 20 upstream of the filter (internally) and a zone 22 (externally) on the downstream side. The external zone 22 typically extends 1 m around the filter and vertically downwards to the solid floor. Where filter changing is done, it is advisable to designate a zone 21 of the same dimensions, so the zone 21 superimposes the zone 22.

Even though the concentration of dust may be well below the LEL in the extracted air, it is common for the filter to be of the 'reverse jet' type, which periodically cleans the filter element by a jet of air, thus creating an internal dust cloud, which is highly likely to be within the explosive range. Thus, the upstream side of the filter is a zone 20, even if the air transfer system is a lower zone classification.

8.5.4 Silos

The default is a zone 20 internally, although a zone 21 may be applied if the silo is only filled periodically. A zone 22 can only be applied if there is clear evidence that the dust concentration does not exceed the LEL in normal operation.

8.5.5 Leaks from the containment system

Unlike for gases and liquids, leaks from solid joints (flanges, screwed joints, seals, etc.) are not regarded as secondary grade releases, since leaks cannot realistically give rise to a flammable dust cloud of significant size. Flexible couplings (typically rubber or fabric) are considered as secondary grade releases but, where the system is at an underpressure, no zone applies, since failure of the coupling at the same time the existence of an overpressure is considered a 'catastrophic' failure and outside the scope of area classification (see section 4.2.4).

Where the system is at an overpressure, failures of flexible couplings will result in a zone 22. EN 61241-10 recommends a zone extending 1 m around the release, extending to the ground. However, minor tears in the flexible couplings may be quickly noticed and repaired, so a smaller zone 22 (even of negligible extent) may be justified. A decision based on experience with the equipment in question may be made.

8.5.6 Equipment for use in zones 20, 21 and 22

The information in this section is outside the scope of area classification, but is provided for guidance. Refer to ESA ICoP 1 for a fuller treatment.

New equipment (electrical and non-electrical) for dust zones will need to be appropriately ATEX-marked. For existing equipment, the approach used in the UK is found in HSG103[U], which permits equipment that is merely protected against dust.

> **Zone 22:** Paragraph 38 states: "In [zone 22]….older equipment made with a dust resistant enclosure to IP5X may remain in service".
>
> **Zone 21:** Paragraph 37 states: "…. in zone 21 …. existing equipment …. with a dust-tight enclosure made to IP6X is still likely to be suitable".

Thus, provided the equipment is in good condition and no further ignition hazards are identified, if it meets these fairly modest requirements, it may be considered satisfactory for continued use; it is not necessary to replace it with ATEX-marked equipment.

> **Zone 20:** historically, BS 7535[V] was applied. The approach can be summarised as follows:
>
> *For flammable dust zones, install equipment that is suitable for the equivalent flammable gas zone and is also dust-tight.*

Thus, for zone 20, intrinsically safe equipment that is also IP6X may be appropriate for continued use, provided due consideration is given to factors such as the ruggedness of the enclosure, ohmic[32] heating of the dust, etc. Non-electrical equipment also requires assessment - refer to ESA ICoP 1.

It should be noted that sparks generated by static discharge are usually of far greater concern than installed electrical or non-electrical equipment.

32 Ohmic heating occurs when the dust is conductive; if the dust collects between uninsulated electrical parts, the current flowing can cause a heating effect due to the resistance of the dust.

9 AREA CLASSIFICATION FOR LEACHATE DISPOSAL

9.1 Effluent holding

Holding tanks containing untreated leachate with a concentration above 0.14 mg/litre (or an unknown methane concentration) should be classified in accordance with Figures 3 and 4.

Most effluent holding tanks only contain leachate with a methane concentration below 0.14 mg/litre. If conditions become anaerobic, then the methane concentration may rise, although this takes many days, by which time the leachate will normally have been discharged into the sewer.

If the effluent is known to be below 0.14 mg/litre, then the tank may be zoned as non-hazardous for the reasons given in section 7.1.

9.2 Sampling points

For the reasons given in section 1.4, small amounts of leachate can release only negligible amounts of methane, so zones are of negligible extent. Thus, there are no hazardous areas associated with leachate sampling points unless there is a possibility of gas being released. In this case, a zone of radius 1 m applies. This will be a zone 1 if methane is normally released or a zone 2 if it is occasionally but accidentally released.

9.3 Discharge to sewers

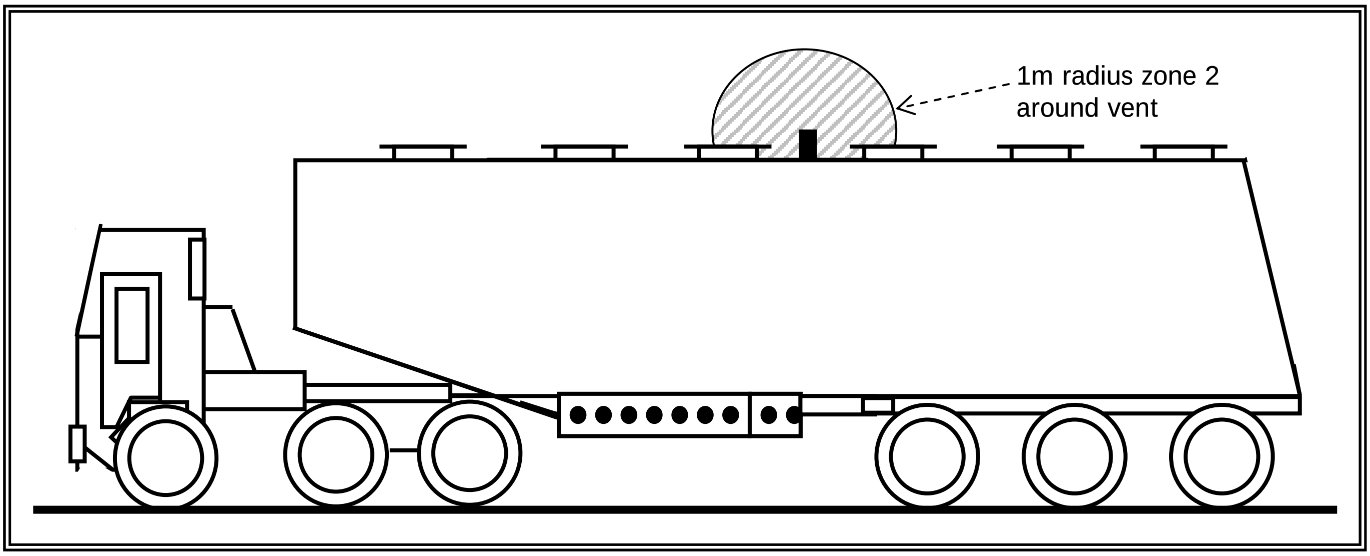
The discharge of leachate may be by gravity or pumping. All leachate should be below 0.14 mg/litre methane in order to comply with the water utility company's normal requirements as defined within the sewer discharge consent. This concentration has been set in order that the utility company can comply under all circumstances with its responsibilities in respect of occupational protection of its own workers. In abnormal situations, some leachate may accidentally be disposed of direct to sewer with levels above 0.14 mg/litre without producing a zoning requirement or an explosion hazard, provided levels are still below the flammable limit. Where methane strippers are not in place, the 0.14 mg/litre limit may accidentally be exceeded and it is possible that the flammable limit of 1.4 mg/litre is also exceeded. This is not acceptable since the utility company's area classification may assume discharges are non-flammable; the utility company should be informed immediately if this is done. However, flammable concentrations of methane are highly unlikely to build up in drains where there is significant ventilation or dilution from other non-flammable flows.

9.4 Tankered removal (treated and untreated leachate)

Treated leachate that has been methane-stripped to below 0.14 mg/litre methane can be regarded as non-hazardous.

Leachate that is above 0.14 mg/litre or that has an unknown methane concentration should be treated as being capable of forming a potentially explosive atmosphere in closed containers such as the tanker – refer to Figure 5 below. A zone 2 around the vent is based on IP15 Figure 3.5 but further zones associated with leaks or spills are not required since small leachate spills release insignificant amounts of methane.

Figure 5: zoning diagram for tanker loading leachate



9.5 Discharge points into reed beds, soakaways to ground etc.

Discharges into such open areas require no zoning for the reasons given in section 7.1.

10 DELIVERY, STORAGE AND DISTRIBUTION OF FUELS

Anaerobic biodegradation needs a raised temperature for which various fuels are used, such as:

- propane
- diesel – held in from storage tanks, delivered by tanker
- landfill gas – piped directly from the landfill
- natural gas

In addition, methanol is used to feed micro-organisms.

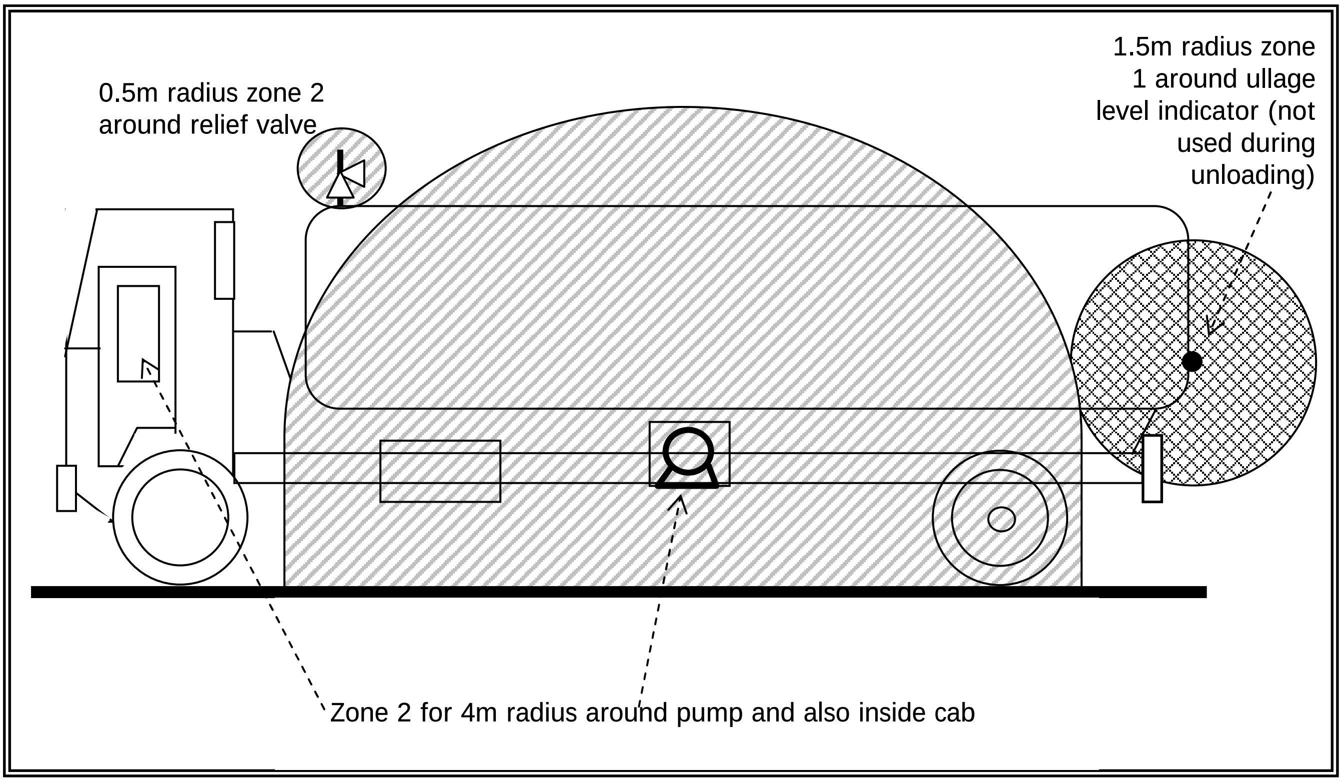
10.1 Propane

Commercial propane may be at pressures up to 5 bar absolute (4 bar gauge) at 45°C ambient[W]. Under modest pressure, propane is a liquid, but, on release into the air at ambient pressure, it will rapidly boil and form a gas; this mixes with the air to form a potentially explosive atmosphere. Pipework and vessels should be installed to a high standard with a minimum number of joints and suitably protected against damage. Ideally, there should be no joints in indoor areas.

10.1.1 Tanker delivery of propane

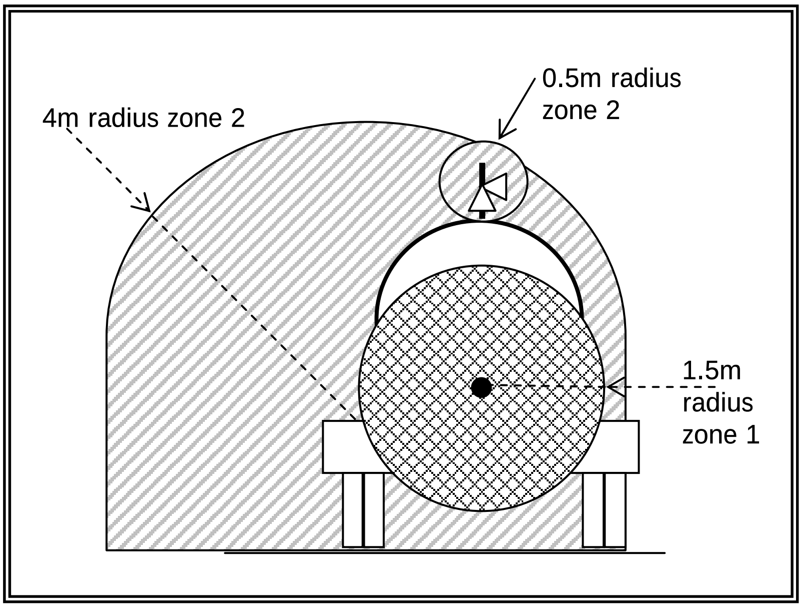
Ideally, there should be a dedicated area assigned to tanker unloading that is not shared by other vehicles. If this is not practical, then measures should be taken (e.g. use of cones) to ensure that no vehicles can be accidentally driven close to the tanker when unloading is taking place. Refer to Figures 6 and 7, which are based on IP15 Figure 3.15.

Figure 6: zoning of propane tanker while unloading – side elevation



Note that there is a zone 2 inside the cab; this is conservative, but is to take account of poor ventilation.

Figure 7: zoning of propane tanker while unloading – rear elevation



10.1.2 Propane storage

Propane (LPG) is held in fixed storage tanks, which are re-filled periodically by tanker. The propane tank may be inside a locked compound and is usually surrounded by a low wall or drain to contain spillages. There is a vent that prevents an excessive pressure within the tank, but the associated pressure relief valve is not designed to lift during filling or normal use, hence there is a zone 2 around this vent, rather than a zone 1.

Refer to Figures 8 and 9, which are based on IP15 Figure 3.3. There is a zone 1 around the coupling point to take account of small releases when making and breaking the connection. Liquid spills result in a zone 2. If present, the drain is classified as zone 1 below ground level since the ventilation is poor.

Figure 8: zoning of a propane storage tank - elevation

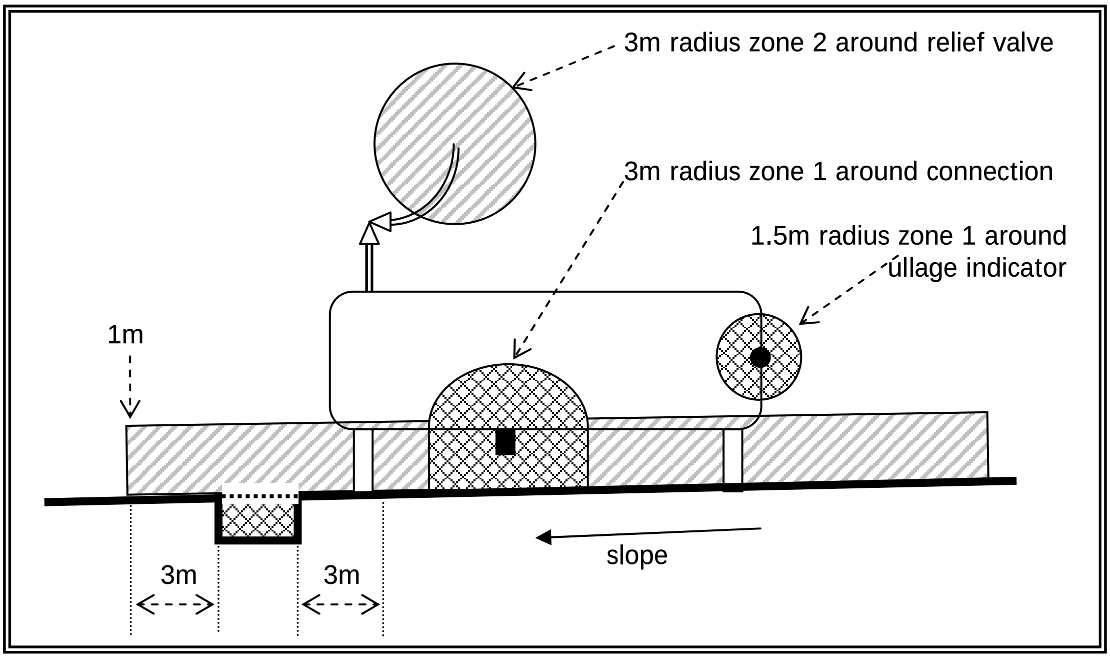
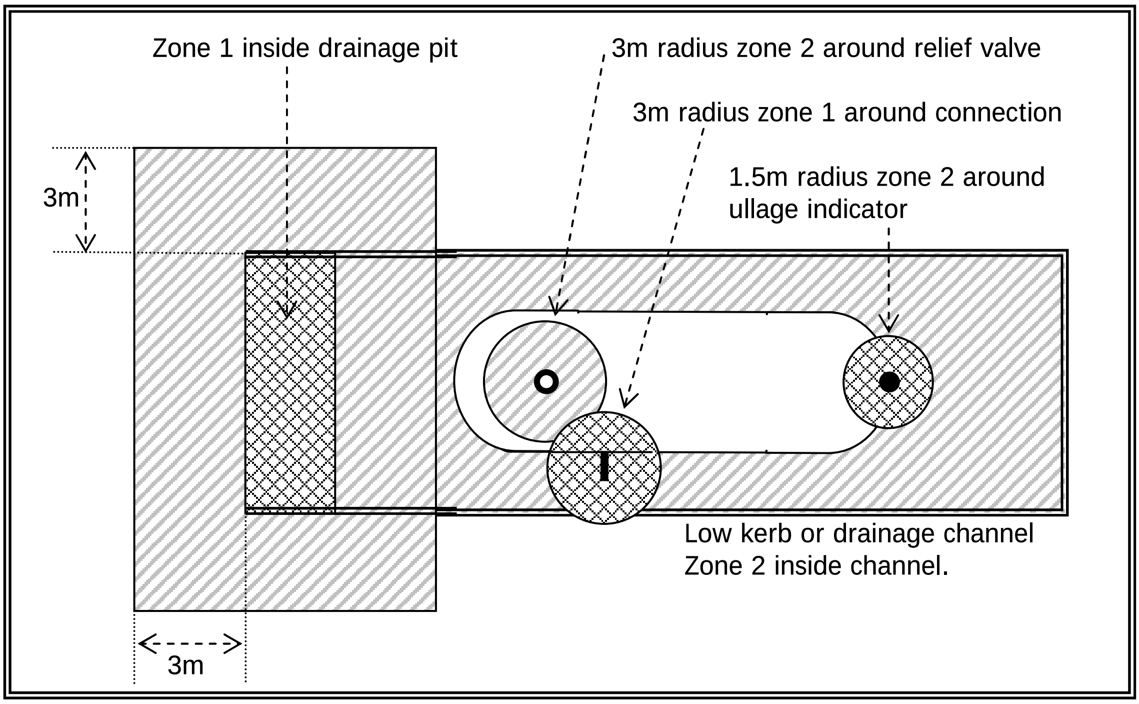


Figure 9: zoning of a propane storage tank – plan view



Further guidance on the installation of such tanks is available from The LPG Association[X].

10.1.3 Propane distribution pipework

There will be zones 2 around distribution pipework joints, valves and other secondary grade releases. IP15 Table C9(b) gives a zone radius of 2 m for a 1 mm hole for pressures up to 5 bara and a Category A fluid[33]. In well-maintained pipework, this hole size is a reasonable upper limit, so a 2 m zone 2 should be assigned around all secondary grade releases in well-ventilated outdoor locations.

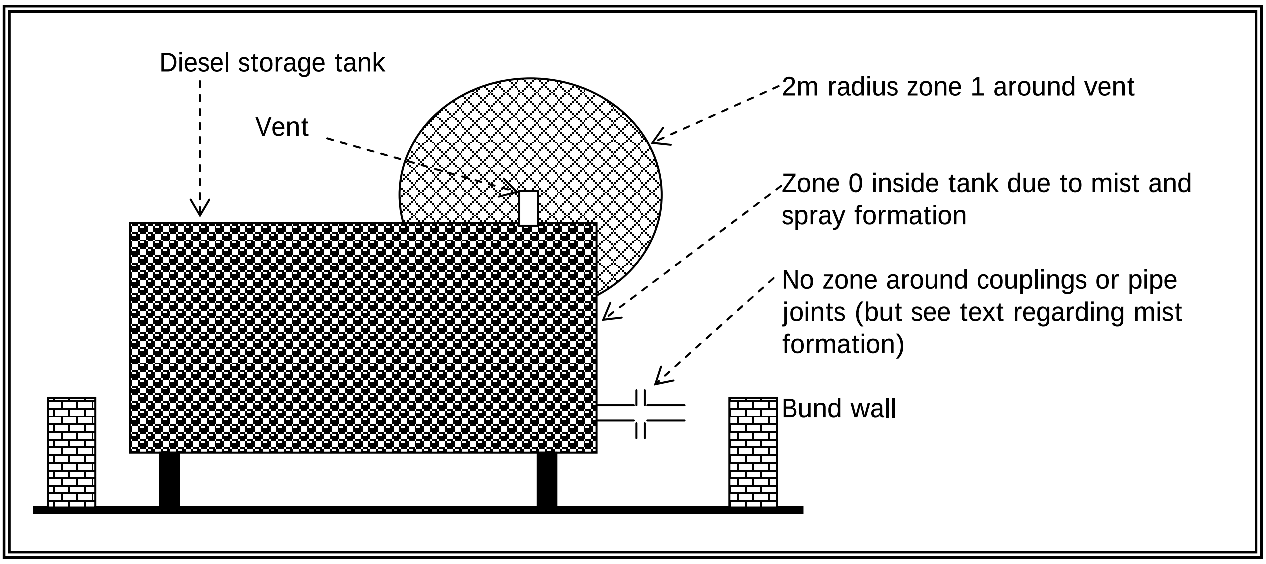
Propane pipework joints should be avoided inside buildings where possible. The zone extent cannot be calculated without consideration of the local ventilation characteristics, but will be considerably larger indoors. To ensure that secondary grade releases do not persist in excess of the time allowed for a zone 2 to be appropriate, IP15 section 6.4.1 requires 12 air changes/hour. This may be produced by forced ventilation or by adequate openings in the structure to allow a sufficient air change rate by natural ventilation. Rather than calculate the extent of the zone within the enclosure, it is simplest to designate a zone 2 throughout the enclosure, with no external extent (since forced or outdoor natural ventilation will rapidly dilute gas from a small leak). A more rigorous approach is to use the equations in EN 60079-10:2003 section B.4.2, which may be used to calculate the hypothetical volume (V_z). Pipework with joints inside unventilated or poorly-ventilated rooms is highly undesirable and urgent consideration should be given to moving the pipework or, failing this, improving the ventilation.

33 IP15 Table A3 defines LPG (liquefied butane, propane, etc.) as Category A fluids.

10.2 Diesel

Diesel is held in tanks with an atmospheric vent, which may be directly on top of the tank (Figure 10) or in a remote location, typically if the tank is located indoors. The zoning is based on IP15 Figure 3.1(a) and note 1.

Figure 10: zoning drawing for diesel tank with integral vent



Diesel has a flashpoint of 55°C minimum, depending on the blend. IP15 clause A1.1 states: "To clarify the position pending further research, ...where a fluid is more than 5°C below its flashpoint and at atmospheric pressure or under only a few metres head in a storage tank, it can be treated as non-hazardous". Therefore diesel, which has a flashpoints more than 5°C above ambient, can be treated as non-hazardous provided it cannot leak onto a hot surface or be released as a mist.

This means that pools of diesel need not be treated as requiring zoning. Care should be taken, however, to ensure that pipework is routed such that potential leaks from joints and seals onto hot surfaces are avoided.

Mist formation at leaks in the pipework system is possible at pressures above 2 barg and it is likely that this pressure is exceeded during delivery and when the diesel is pumped to the burner. However, although it is appropriate to consider assigning a zone 2 around secondary grade releases, the level of protection required for electrical equipment encompassed by the mist zone 2 is minimal. Much or all of this equipment may not be compliant with zone 2 requirements for gases and vapours. This is, however, not necessary for either pre-ATEX or post-ATEX equipment. The following guidelines may be used[Y]:

> If equipment suitable for use in zone 2 is not fitted, it is permissible to use industrial equipment, which does not have an external hot surface within 5°K of the flashpoint of a pure liquid[34] (or within 15°K[Z] of the flashpoint of a mixture) and is *sealed from the ingress of mist*.

IP5X (dust-proof) equipment is more than sufficient to cause mists to coalesce. Diesel is a mixture with a flashpoint of above 55°C, so surface temperatures below 40°C can be assumed to be low enough to prevent significant vapour generation.

10.3 Landfill gas

ESA ICoP 2 should be referenced for the utilisation of landfill gas, notably section 6. To summarise the information contained in ICoP 2, where landfill gas is used to generate heat in a boiler room, the boiler rooms are generally not zoned, provided the pipework is installed to the appropriate standards and the room has adequate ventilation. Experience has shown that small releases of fuel gas do not accumulate into potentially explosive atmospheres of significant size.

34 Value taken from section A1.1 of Area Classification Code for Petroleum Installations, Part 15, 2004, Institute of Petroleum

10.4 Natural gas

Where natural gas is used to generate heat, the same guidance applies as for landfill gas – refer to ESA ICoP 2. The compound or building housing the incoming supply is the responsibility of the gas supplier.

10.5 Methanol storage and distribution

Where methanol is used, it is held in a storage tank, supplied by a road tanker. There is an electronic dosing pump that injects the required amount of methanol into the biological reactor; the dosing pipe should dose below the bottom water line of the process vessel. Methanol concentrations achieved during dosing within the reactor will be minimal as bacteria will readily oxidise applied solutions. With dilution factors of over a 1000 times plus oxidation rates, methanol will not be released into the upper atmosphere, or , if so, in negligible concentrations.

From an area classification perspective, consideration needs to be given to:

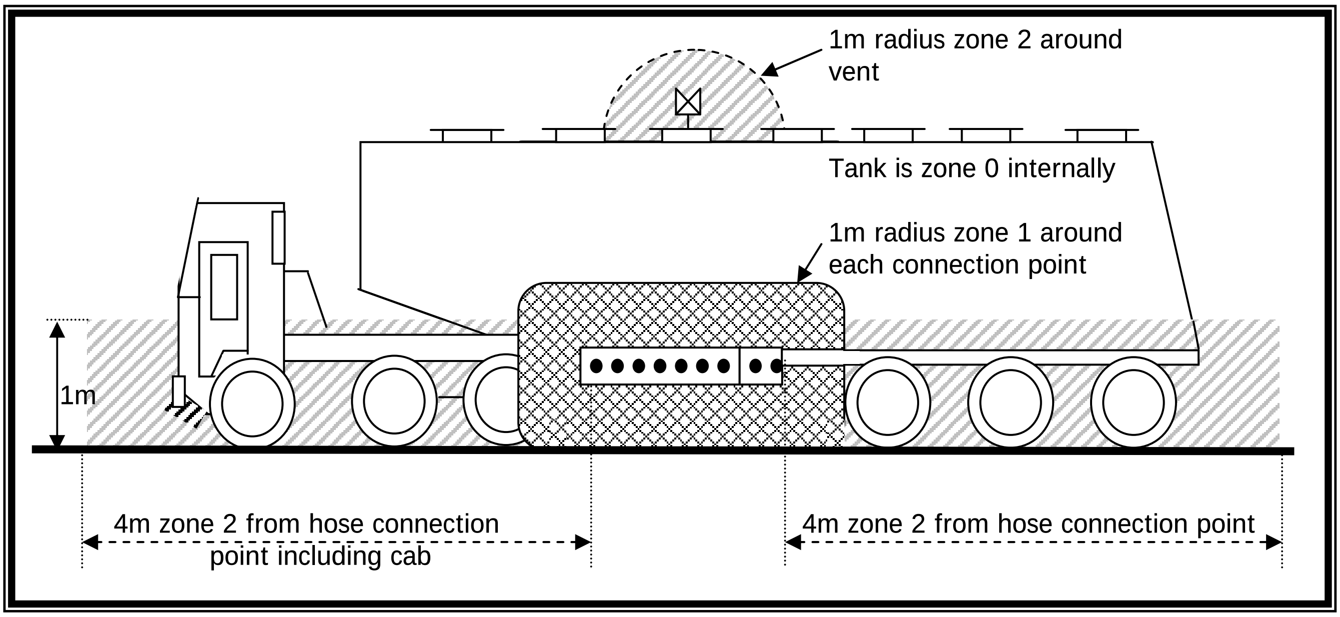
- tanker delivery
- storage tanks
- pipework
- pumps

These are covered in the following sub-sections.

10.5.1 Tanker delivery of methanol

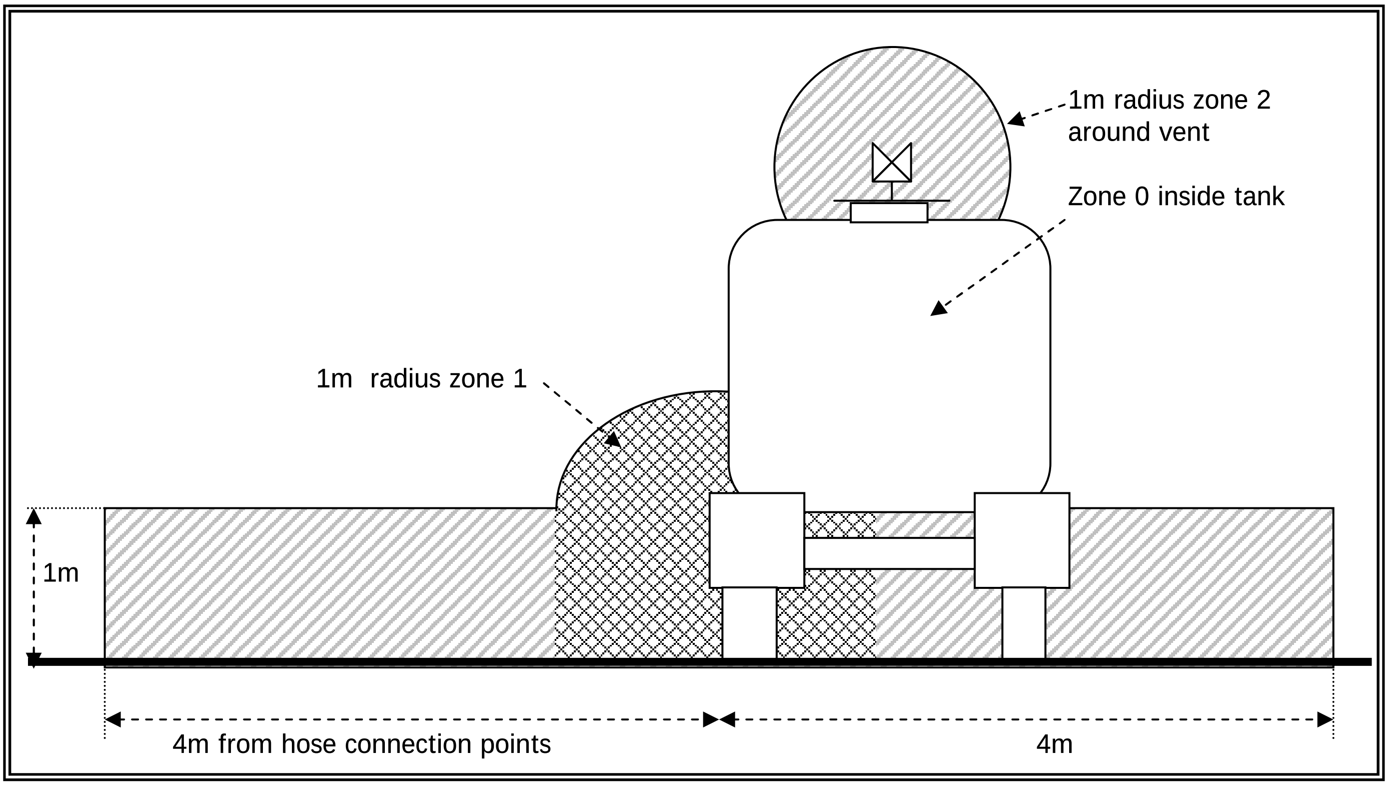
Refer to Figures 11 and 12, which are based on IP15 Figure 3.12 for a tanker unloading a low flashpoint liquid. Ideally, there should be a dedicated area assigned to tanker unloading that is not shared by other vehicles. If this is not practical, then measures should be taken (e.g. use of cones) to ensure that no vehicles can be accidentally driven close to the tanker when unloading is taking place[35].

Figure 11: zoning drawing for tanker unloading a low flashpoint liquid (side elevation)



[35] This is a summary of the control measures are required – IP15 section 3.4.2 should be consulted for the full range of controls.

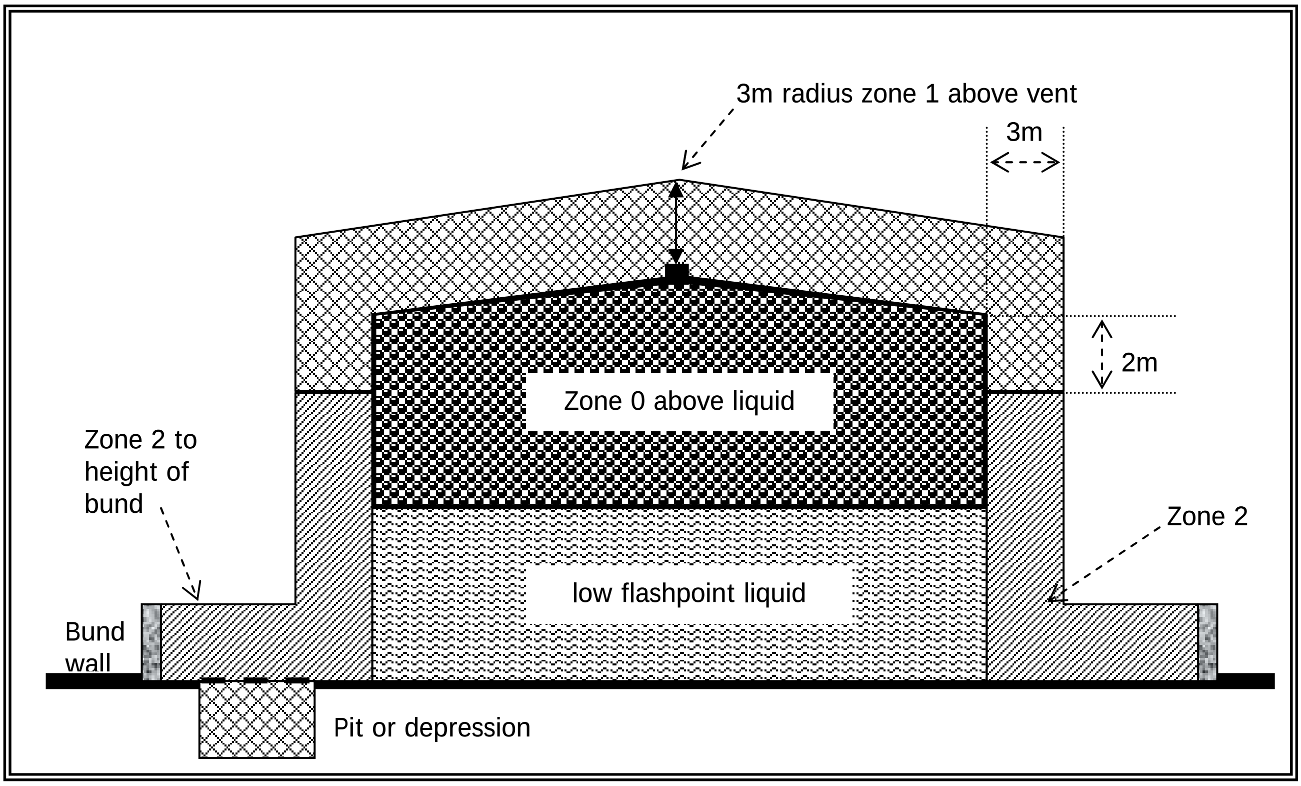
Figure 12: zoning drawing for tanker unloading a low flashpoint liquid (rear elevation)



10.5.2 Methanol storage tanks

Figure 13 below is based on Figure 3.1 of IP15, which deals with the storage of low flashpoint liquids.

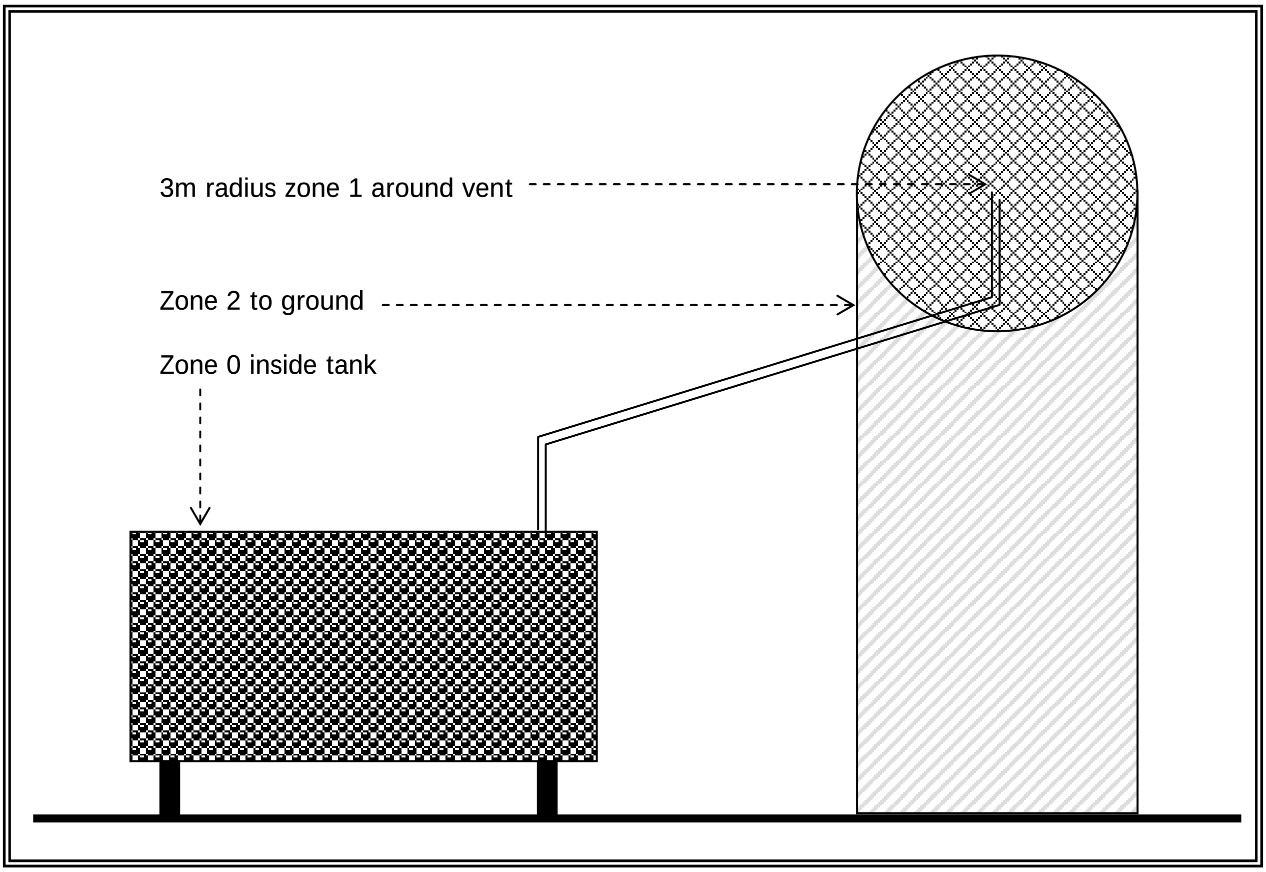
Figure 13: bunded storage tank for low flashpoint liquid (e.g. methanol)



The zone 1 shown on figure 13 around the vent is due to vapour expelled when the tank is filled or gets warm. The zone 2 shown is in case of overfilling the tank or secondary grade releases in the bund, such as flanges and valves.[36]

If the tank is inside a building, refer to Figure 14. In this case, the vent is remote from the tank then a 3 m zone 1 applies around the vent and the zone 2 extends down to the ground, to take account of over-filling or very low wind conditions (based on guidance in IP15 Figure 5.3).

Figure 14: zoning drawing for an indoor tank containing a low flashpoint liquid with remote vent



10.5.3 Methanol distribution pipework

Pipework systems contain a number of potential secondary grade releases, for example:

- flanges
- screwed joints
- valve seals

Leaks from these items will result in a zone 2 in outdoor or well-ventilated indoor locations. It is not possible to define a zone radius that will fit all situations, but some general guidance is given below that will fit most outdoor situations.

Flanges

For *outdoor* locations, a zone 2 extent of 2.5 m is reasonable worst-case value, which takes account of reasonably foreseeable failures[37]. These values are based on IP15 Tables C9(a) and C9(b)[38], from which the values of R_1 and R_2 respectively in Figure 15 are derived. These values apply for pressures up to 5 bara

36 In the event of a large loss of containment which fills the bund, the potentially explosive atmosphere would extend beyond the bund wall. This should be too improbable to be within the scope of area classification, but if it is regarded as a reasonably foreseeable failure, then refer to IP15 Table 5.7 for the zone extent. Generally, there is no zone 2 beyond the bund.

37 Such failures equate to LEVEL I and LEVEL II failures from IP15 Table C6.

38 IP15 considers methanol to be 'Category C' provided it is not handled above its boiling point.

(4 barg) and for an equivalent hole diameter of 1 mm (cross-sectional area 0.9 mm^2), which is a reasonable upper limit for well-maintained pipework.

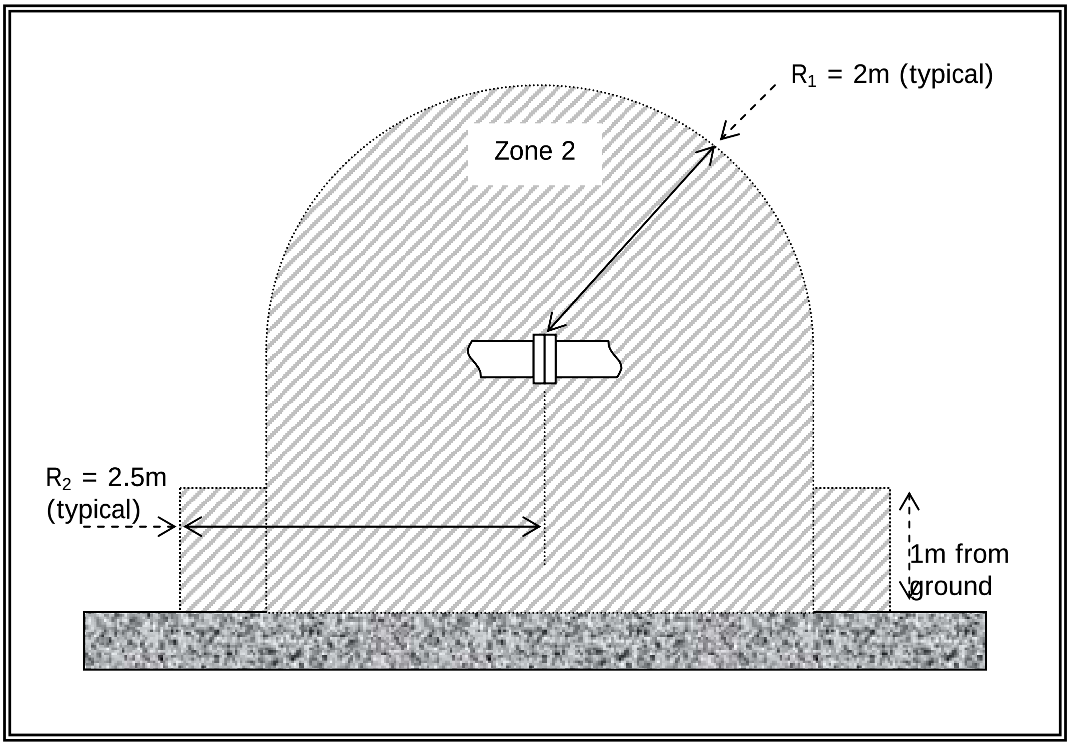
To take account of liquid drops falling to the ground, the zone extends to the ground. For flanges that are a distance greater than R_1 from the ground, two zones may be defined: one around the flange and one at ground level to take account of pool formation.

Screwed joints
Screwed joints are, in general, likely to have smaller equivalent hole diameters than flanges, so the same zoning can be applied if a conservative approach is followed.

Valves
According to IP15 Table C6, the commonest failure mode of valves is from an equivalent hole diameter of 0.1 mm (cross-sectional area 0.008 mm^2), with a larger leak from an equivalent hole diameter of 2 mm (cross-sectional area 3.14 mm^2). If consideration of the process conditions, environmental factors and maintenance regime leads to the conclusion that leaks more serious than a slight weeping of liquid are highly improbable, then valves can be zoned as for flanges, although the zoning will be conservative.

If other than minor leaks are considered reasonably probable, then the zoning drawing in Figure 15 can be used, but R_1 = 4 m, R_2 = 4 m (based on IP15 Tables C9(a) and C9(b) for a 2 mm hole diameter and a pressure up to 4 barg).

Figure 15: zoning drawing for joint or valve carrying low flashpoint liquid - outdoors



Many flanged joints give rise to smaller leaks than an equivalent hole diameter of 1 mm, depending on the integrity of the joint and whether operating conditions are adverse or relatively benign. IP15 Tables C9(a) and C9(b) do not give smaller values than those quoted above, so other methods can be used to define smaller zone extents if required; such methods are outside the scope of this ICoP.

For higher pressures and larger leak orifices, IP15 Table C9(a) gives the following information (Table 8) for a release that is not close to an obstruction, such as the ground:

Table 8: zone 2 radii for flanges etc not at ground level - outdoors

Release pressure (bara)	Hazard radii R_1 (m) for given release hole equivalent diameter			
	1mm	2mm	5mm	10mm
5	2	4	8	14
10	2.5	4.5	9	17
50	2.5	5	11	21
100	2.5	5	12	22

If the release is close to the ground, higher zone extents are appropriate, as shown in Table 9 (data from IP15 Table C9(b)):

Table 9: zone 2 radii for flanges etc at ground level - outdoors

Release pressure (bara)	Hazard radii R_2 at ground level (m) for given release hole equivalent diameter			
	1mm	2mm	5mm	10mm
5	2.5	4	20	50
10	2.5	4.5	21	50
50	3	5.5	21	50
100	3	6	21	50

Clearly, potential hole sizes with equivalent hole diameters in excess of 2 mm give rise to unacceptably large zones and do not, in fact, generally apply to pipework – the 5 mm and 10 mm columns relate to potential releases from, for example, pump seals with large diameter shafts. The zone extents for indoor releases will be larger than the equivalent outdoor releases, but an estimation of zone extents indoors is a complex process and is beyond the scope of this ICoP.

Smaller zones 2 or zones of negligible extent may be appropriate if the pipework is high integrity and/or the risk to workers of a possible ignition is assessed of being low. IP15 section 5.4.5.1 allows a more relaxed approach to joints and valves in certain circumstances. The relevant extract is quoted below:

> "For both flanges and valves, the likelihood of release from an individual item is very small and so it may not warrant classification as generating a hazard if a risk-based approach is followed, particularly if it is not operated at high pressures or temperatures. Only when there are a number of possible leak sources close together …. should this area be classified. As a guide, where there are more than 10 leak sources within close proximity (i.e. where their notional Zone 2 areas would overlap), the area should be classified as Zone 2."

10.5.4 Methanol dosing pump

The dosing pump is required to inject a measured quantity of methanol into the reactor. This section applies to all pumps, however.

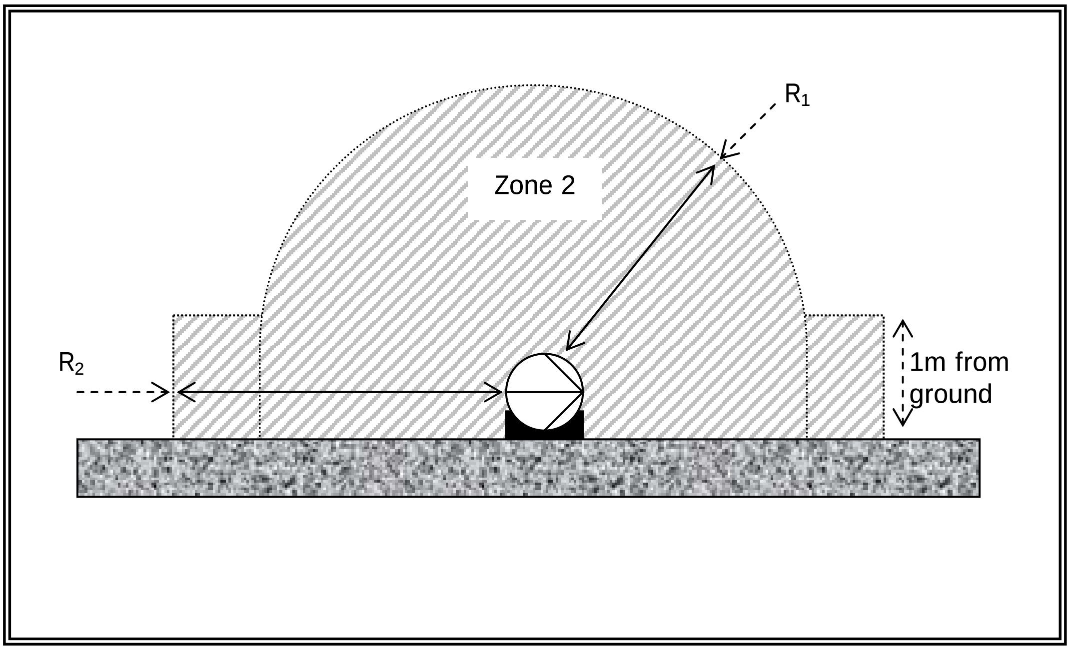
Pump design varies widely between standard industrial pumps with a fairly basic seal to high integrity pumps with a double seal that will only leak under catastrophic failure conditions, so need not be considered for area classification purposes.

IP15 Table C6 quotes leak diameters the commonest ("Level I"), less common ("Level II") and rare ("Level III") failure modes of different types of pump seal. The 'levels' take account of the fact that there is no single failure mode for seals. If required, IP15 should be consulted for fuller details on how these levels relate to the 'risk-based approach'.

It is recommended that the manufacturer is consulted where necessary to obtain a leak aperture, but the values in IP15 may be used *where leak diameter information from the manufacturer is not available*.

For a pump with a single seal and a throttle bush (or an equivalent level of integrity), IP15 gives a leak diameter of 0.1SD for a 'Level I' failure (SD = shaft diameter). For pumps handling methanol at up to 4 barg pumping pressure, the approach used in IP15 Tables C9(a) and C9(b) (for a Category C fluid) give the zone radii as shown in Tables 10 and Table 11. The zone extents from IP15 calculated for larger shaft diameters are unacceptably large (shaded areas).

Figure 16: zone radii for a pump - outdoors



The values of R_1 and R_2 are taken from table 10 below.

Table 10: zone radii for pump, single seal, with throttle bush, outdoors up to 4 barg (shaft diameters 10 to 100 mm) – LEVELS I & II

Shaft diameter (mm)	10	15	25	40	50	80	100
Equivalent hole size, D_{eq} = 0.1SD (mm)	1	1.5	2.5	4	5	8	10
Zone 2 radius, R_1 (m)	2	4 (3)	8 (5)	8 (7)	8	14 (12)	14
Zone 2 radius at ground level, R_2 (m)	2.5	4 (3.3)	20 (5)	20 (17)	20	50 (40)	50

Table 11: zone radii for pump, single seal, with no throttle bush, outdoors up to 4 barg (shaft diameters 10 to 100 mm) – LEVELS I & II

Shaft diameter (mm)	10	15	25	40	50	80	100
Equivalent hole size, D_{eq} = 0.23SD (mm)	2.3	3.45	5.75	9.2	11.5	8	10
Zone 2 radius, R_1 (m)	8 (4.8)	8 (5.5)	14 (8.9)	14 (13)	no data		
Zone 2 radius at ground level, R_2 (m)	20 (5.6)	20 (12)	50 (25)	50 (46)			

The values in brackets are interpolated zone radii from the values given in IP15 Table C9(b). These values apply to outdoor locations; pumps located indoors will have larger zones and an estimation of zone extent is outside the scope of this ICoP.

Further information

The approach used in IP15 has been simplified by considering only the shaft diameter as a guide to the leak orifice. IP15 Table C6 quotes leak diameters for the commonest ("Level I"), less common ("Level II") and rare ("Level III") failure modes of different types of pump seal. The 'levels' take account of the fact that there is no single failure mode for seals. Tables 10 and Table 11 above consider only Levels I and II.

APPENDIX 1: CALCULATION OF MAXIMUM METHANE CONCENTRATION ABOVE LEACHATE

Methane is slightly soluble in water, so a large volume of leachate contains a significant quantity of methane. In a closed system, such as an unventilated tank, methane escapes from the leachate into the air space and an equilibrium is set up. Under equilibrium conditions, methane molecules are released from the surface of the leachate at the same rate as they hit the surface of the leachate and are re-dissolved. The solubility of methane in water reduces with temperature under normal pressures and temperatures[AA].

Gases dissolve in liquids to form solutions. This dissolution is an equilibrium process for which an equilibrium constant can be written. For example, the equilibrium between methane gas and dissolved methane in water is

$$CH_4(aq) <--> CH_4(g).$$

The dimensionless equilibrium constant for this equilibrium is represented by H:

H = C(air)/C(water

where C(water) = concentration of methane in air
C(water = concentration of methane in water

This is one way of representing Henry's law, which is found to be an accurate description of the behaviour of gases dissolving in liquids when concentrations and partial pressures are reasonably low. This is the case for methane in leachate.

For methane, the dimensionless version of Henry's Law constant at 20°C is 26.9, i.e. the ratio of the concentrations in air and water using any units.

The upper permissible methane concentration is given as 0.14 mg/litre, in most Water Company consents.

The intention is that the maximum permitted discharge concentration should provide a very low risk of explosion to sewer maintenance operatives, and as such the occupational risk is set at 1/10th of the LEL, (in accordance with WHO Guidelines?) which is normally considered to be 5%. Therefore, the consent limit is based upon achieving 0.5% LEL allowing a factor of safety of 10.

The calculation is as follows:-

H = 26.9 = C(air)/C(water)

= C(air)/0.14

Thus C(air) = 26.9 x 0.14 = 3.766 mg/litre
= 3.766/16000 mol/litre (where 16000 is the number of mg in 1 mole of methane)
= 0.000235 mol/litre
= 0.000235 x 24 litres/litre (where 24 litres is the molar volume at 20°C)
= 0.00564 litres/litre
= 0.564% v/v

Thus, a concentration of 1.4 mg/litre could give a concentration of 5.64% v/v, which is just above the LEL. This calculation validates the threshold value found by test.

APPENDIX 2: REFERENCES

The following publications were referenced in compiling this document:

A Dangerous Substances Explosive Atmospheres Regulations:2002 ('DSEAR') regulation 7 requires area classification to be undertaken

B EN 60079-10:2003 - Electrical apparatus for explosive gas atmospheres - Part 10: Classification of hazardous areas (technically identical to IEC 60079-10:2002)

C Area Classification Code for Petroleum Installations, Part 15, Third Edition, 2005, Institute of Petroleum (IP15)

D ATEX Directive 1999/92/EC: Minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres – also known as the 'ATEX 137 Directive' or 'ATEX Worker Protection Directive'

E A. McMillan: Electrical installations in hazardous areas, Butterworth Heinemann, 1998.

F British Compressed Gas Association – numerous codes and guidance notes

G EN61241-10:2004: Electrical apparatus for use in the presence of flammable dust – Part 10: Classification of areas where combustible dusts are or may be present

H HSG103: Safe handling of combustible dusts: preca utions against explosions, HSE Books, 2003

I HSG51: The storage of flammable liquids in containers, 2nd Edition, 1998

J HS(G)113:Lift trucks in potentially explosive atmospheres, 1996

K BS 6133:1995 – Code of Practice for the safe operation of lead-acid stationary batteries

L This term is used in 'A risk-based approach to hazardous area classification', Institute of Petroleum, November 1998, Annex D

M American Water Works Association in 1938, T E Larson

N Hjelmar U., Johannessen L.M. Knox K., Ehrig H-J., Flyvberg J. Winther P. and Christensen T.H. (1995): 'Management and Composition of Leachate from Landfills.' Final report to the Commission of the European Communities, DGXI A.4, Waste '92, Contract No: B4-3040/013665/92

O A Review of the Composition of Leachates from Domestic Waste Leachates in landfill Sites, Env. Agency Research & development, Technical Report CWM 072/95, 1995

P Pollution Inventory Discharges to Sewer or Surface Waters from Landfill Leachates, Ref: REGCON 70 May 2001

Q Data based on kerosene from IEC 79-20:1996 - Electrical apparatus for explosive gas atmospheres - Part 20: Data for flammable gases and vapours, relating to the use of electrical equipment

R Guidance for monitoring trace components in landfill gas, document LFTGN 04, September 2004, Environment Agency

S BS EN 1127-1:1998 – Explosive atmospheres – explosion prevention and protection: Part 1: basic concepts and methodology

T EN 61241-10:2004: Electrical apparatus for use in the presence of flammable dust – Part 10: Classification of areas where combustible dusts are or may be present

U HSG103: Safe handling of combustible dusts: precautions against explosions, HSE Books, 2003

V BS 7535:1992 – Guide to the use of electrical equipment complying with BS 5501 or BS 6941 in the presence of flammable dusts.

W Institute of Petroleum Model Code of Safe Practice Part 9, 1987: Bulk pressure storage and refrigerated LPG

X See www.lpga.co.uk

Y Sira report R/420/10954/Issue 3: Mists (aerosols): area classification and equipment selection

Z EMPL-2002-10812-03-00-EN-TRA-00: Non-binding guide of good practice for implementing Directive 1999/92/EC, Jan 2003, European Commission, section 3.1.2, example

AA Yamamoto, S Alcauskas, J B and Crozier, T E (1976). Solubility of methane in distilled water and seawater. Journal of Chemical and Engineering Data, 21, (1), 78-80.

WASTE MANAGEMENT INDUSTRY

LANDFILL OPERATIONS INVOLVING

POTENTIALLY EXPLOSIVE ATMOSPHERES

INDUSTRY CODE OF PRACTICE

ESA ICoP 5, edition 1, August 2007

This work was commissioned by ESA and funded by Ascot Environmental, Biffa, Clark Energy, Cory Environmental Ltd, Enitial, the Environmental Services Training and Education Trust (ESTET), SITA UK, Veolia Environmental Services, Viridian Systems and Viridor Waste Management

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FOREWORD

James Barrett, Head of the Manufacturing Sector of the Health and Safety Executive.

This code has been prepared by the Environmental Services Association in consultation with the Health and Safety Executive and has been endorsed by the Waste Industry Safety and Health (WISH) Forum which represents the interests of the industry.

This Code should not be regarded as an authoritative interpretation of the law, but if you follow the advice set out in it you will normally be doing enough to comply with health and safety law in respect of those specific issues on which the Code gives advice. Similarly, Health and Safety Inspectors seeking to secure compliance with the law may refer to this Guidance as illustrating good practice.

The HSE believes that the contents of this Code demonstrate good practice in the waste management industry and commends its use.

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In this document, footnotes are indicated with letter ([a]) and endnotes (references to documents used) with a number ([1]).

1 INTRODUCTION AND SCOPE

1.1 Executive summary

This document (ESA ICoP 5) is one of a number called up by the primary document (ESA ICoP 1) that, together, advise on how to fulfil the requirements of the Dangerous Substances Explosive Atmospheres Regulations:2002 ('DSEAR')[1] for the waste management industry. Within this ICoP, a 'hazardous area' is one in which a flammable gas/air mixture is, or could be, present. Other risks not relating to the risk of fire or explosion (e.g. toxic risks) are not covered.

ICoP 5 attempts to apply existing codes of practice to the specific situations found in waste management industry operations associated with landfill gas extraction. ICoP 6 will deal with operations associated with landfill gas treatment and other waste management activities.

ICoP 5 comprises a set of recommendations only and is not mandatory, but is intended to represent good practice. Alternative practices may be employed provided the level of safety is maintained. Site-specific factors should always be considered when applying this ICoP. Throughout ICoP 5, there are situations covered that may require additional verification of the validity of the assumptions. On a particular site, it is the Site/Facility Manager[a] who holds the final responsibility to ensure DSEAR compliance.

The intention is that as many as possible of the standard situations will be included in this ICoP to allow the operation of waste management facilities to be performed in a consistent manner across the industry by suitably-qualified persons, while complying with DSEAR.

It is envisaged that this Edition will be reviewed and re-issued during 2007. In the interim, further information in the form of method statements may be made available as addendums. Comments from the industry are welcomed and should be sent to ESA (m-kelly@esauk.org) before 31 December 2006.

1.2 Scope

This ICoP should be applied in the design of new works, the maintenance and extension of existing works and other operations performed by the waste management industry.

Part 1 operations associated with landfill gas extraction
This will be further sub-divided into the following:

Engineering, covering
1 Development
2 Construction (capping and completion)
3 Maintenance and aftercare
4 Temporary works
5 Day-to-day operations

Part 2 operations associated with landfill gas treatment and other waste management activities; this will be included in a subsequent edition of this ICoP.

This document does **not** consider
- drilling operations, for which a safe system of work is currently being developed in association with the relevant bodies;
- safety issues associated with toxic, asphyxiant or other hazards associated with landfill materials;

a Wherever this term is used, it should be understood that the Site/Facility Manager can appoint another person for certain duties, but the Site/Facility Manager holds overall responsibility for ensuring that the duties are carried out.

Many aspects of waste industry activities that relate to DSEAR compliance are covered by other ICoPs in the series:

- Top-level document (ESA ICoP 1) – Edition 1 published November 2005
- Area classification for landfill gas (ESA ICoP 2) – Edition 2 published April 2006
- Leachate storage, treatment and disposal (ESA ICoP 3) – Edition 1 published April 2006
- Drilling (ESA ICoP 4) – under discussion
- Operations (treatment) (ESA ICoP 6) including liquid treatments/solidification, advanced conversion technologies, aerosol destruction facilities – under discussion
- Solid waste non-destructive facilities (ESA ICoP 7), including civic amenity (CA) sites, transfer stations and materials recycling facility (MRF) – under discussion

1.3 Quick-start guide

The following steps give a typical route for a site to be DSEAR compliant. ICoP 1 gives more details. This is only a summary of the requirements and is not intended to be an exhaustive coverage. The most useful document that covers DSEAR requirements in general terms is the HSE publication, Approved Code of Practice L138[2].

1. Perform an area classification of the site and produce an area classification drawing (guidance in ICoP 2 Edition 2)
2. Mark hazardous areas and pipes (see section 5.6.7 of this ICoP)
3. Identify activities associated with an explosion risk that require risk assessments and write the relevant method statements (use the templates in the relevant Appendices in this ICoP).
4. Compile a database of all fixed electrical and non-electrical equipment that is located in zoned areas plus all portable/transportable equipment that may be used in hazardous areas. Each item should be uniquely identified.
5. Set in motion an inspection programme such that all the equipment in hazardous areas is inspected at least once every three years against EN 60079-17 (every 12 months for portable equipment). Many companies employ outside contractors to do this, but the database will need to be up-to-date before they can start.
6. Ensure the site procedure for accidents, incidents and emergencies is available and up-to-date – more information is given in section 5.6.5 of this ICoP.
7. Ensure that the Site/Facility Manager (or another suitable person) is adequately trained to verify that new installations comply with DSEAR, since this is the person who must sign off new installations before they are put into service. Identify any other training needs, particularly ensuring that the explosive risks of landfill gas are included in site inductions. Ensure that the duty of co-ordination between the Site/Facility Manager and the contractors is carried out. More information is given in section 5.6 of this ICoP.

2 GLOSSARY OF TERMS

Table 1: glossary of terms

Term	Explanation
Apparatus group	The part of the certification code (IIA, IIB, IIC or II) that indicates the range of gases and vapours for which the equipment is suitable. Equipment marked IIC or II is suitable for all gases and vapours (provided the temperature class is appropriate). IIB equipment is suitable for IIA and IIB gases. IIA equipment is suitable only for IIA gases.
Area classification	The process of zoning the site to delineate between hazardous areas and non-hazardous areas
Basal seal	Mineral liner, plastic membrane, combination liner or other impermeable material underneath the waste, primarily engineered to prevent leachate from seeping into the ground below the landfill.

Table 1: glossary of terms	
Term	**Explanation**
Butt welding (of pipes)	This is usually a fully-automatic process, but overseen by an operator. The pipe is placed into a mechanical alignment machine. A planer is placed between the pipe ends and the pipe ends are planed square. The planer is powered by an electric motor. A hot plate is then placed between the two pipes ends to melt the pipe; once melted, the two ends are forced together for a set period of time. The hot-plate is a hollow-steel plate which is oil filled, with heating coils immersed in the oil. These machines are usually powered by an external portable generator.
Category 1G equipment	Equipment with a very high level of protection, suitable for installation in zone 0[b]; it may equally be used in zones 1 and 2. Most category 1g electrical equipment is protected by intrinsic safety.
Category 2G equipment	Equipment with a high level of protection, suitable for installation in zone 1; it may equally be used in a zone 2.
Category 3G equipment	Equipment with a standard level of protection, suitable for installation in zone 2.
Electrofusion welding (of pipes)	A method for welding together two pieces of HDPE pipe. A collar with integral heating coils is placed over the pipe and connected to a control box, which supplies the current to heat the coils; when the joint is made, the collar and integral coils remain on the pipe
Extrusion weld	Extrusion welding uses a commutator-type electric drill with a heater box attached. The heater box is designed on the same principal as a hot air drier with the same exposed heating elements, Both the motor and the heater box receive air from the surrounding environment.
FID	Flame ionisation detector – generally used for surface emissions monitoring, typically up to 1000 or 10,000 ppm of hydrocarbons depending on the model
Flameproof (Ex d)	A method of protection whereby the equipment is protected for use in a potentially explosive atmosphere by being enclosed in an explosion-proof enclosure. This method is suitable for a wide range of applications, such as motors, luminaires, junction boxes, switch units, instruments, etc. Such equipment is permitted in zones 1 and 2. See also Appendix 3.
Flux box	A chamber that, when sealed against a landfill surface, allows surface emissions to enter by diffusion as a result of the concentration gradient between the landfill surface and atmosphere.
FML	Flexible membrane liner (synonymous with 'geomembrane') – used for capping cells. There are various grades of flexibility (e.g. VFML = very flexible membrane liner)
Fusion weld	Fusion welding involves the use of commutator-type electric motor to power a heated wedge (also known as a wedge welder) along the joins between two geo-membrane panels. The electric motor receives cooling air from the surrounding environment, notably at the seam where the edges of the panels meet.
Geomembrane	A plastic sheet used to cap wells – also known as a 'flexible membrane liner'.
Hazardous area	An area where there is a reasonable probability of finding a potentially explosive atmosphere
Increased safety (Ex e)	A method of electrical protection that eliminates sources of ignition inside the enclosure, which is also weatherproof. Increased safety is used as an alternative to flameproof for some items, such as luminaires, junction boxes and larger-frame motors. Like flameproof, Ex e equipment can be used in zones 1 and 2. See also Appendix 3.
Intrinsic safety (Ex ia, Ex ib)	A method of protection, only applicable to low-power electrical equipment, which prevents the equipment igniting a potentially explosive atmosphere by limiting the energy of sparks to a safe level; similarly, there are no excessively hot surfaces. Intrinsic safety is the most common method of protection for instruments and allows them to be used in zones 0, 1 and 2 (Ex ia) or zones 1 and 2 (Ex ib). Such equipment is describe ed as being 'intrinsically safe' – this term is frequently over-used and cannot, for example, be used to describe motors, luminaires, pumps, etc. Some torches are partly or fully intrinsically safe. See also Appendix 3.

[b] Note that equipment should ideally be installed in the non-hazardous area or, if in a hazardous area, in the zone of least risk

Table 1: glossary of terms	
Term	**Explanation**
Leachate	A water-based liquid that collects in a landfill site, containing numerous contaminants depending on the constituents leached from the landfill mass
Lower explosive limit (LEL)	The minimum amount of flammable gas that, mixed with air, will produce a potentially explosive atmosphere; it is usually expressed as a percentage by volume
Maintenance	See section 4.
Negligible extent	Where the estimated volume of a potentially explosive atmosphere is small (less than 0.1 m^3, equivalent to a sphere of radius 0.3 m)[c], it is defined as having 'negligible extent' and no zoning applies.
Non-hazardous area	An area where there is a negligible or extremely low probability of a potentially explosive atmosphere being present; such an atmosphere may be present under catastrophic failure conditions or during maintenance activities
Permit-to-work	See section 5.5.13
Potentially explosive atmosphere	A mixture of gas and air that is within the flammable range, i.e. Between the LEL and UEL
Potentially flammable atmosphere	Synonymous with 'potentially explosive atmosphere' – this term is preferred by the Institute of Petroleum Code Part 15 for area classification ('IP15')
Purging	A process for replacing one gas with another, usually landfill gas with air (or sometimes nitrogen). Purging may be required prior to pipe repairs and achieved by inserting an air supply pipe into the section of isolated pipe or using the air leaking in from a break to flush the landfill gas down the pipe to the next isolation valve.
Saddle patch	A plastic patch, shaped so that it fits snugly over a pipe, which is then electrofusion welded to the pipe to give a permanent repair
Second-hand equipment	From the point of view of the ATEX Directive, this is all equipment except that purchased directly from the manufacturer. It could be previously used/installed equipment, hired in equipment, new equipment that has been held in stores, or new equipment that has been purchased from a distributor.
Site/Facility Manager	The person holding overall responsibility for ensuring that all duties relating to compliance with the various regulations are carried out. Wherever this term is used, it should be understood that the Site/Facility Manager can appoint another person for certain duties.
Temperature class	Equipment is designated with a temperature class, T1 to T6; T6 equipment is the coolest (below 85°C), whereas T1 equipment is the hottest (below 450°C). Gases and vapours are also assigned temperature classes T1 to T6 to allow suitable equipment to be chosen.
Type 'n' (or 'N') protection	This is a level of protection that is only applicable to electrical equipment for use in zone 2 and uses a variety of protection methods to provide a basic level of security against igniting a potentially explosive atmosphere. See also Appendix 3.
Upper explosive limit (UEL)	The maximum amount of flammable gas that, mixed with air, will produce a potentially explosive atmosphere; it is usually expressed as a percentage by volume
Vacuum tester	A box-like piece of equipment that is used to test the integrity of a extrusion-type plastic weld on geo-membrane.
Wedge welder	See 'Fusion weld'
Zone 0	A place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is present continuously or for long periods or frequently.
Zone 1	A place in which an explosive atmosphere consisting of a mixture with air or flammable substances in the form of gas, vapour or mist is likely to occur in normal operation occasionally.

c Strictly speaking, a 'hypothetical volume' (V_Z) of less than 0.1 m^3 rather than a zone volume is the criterion for being "of negligible extent". EN 60079-10:2003 calculation 4 (conclusion) states that a V_z <0.1 m^3 allows the ventilation to be assessed as degree 'high'. From the definition of degree 'high' in clause B.3.1, a zone of negligible extent results.

Table 1: glossary of terms	
Term	**Explanation**
Zone 2	A place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is not likely to occur in normal operation but, if it does occur, will persist for a short period only.

3 PROPERTIES OF LANDFILL GAS

Table 2: properties of landfill gas		
Property	**Value**	**Comments**
Constituents	Methane (CH_4)– 60% v/v Carbon dioxide (CO_2)– 40% v/v 35.3% CH_4 by mass	Proportions may vary but these values will be used for calculation purposes (see table below). CO_2 is not flammable.
Molecular mass (M)	27.2 kg/kmol (60% CH_4)	Methane has a molecular mass of 16; carbon dioxide has a molecular mass of 44. Therefore, landfill gas containing 60% methane will have a molecular mass as follows: M = [(60 x 16) + (40 x 44)]/100
Explosive limits[3]	4.4 – 16.5% v/v[d]	Assumed as for pure methane[e] in air
Relative density (air = 1)	0.94	Air has an average molecular mass of 29 kg/kmol
Minimum temperature of landfill gas (for calculation purposes)	10°C	From LFTGN 03[4]
Apparatus group	IIA	As for methane
Auto-ignition temperature	537°C	As for methane
Temperature class	T1	As for methane

Since landfill gas has the least onerous apparatus group and temperature class, all hazardous area equipment is suitable for use with landfill gas provided it has been correctly selected against other criteria, notably the zone.

In preparing this ICoP, the presence of hydrogen as a gas produced in the microbial decomposition of waste has not been considered. In general, as hydrogen is associated with the early stages of the degradation process, it is unlikely that gas extraction for power generation or utilisation (combustion) within a landfill gas flare would be initiated. However, it may be the case where some form of odour control involving gas collection from waste is required.

Monitoring may take place, indicating the presence of a significant concentration of hydrogen approaching or exceeding the LEL. If this is the case, then a specific risk assessment based on actual measurements and conditions present should be undertaken to identify any risk of a potential explosive atmosphere being present with, where required, suitable and sufficient mitigating measures put in place. Hydrogen is a IIC/T1 gas with an LEL of 4% v/v.

There are many other components associated with the decomposition of waste – refer to LFTGN 04[5] which addresses the health and environmental aspects, but not primarily the flammable risk.

d BS EN 61779-1:2000 quotes 4.4% – 17%

e It is likely that the LEL for landfill gas is higher than that of pure methane, on account of the CO_2 content

4 GENERAL PRINCIPLES OF OPERATIONS ON LANDFILL SITES

The approach should be to ensure that, **wherever possible, flammable materials should be absent from the workplace** when maintenance activities are being performed. This is not possible in all situations in the waste management industry, but current practices should always be assessed to attempt to find a safer way of working. Hot work (e.g. oxy-acetylene welding) should always be done in a non-hazardous area wherever possible, otherwise under a relevant permit to work.

The sites will already have been zoned in accordance with ICoP 2. The zoning is relevant when temporary working is done in a zone 1 or zone 2, usually without affecting the gas containment. Safety is usually achieved by working under a relevant permit, involving continuous methane monitoring where necessary. Certain equipment should be located outside the hazardous area as a matter of course: Photo 1 shows a generator that could easily be moved outside the zone. (The temporary method of sealing the well is also suspect).

Photo 1: Generator located within a zone 2

Generally, the zoning does not apply to engineering activities involving opening of the containment system, as area classification does not cover such activities, although the zoning is useful background information[f]. In effect, the concept of zones (which relate to everyday running) should be replaced by a consideration of how a potentially explosive atmosphere can be avoided to a very high level of confidence while work is progressing. This may be achieved in a number of ways, singly or in combination, for example:

- isolation valves
- bagging (blocking the pipe being worked on to prevent landfill gas entering the working area)
- squeezing the pipe to cut off the gas
- vacuum testing to determine if a well is under vacuum prior to removing the cap
- purging with air or nitrogen[g]
- continuous methane monitoring
- installation of blanking plates between flanges

Isolation methods may not be completely reliable at preventing gas from seeping through. Insufficient time may be left between isolation and the start of work, such that landfill gas may remain in the pipe in an explosive concentration. Also, gas from another source may be present. For these and other reasons, a gas test is essential, using an appropriate, suitably-certified gas analyser.

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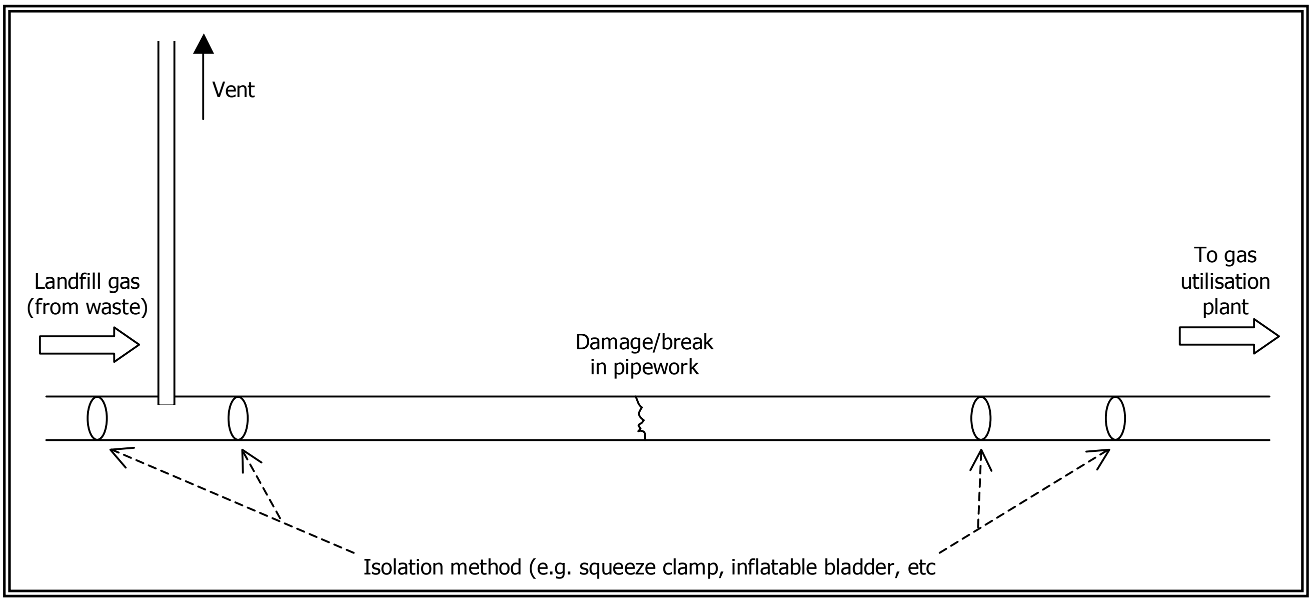
f Some maintenance activities, such as sampling, that do *not* generate an excessively large potentially explosive atmosphere may be included within the area classification process.

g Beware of asphyxiation

Figure 1 shows one method for ensuring effective isolation is that used by the gas industry, using a 'double-block-and-vent' system.

Figure 1: Double block and vent system for isolating pipes



Only when all other options have been exhausted should work in the presence of a potentially explosive atmosphere be contemplated. The risk assessment for such situations is outside the scope of this ICoP.

All work must be carried out by competent persons, using equipment in accordance with the manufacturer's instructions. The various ICoPs assume that the pipework and fabrications are selected, installed and maintained in accordance with best industry practice.

In addition to the correct selection of equipment, it should be noted that wiring faults are a potential ignition source unless the circuit is intrinsically safe and cabling should be installed to minimise the risk of mechanical damage.

5 LANDFILL SITE OPERATIONS

5.1 Development operations

5.1.1 Design

A consideration when designing new facilities is to take account of flammable gases and explosive atmospheres in and around features which are within the waste. It is important that workers can work safely during the life of the installation, without being exposed to potentially explosive atmospheres.

Examples of design considerations are:

1 Segmented concrete rings in a leachate tower are prone to being a source of gas emissions during construction.

2 Some engineering activities take place adjacent to areas where landfill gas is present. Therefore, the impact on these operations needs to be considered, for example extending perimeter walls from an existing (gassing) cell to a new (non-gassing) cell.

3 Designing a feature such as a side-wall riser that has a zone that extends over the site boundary;

4 Inclusion of means of isolation[h] at suitable intervals on the gas collection system to facilitate repair, maintenance and in case of emergencies.

5 Conduits can create a gas path that allows landfill gas to be present in an unexpected place

The designer is required to consider hazards associated with the design and, where possible, reduce the risk by modifying the design. Refer to the designer's role in the CDM[6] Regulations. The CQA[i] plan should pay

h For example, valves, access areas for pinching, port for pigging, etc.

i Construction Quality Assurance procedures due regard to DSEAR requirements. Non-CDM activities should also be assessed with regard to DSEAR requirements.

The following should be considered
- Mount any control cabinets outside the zone from the gas or leachate well
- Install wells after tipping has ceased, so that it is not necessary to control the risk of vehicles close to the well
- Avoid jubilee-clip type connections where better alternatives are available
- Design wells that can be securely capped, so that foam and other unreliable temporary measures need not be used
- Include a vent-trench a few metres from the edge of any geo-membrane liner to extract landfill gas so that welding to the next cell is not done in the presence of a potentially explosive atmosphere
- Avoid perforated pipes above the cap, as these allow landfill gas to escape and also allow air in, producing a potentially explosive atmosphere inside the pipe
- Mild steel rusts quickly and makes modification difficult, encouraging unreliable temporary measures
- Consider locating in-waste monitoring boreholes at the edge of the site rather than in the middle, to avoid having to divert vehicles around these obstructions
- Drainage layers should be capped to avoid the potential of gaseous emissions and the potential for an explosive atmosphere to form
- Side slope risers should be selected to allow for a properly-fitting end-cap, which will facilitate the subsequent installation of pumps and control mechanisms
- Large metal covers that are too heavy to lift easily are a potential spark hazard if dropped down a metal- or concrete-lined well
- Pipework and pipework connections should be to an approved industrial standard: 'home-made' flanges and other connections should be avoided

5.1.2 Environment Agency and other regulatory bodies

The Environment Agency (or equivalent regulatory body[j]) often has a focus on license or permit conditions which control environmental hazards. Within this, there may be no consideration of DSEAR issues, in which case there is an urgent need to discuss this via the appropriate forum. Health and safety issues must take precedence over environmental considerations.

5.1.3 Construction

Constructional activities are to be undertaken with due regard to DSEAR; this will include specific details in such areas as:
- site set-up
- training
- permit to work – see section 5.5.13
- contractor's health & safety plan including method statements, risk assessments, etc.

5.1.4 Designing to minimise equipment in hazardous areas

Wherever possible, installing equipment in hazardous areas should be avoided. If unavoidable, the equipment should be installed in the zone of lowest risk. There are safety benefits with his policy, but there are also a number of additional costs associated with equipment installed in hazardous areas:
- the initial cost is usually considerably higher than equivalent standard industrial equipment;
- installation may involve additional costs if a suitably-qualified person needs to be hired to install it;
- maintenance or calibration may take longer because the equipment may require isolating, due to the flammable risk;
- the equipment requires a periodic inspection[k] to cover its explosion-protection properties, not just its functionality.

Examples of equipment that can usually be located outside the hazardous area are instrument control panels for environmental management systems, pumps, etc. However, where panels are supplied as suitable for use in hazardous areas, these can, of course, be used within a zoned area. Further information on the marking of hazardous area equipment is given in Appendix 3.

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j In Scotland, the appropriate body is SEPA.

k Reference ESA ICoP 1 section 7 for further information; a typical inspection frequency for fixed equipment is every 3 years.

5.2 Capping and completion

Capping normally takes place when a cell is at the early stages of landfill gas production. Before capping, landfill gas comes out of the waste mass at a relatively even rate and disperses rapidly, such that surface emissions testing usually detects only low concentrations of gas, well below the LEL, a few centimetres above ground level. Placing a geo-membrane[I] on top of the waste mass collects the gas and prevents dispersion, increasing the risk of a potentially explosive atmosphere forming. This is particularly likely to occur, for example, around the points where wedge welding cannot be used and patches are required. However, if scavenger pipes are laid before the geomembrane is deployed then this risk ia eliminated or at least greatly reduced.

This being the case, primary consideration should be given to capping systems that do not involve welding. The welding process itself introduces the following potential ignition sources:

- heat guns
- sander
- fusion (wedge) welder

These are not normally certified items.

The risk of ignition from sanders and wedge welders is low. The risk from hot air guns can be greatly reduced by decreasing the wattage of the heating element. Additional procedures to control the risk from local concentrations of landfill gas are given later in this section.

Alternatives to welding include:

1. 'lap-and-lay' of the geo-membrane (although a limited amount of welding may be required to weld the boot)
2. geo-synthetic clay liners
3. engineered clay
4. adhesives (under consideration by the industry but demonstrated not to provide durable jointing)

Where practicable, non-welding methods should be used. However, there are a number of other factors (apart from DSEAR considerations) that need to be considered, e.g.:

- the ingress of air under conditions of over-extraction;
- the ingress of surface water, particularly in the short term;
- in some areas of the country, there is a shortage of inert material for covering the geo-membrane and welding reduces emissions in these circumstances.

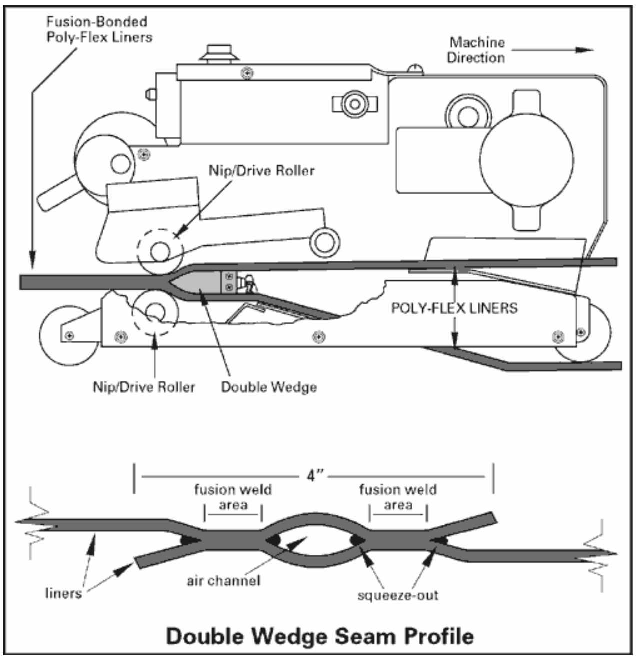
Therefore, welding techniques need to identify the risks and control them.

5.2.1 Welding and patching geo-membranes

Sheets of geo-membrane (known as 'panels') are laid across the landfill mass and welded to each other using a 'wedge-welder' (see Figure 2 below).

[I] The geo-membrane is commonly a high density or medium density polyethylene sheet

Figure 2: Wedge welder



Wedge-welding. A wedge welder is used to fuse the edges of panels together. It comprises a copper block with heated metal elements and the maximum temperature employed is normally limited to 420°C[m]. It is a low volume device, frequently hand-built and is uncertified. However, there may be sufficient time for a significant quantity of flammable atmosphere to accumulate underneath the panels. In this case, a system of gas extraction or another effective measure should be employed to purge the area.

As an example of a gas control measure, scavenger pipes may be laid before capping starts, e.g. where the landfill gas is collecting in significant quantities underneath the panels – see Photo 2

Photo 2: 'Ballooning' due to landfill gas collecting under geo-membrane

Patching. Where four panels join, there is a need for a patch to be added, since the wedge welder requires access to both sides of the geo-membrane. Once the panels of the geo-membrane are in place and welded together, they tend to concentrate landfill gas and a likely escape route is through the area where the four panels join. The usual procedure is as follows:

1 A hot air blower (manufactured by Leister and others) is used to melt the geo-membrane at certain points and form a tack weld around the patch over the hole.

2 A 240 V[n] standard industrial sander is used to buff the surface to break the slightly oily surface on the membrane to be able to create a good weld.

3 An extrusion-type welder is then utilized, which incorporates a heavy-duty hot air blower to pre-heat the geo-membrane. This device also has a heated barrel that warms a plastic welding rod or plastic

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m This is the maximum quoted by manufacturers of wedge welders.

n There is too much voltage reduction and too high a current with a 110 V sander.

granular to approximately 220°C, the extruded material then being directed to a shoe that shapes the extrusion weld or ribbon.

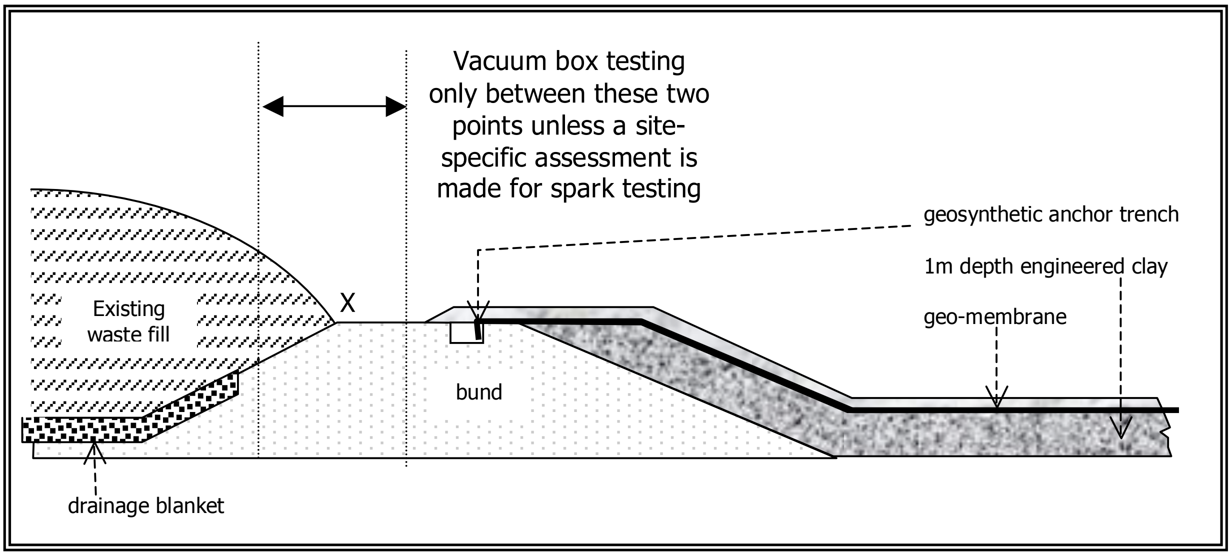
4 The weld is tested using one of two methods:
   a Spark testing: this requires a thin metal wire to be included in the joint, which is then covered with the extruded weld ribbon. A spark gun is run over the weld ribbon, just above the buried wire, and produces a spark between the gun and the rod. If there is a fault in the weld, the spark concentrates in the hole and the weld can be repaired by extrusion welding over this point.
   b Vacuum test: the weld is sprayed with a soap-like solution and a box with a transparent lid placed on top. A vacuum is produced in the box and bubbles can be seen emerging from any faults in the weld.

In some patching operations, the various stages may be carried out in the presence of a potentially explosive atmosphere but none of the items are certified. A high-power hot air source is needed for steps 1 and 3 and the temperature is sufficient to cause the ignition of the geo-membrane if played on one spot for too long. Hot-air blowers (step 1 above) have red-hot elements to heat the air. The air temperature could be sufficient to cause the ignition of the geo-membrane if played on one spot for too long. However this has never been observed and is considered most unlikely. This risk is eliminated by proper use of the hot air blower and by controlling the outlet air temperature by limiting the heating element size and by regular cleaning of the air intake filter to avoid accumulation of dust particles. Similarly, the hot air blowers incorporated in the extrusion welders (step 3 above) are equipped with lockable temperature controllers that prevent overheating, or if necessary can be fitted with air heaters of reduced power rating.

Where sealing of the panels of the geo-membrane is required, there are currently no practical alternatives to the seam-welding and patching method.

Because of these precautions, welding is not a high-risk activity, although ignitions and fires have been recorded. Incidents involving ignitions are usually associated with spark testing. Therefore, spark testing should be restricted to areas where there is a low probability of landfill gas being present, e.g. most basal linings. However, when connecting to an existing cell, the probability of an ignition is increased and spark testing should not be used unless a site-specific risk assessment has been carried out. It should be noted that there is a significant probability of a potentially explosive atmosphere forming where existing waste meets a bund (point X on Figure 3 below), as this is at the extreme limit of the extraction system.

Figure 3: areas where spark testing may not be permitted



It is difficult to estimate the extent of the potentially explosive atmosphere at the interface, X. The amount of landfill gas escaping depends on factors such as the extraction rate, age of the deposited waste, etc. Since the landfill gas is likely to be escaping along the line of the membrane rather than at a single point, it is not unreasonable to assign the same extent as used in ICoP 2 for a gas well, typically 2.2 m.

A common situation is where new waste has been tipped across the entire bund and on top of the existing waste fill. It is necessary to remove this waste to expose at least 2m width of geomembrane on the bund. The issue of vehicles relocating old waste is addressed in section 5.3.2.

The completed capping area may look like Photo 3. Note the bund is to the left of the capped cell – where the two meet is where an explosive atmosphere could be present.

Photo 3: Completed capped cell

5.2.2 Sample requirements for seam welding on temporary liner installations

The purpose of this guidance is to allow the safe operation of the welding equipment while in use.

1 Risk assessments and method statements must be submitted by the contractor undertaking the work. These will include:

- use of the seam welder
- use of the extrusion welder
- working on a steep gradient
- working on changing surfaces
- working in adverse weather conditions

2 All documentation supplied by the contractor must consider the DSEAR implications of the work.

3 A contractor safety plan must be completed and all contractors inducted; a relevant permit should be issued for all aspects of the work[o].

4 An FID and gas analyser must be available for use throughout the period of work. These instruments must carry a service record and an in-date calibration certificate.

The gas detection limits from the FID at the seam are as follows:

- 1000 ppm – cease operation;
- 5000 ppm – cease work.

At the vent or extraction equipment used to extract gas from the joint area:

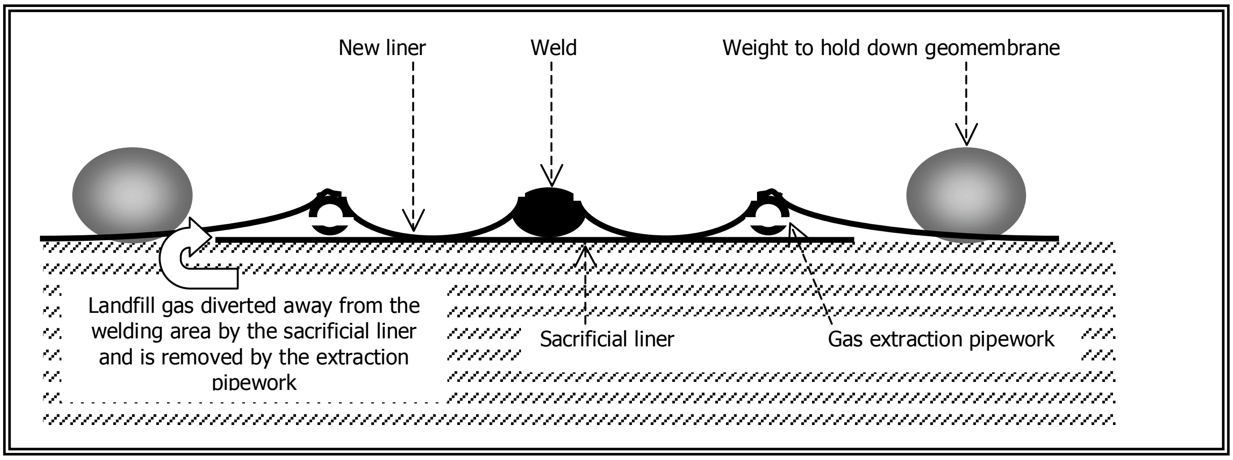
- 0-3% CH_4 is the operating range when work may continue;
- 3-4% CH_4 – increase the rate of extraction;
- above 4% - cease work and contact the site manager; readings should be taken at intervals of no greater than 2 hours.

5 Installation of the liner should be undertaken using the contractor's standard risk assessment and method statements. The CQA will be agreed on a site-specific basis in conjunction with the contract.

o For a CDM project, this will generally be the principal contractor; for a non-CDM project, this will generally be the Site/Facility Manager

Figure 4 below show an example of one possible method of controlling the levels of landfill gas when seam welding.

Figure 4: Location of extraction pipes when seam welding – side view

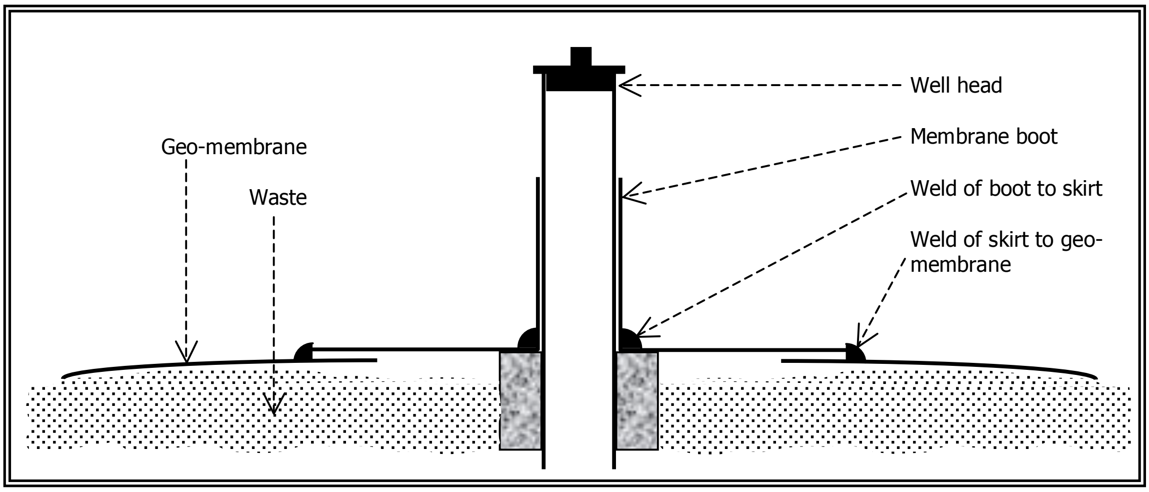


A similar system incorporating a sacrificial membrane but without the extraction pipes has been employed on German landfill cappings. Ballasting by flat hoses would appear to be unnecessary in consideration of contractor's normal ballasting against wind uplift

5.2.3 Connecting the geo-membrane to the well head

There are special considerations around the gas/leachate well itself when the geo-membrane is connected to the well head using a 'boot'. The boot is a pre-fabricated sleeve that is placed over the well. The boot and skirt are usually welded to each other elsewhere, which is advisable, as this therefore makes it unnecessary to weld close to the well (a zone 2[p]). The extraction pipe is removed from the well head, the 'boot' is placed over the well and the extraction pipe replaced. The boot is then welded to the geo-membrane – see Figure 5 and Photo 4.

Figure 5: well with boot and skirt fitted



Refer also to section 5.2.1 for a discussion of welding geomembranes.

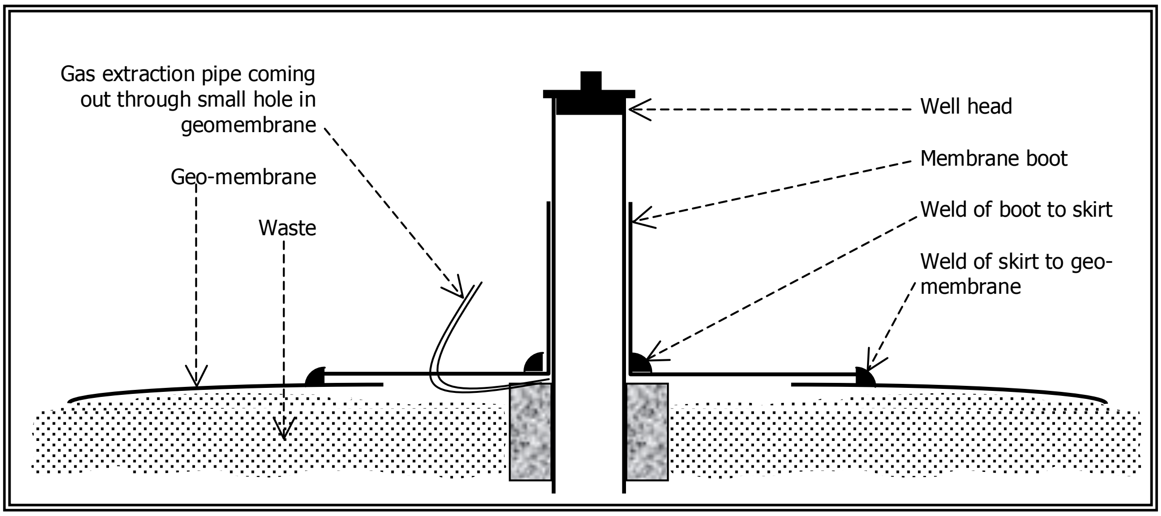
[p] ICoP 2 assigns a zone 2, typically of radius 2.2 m around wells

Photo 4: Boot and skirt around a leachate well

Note that Photo 4 shows a pipe that is open and venting to atmosphere, which is not good practice.

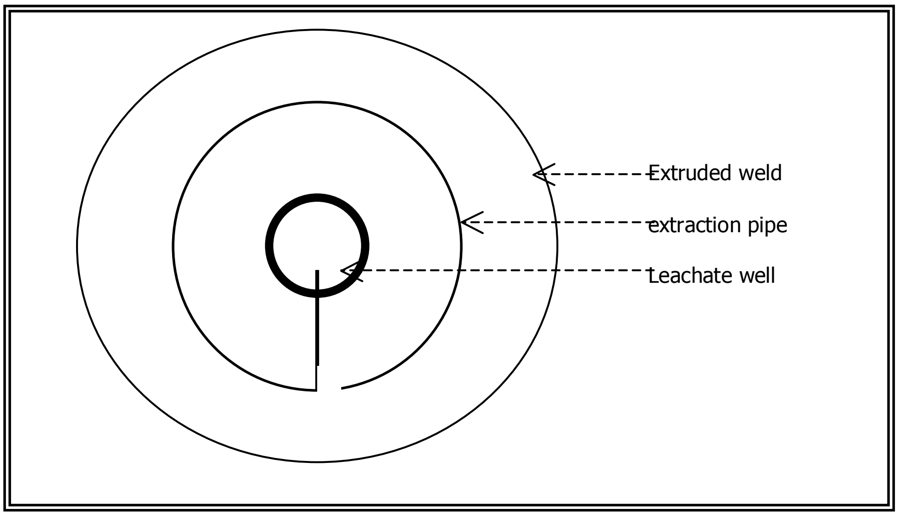
One problem is that it is likely that landfill gas will be collecting underneath the geomembrane to which the boot is being welded. Where this is the case, one method that has been employed uses a gas extraction pipe, connected to a suitable extraction system, which may be used to minimise the danger. This is shown diagrammatically in Figure 6.

Figure 6: Gas scavenging when welding a boot to the geomembrane



The gas extraction pipe (a 32mm water pipe is suitable) will be typically be drilled with 8 mm holes, 250 mm apart. The pipe is arranged around the well as shown in Figure 7.

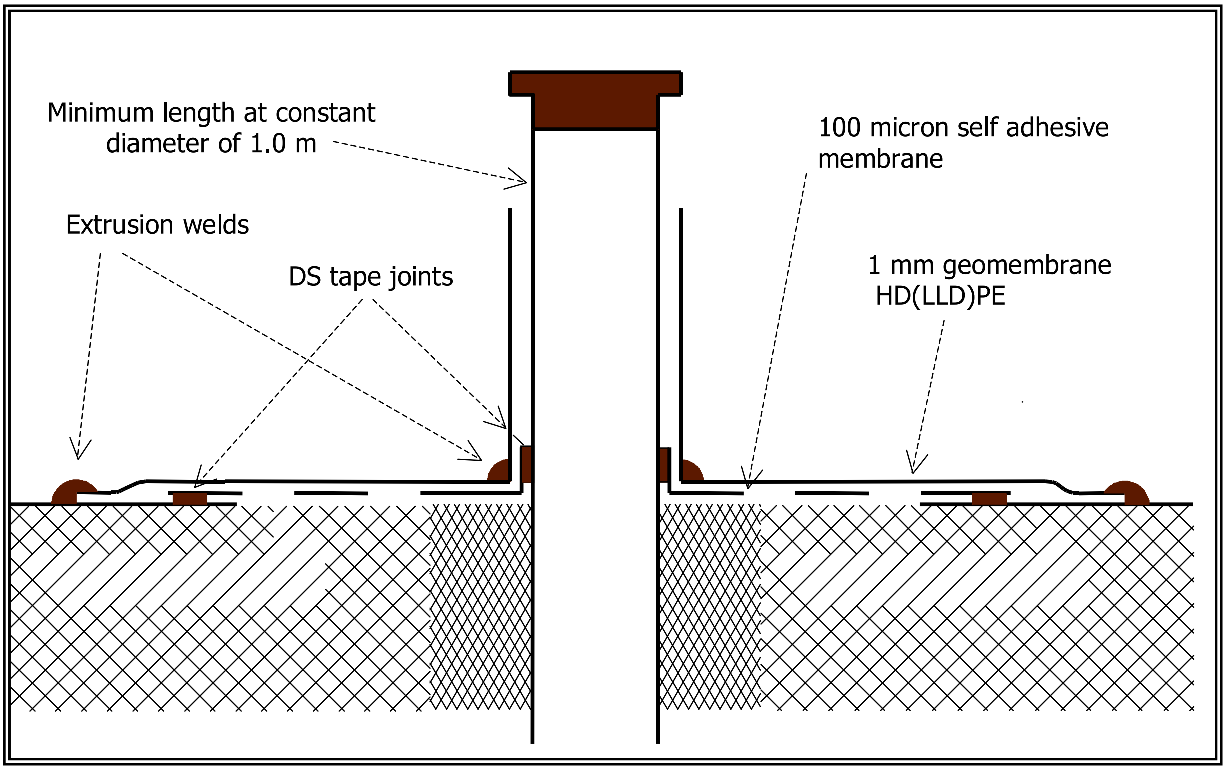
Figure 7: Plan view of gas extraction hose around a well during welding



A simpler approach to the problem of welding around gas welds is currently employed in Germany and is shown in Fig 6A below. The thin sacrificial geomembrane is installed first with attachment to the permanent geomembrane left outside the limiting radius. Gas is thereby prevented from rising into the area where the permanent geomembrane pipe boot can then be fabricated and installed in situ or prefabricated if preferred.

This procedure can also be applied to welding of capping around leachate risers –see Photo 4 above.

Figure 8: Gas well with temporary membrane pipe boot



5.2.5 Lap-and-lay capping

Panels of geo-membrane are placed so that they overlap. The addition of subsequent restoration layers on top of the geo-membrane holds the two panels together without the need for welding. There are no specific issues with this method relating to DSEAR, since welding is not employed, but note that a potentially explosive atmosphere may be present at the joint until such time as it is covered with restoration material. However, even when lap-and-lay is used for the general capping, it is possible that the geo-membrane will be welded around the well – see section 5.2..

Lap-and-lay and other mechanical alternatives to the welded boot have not been found to work as successfully as welding to the geo-membrane at the well head.

5.2.6 Welding pipework by electrofusion

In-situ pipework welding often requires electrofusion welding techniques, which are different to welding during capping operations. Electrofusion welding poses a controllable ignition risk if the process is carried out in accordance with the electrofusion fitting manufacturer's recommendations. In particular, the pipe ends must be cut 'square' and fully inserted in to the fitting to cover all of the electrofusion heater coils and the pipes must be correctly aligned using appropriate clamps to ensure that there is no deflection of the pipe ends within the fitting. The clamps must remain in place for the duration of the manufacturer's recommended cooling cycle. (Note: it is not always feasible to utilise clamps and so every effort must be made to ensure correct alignment of the pipes).

If the electrofusion fitting is assembled and fused correctly, the temperature rises at the fusion-interface, causing considerable 'melt-pressure' to develop which is contained by 'cold-zones' at each end and the centre of the fitting. The temperature at the fusion-interface is typically in the range 200-280°C (depending on the size of fitting and manufacturer), which is sufficiently far below the auto-ignition temperature of landfill gas (537°C). However, if the fitting is faulty or the joint has been assembled incorrectly, overheating can develop or the heater coils can short-circuit causing excessively high temperatures to develop, which can exceed the auto-ignition temperature of polyethylene which is in the range 340-400°C depending on the resin type used in manufacture. If sufficient air is present, flames can develop that could ignite gas if present. Vertical leachate wells are often extended using electrofusion couplers; heat generated by fusing the couplers can create a 'chimney' effect. (Note: once assembled prior to fusing, the joint it is not leak-tight).

If monitoring shows the pipe contains a potentially explosive atmosphere, as may be the case when the final connection to a system is made, the pipes should be isolated from gas by utilising one of the following techniques: 'squeeze-off', inflatable bung or balloon[q], purged or vented and continuously monitored for gas. The means of isolation should not be removed until the cooling cycle of the electrofusion fitting has been completed.

In general, electrofusion and butt fusion equipment is not explosion-protected and should not be used unless the area has been shown to be free from a potentially explosive atmosphere.

Repairing pipes already connected to the system also requires consideration. Repairs are necessary when, for example, an excavator fractures or cuts through the pipe. The pipe is likely to be at an under-pressure in normal operation, but when isolated, gas pressure can build-up rapidly and start to escape from the breach in the pipeline. The damaged section should be isolated on each side of the breach to prevent gas escape and air ingress into the landfill gas extraction system.

The usual sequence of events is as follows:

1. dig out around the pipe[r]
2. block off the flow of landfill gas using isolation procedures as given in section 4
3. wait enough time until a gas test using a certified gas analyser[s] shows that the landfill gas is below its LEL inside and around the pipe – however, if this proves to be an unacceptably long time, purging or ventilating by an appropriate method may be necessary
4. cut out the damaged section of pipe using a suitable tool[t]
5. clean the pipe
6. weld a new section of pipe
7. reconnect to the gas extraction system and remove the bladders (if fitted)

This procedure is covered by a method statement – see Appendix 10.

Ideally, damaged sections should be cut out and replaced. However, it is also possible that minor damage could be repaired using an electrofusion-welded saddle. A possible problem with this method is that the extent of the crack in the pipe may not be visible and the repair is therefore ineffective. Saddles also protrude and are therefore more vulnerable to damage.

With respect to #1, digging out around the pipe may introduce ignition sources by impact between the digging implement and buried stones or metal. Landfill gas is sometimes denser than air, depending on its composition and temperature, and may linger in the pit. This produces risks of explosion and asphyxiation. The worst-case scenario is where there is sufficient air in the pipe for there to be a potentially explosive atmosphere inside, which, if ignited by an external source, could cause an explosion within the pipe. It should be remembered that the *inside* of landfill gas collection pipes are usually classified as zone 1 or zone 2, depending on their location in the system (see ICoP 2), recognising the fact that a potentially explosive atmosphere is a reasonably foreseeable event. A damaged pipe is much more likely to have air inside. An explosion in the pipe is likely to cause injury to someone working in the pit and it is unacceptable to introduce a 'medium' ignition source, such as a shovel. Therefore, work with a shovel can only take place when the flammable gas has been proven to be below the LEL[u].

Little test data currently exists as to whether a worst-case landfill gas/air mixture inside a pipeline produces a dangerous explosion if ignited. The pressure rating of the pipework is commonly specified as 6 barg, which should contain the maximum anticipated explosion pressure. Nevertheless, experience within the

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q A method statement for drilling holes in pipes is included in Appendix 5

r Consider the implication that digging a hole may create a confined space.

s The personal gas monitor worn by the worker is not generally sufficient for this purpose because it typically does not measure up to LEL concentration. Suitable monitors are available, however.

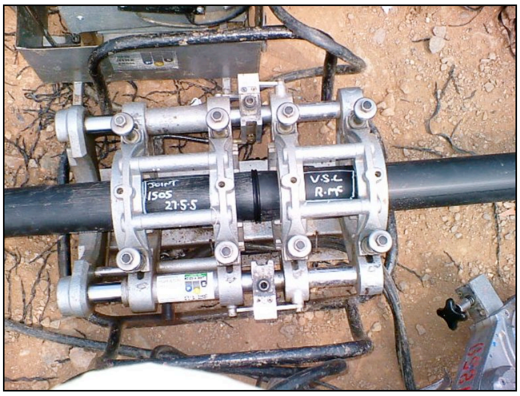
t Power tools are permitted provided it can be guaranteed that the area remains gas-free

u Note: COSHH considerations would also prevent someone working in an area with high gas concentrations industry suggests that an explosion within the pipe is a significant hazard. Therefore, every attempt should be made to ensure that the digging out process does not introduce an ignition source. A mechanical excavator is often used, but if used carefully, the bucket is likely to be moving too slowly to be a credible ignition source. The remnants of soil are removed with a shovel; the person should be aware that this is a potential ignition source, though it is unlikely that, in these circumstances, a spark could be generated. The pipe is invariably non-metallic.

5.2.7 Butt fusion (automated method)

Butt welding is generally used for new pipework, where there is no flammable gas risk. If there is a possibility of a flammable gas, then the same precautions as for electrofusion welding should be applied.

Photo 5: Butt fusion operation showing clamps holding pipe in position



5.2.8 Vent trenches

A vent trench is a means of prevention of gas migration from a landfill site into the surrounding area. It is a low resistance route for gas flow to atmosphere. Generally, the trench is filled with stone to make it permeable. Although a vent trench is specifically designed to release gas, it is generally at such low concentrations that the potentially explosive atmosphere will be of negligible extent and no zone is required. However, work in the vicinity of a vent trench should only be carried out after atmospheric testing has been undertaken.

5.3 Vehicles within already-zoned areas

5.3.1 Landfilling in already-zoned areas

The landfill mass is usually built up over days or weeks, whereby fresh waste is deposited on top of existing compacted waste, which may have been in place long enough for anaerobic decomposition to have started, with the consequential production of significant amounts of landfill gas.

A vertical leachate riser, for example, is built up section-by-section, with fresh waste being added on top of old waste. This requires vehicles to operate very close to the riser itself, both to deposit the waste and to move it into position around the riser. Photo 6 shows this.

Photo 6:Depositing waste close to a leachate well

Industry experience is that ignitions from this source are rare. However, the risk, though small, must be minimised, typically by ensuring that features such as leachate risers are well sealed.

ICoP 2 classifies uncapped landfill as a zone 0 of negligible extent, implying that gas in small amounts is leaching out of the ground on an almost continuous basis. FID measurements confirm this. Ignition of this amount of gas by a vehicle would be unlikely as the ignition sources associated with the vehicle are not usually close to the ground. Ignition would not cause a dangerous situation and would not usually be noticed. ICoP 2 also recognises that there are exceptions to this and that landfill gas will collect below ground and travel up fissures or natural barriers.

The potential ignition sources from vehicles at or close to ground level are as follows:

- hot exhaust of mobile plant
- hot brake drums or discs
- impact sparks from blade/wheel of mobile plant
- static discharges between the mobile plant and the ground
- tipping of 'hot loads'

The physical size of the mobile plant is such that most of it will be outside the zoned area. Also, landfill gas has a relatively high auto-ignition temperature (537°C) and it is unlikely that it will be ignited by a hot surface on the vehicle. Of the two spark sources, electrostatic discharges to earth are unlikely. Impact sparks are a possible ignition source under the right circumstances.

Hot loads[v] should not be tipped close to a zoned area.

To these ignition sources, the driver may introduce others, particularly when out of the cab:

1 static charge on the driver when leaving the vehicle;
2 smoking;
3 carrying unauthorised electrical equipment.

2 and 3 can and should be eliminated by safe working practices for those working in hazardous areas. All sites are non-smoking and this must be enforced. There is a theoretical risk of a static discharge causing an ignition but the driver should not leave the vehicle while it is in a hazardous area – this is typically within 2.2 m of a well – beyond this is a non-hazardous area.

The overall risk of ignition of a significant quantity of landfill gas is very low and the result of an ignition is likely to be a flash-fire rather than an explosion *provided there is no explosive atmosphere within an adjacent gas/leachate collection well*. Therefore, the use of mobile plant in uncapped areas is acceptable provided measures are taken to ensure that the well is not potentially explosive.

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[v] Hot loads are not normally accepted, although they may be tipped without the knowledge of the Site/Facility Manager.

Examples of such measures are:

- gas-tight sealing of the well (note – temporary capping or other temporary sealing measures may not be effective, especially if the well is under significant pressure)
- knowledge that the age and/or condition of the well are not conducive to significant landfill gas production
- knowledge that gas extraction is effective
- gas testing before work starts

5.3.2 Relocating old waste

A specific risk is associated with disturbing waste that has been in place for some time and therefore generating landfill gas in significant quantities. Pockets of landfill gas may be opened and the gas released, possibly underneath the vehicle. However, experience within the industry suggests that the risk of an ignition is, nevertheless, low and the consequences of an ignition unlikely to cause injury to the driver. No specific precautions are therefore required, but consideration should be given to the nature of the waste being moved, e.g. the possible presence of aerosols or LPG containers.

5.3.3 Agricultural vehicles in zoned areas

During and after completion of restoration of the landfill site, it may be used for agricultural purposes. This could involve ripping, ploughing, seeding, mowing, etc. requiring vehicles to be close to wells, i.e. within a zoned area. This is a zone 2 close to the well, so the probability of a potentially explosive atmosphere is very low, but the same justification applies as in the previous section, i.e. no specific precautions are required.

A specific risk is with damaging surface-laid pipes that are not visible to the vehicle driver due to the length of the grass. Under normal circumstances, pipework should not be surface-laid for this reason and, if it exists, measures must be implemented to reduce the risk of damage.

5.4 Maintenance and aftercare

The sub-sections below do not constitute an exhaustive list; any activity must be assessed with respect to the risk of ignition of an explosive atmosphere, if present.

5.4.1 Cap maintenance

Leaks are usually detected as a result of a surface emissions survey. Cap maintenance involves exposing the cap and repairing it. Refer to section 5.2.1.

5.4.2 Pumps: removal, replacement and general use

The term 'pump' will be taken to include the integral electrical motor where relevant.

Submersible pumps in gas and leachate wells are removed for maintenance and replaced with reconditioned pumps on a rolling programme. These pumps have a permanently-attached lifting line.

The use of pumps that are not marked as suitable for hazardous area duty is addressed in sections 5.7.4 and 5.7.5 for non-electrical and electrical equipment respectively. In summary, these sections indicate how such non-approved equipment may continue to be used in zone 2. Non-approved equipment without any electrical part may be used in zone 1[w]. It is permitted to recondition an existing non-approved pump and re-install it, or fit a spare non-approved pump from stores, but if a *new* pump is purchased as a replacement, it should be ATEX-marked. Typical marking is given in Appendix 3.

As with all equipment, approved or not, pumps should be operated outside the zoned areas where possible. However, where use in a hazardous area cannot be avoided, the operational problems listed in Table 3 should be borne in mind:

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w In both cases, the end user needs to have a written justification for the use of the pump.

Table 3: operational problems with pumps				
	Applicable?			Problem
	air-driven	pneu-matic	electric-ally driven	
1	applies	N/A	applies	When a pump is first started, there is torque induced movement that may lead to chafing of: ♦ the power cable insulation (if electrical) – this is a potential ignition source; or ♦ the air line (if air-driven) resulting in air ingress into the system - may produce a potentially explosive atmosphere where none existed before For electrical pumps, it is possible to use a pump that has the cable covered between the motor and the top of the pump; the cable is tied to the pipework to ensure it does not rub the side of the borehole.
2	N/A	N/A	applies	Various types of electrically-driven pumps may be installed with different over/under-current protection requirements, for example: 1 progressing cavity (Archimedes screw) type – if it runs dry, the current demand increases; 2 multi-stage centrifugal – if it runs dry, the resulting cavitation causes the current demand to decrease and may cause damage to the impeller (possibly fragmentation) The types of pump are readily interchangeable, so a technician with no knowledge of the safety system already installed may not set the required over/under-current protection. The protection system must match the type of pump motor. Undercurrent protection on both 'auto' and 'manual' settings is necessary for all standard borehole pumps.
3	applies	applies	applies	Most control systems for leachate pumps include a 'hand' setting allowing manual control of the operation of the pump. This can lead[x] to the pump running dry and overheating. However, even on a "hand" setting, there should be suitable protection to prevent the pump running dry - normally this is undercurrent or overcurrent protection. The "auto" control is usually for devices such as transducers, timers, thermostats etc.
4	√	N/A	N/A	Leaking of the air lines to and from an air-driven pump down a well could create a potentially explosive atmosphere in the well where none may have existed before, by introducing air and bringing the landfill gas into its flammable range. 'Air fuses' in pneumatic lines to shut off air supplies in the event of a failure of the line are becoming available and should be considered. Exhausting inside the headworks is bad practice and exhausting to atmosphere should be encouraged. If exhausting into the headworks is done deliberately to avoid spurious operation of the differential pressure switch on the pump, other pump designs are available.
5	√	√	√	Many leachate wells are constructed from steel - these are known to rust, leading to flaking of the metal into the leachate. This then gets ground up in the pump, causing premature failure and a potential ignition source. However, pumps selected for leachate extraction are designed to deal with such abrasive and sticky materials so no specific action is required apart from routine maintenance of the pumps.
6	√	√	√	There is a risk of an impact spark between a pump and a metal or concrete pipe. Aluminium-bodied pumps are a particular spark risk with steel pipes, especially if the steel is rusty[y]. The risk can be reduced by careful consideration of the lifting technique and lowering the pump slowly into position.

x There are numerous examples of this

y Aluminium reacts with rust, liberating energy (the so-called 'Thermite Reaction'), so impacts between the two materials are particularly spark-prone

Table 3: operational problems with pumps				
	Applicable?			Problem
	air-driven	pneu-matic	electric-ally driven	
7	√	√	√	Pumps with a plastic body can become electrostatically charged and transfer the charge to a metal part of the enclosure – since this may not be earthed in the case of a portable device, an electrostatic spark to earthed metal is possible.

When pumps are replaced, the balance of risk is in favour of non-electrical pumps and these types, rather than electrically-driven pumps, should be specified[z] where possible. However, there are situations where an electrically-driven pump is the only practical option (e.g. high volume throughput) and such pumps may be used provided measures are taken to minimise the risks associated with such pumps.

Existing non-approved electrically-driven pumps may still be used in a zone 2 (see Appendix 1) provided care is taken to protect the electrical cable. Note that electric pumps lowered down a well for submerging in the leachate will be passing through a zone 1, so should be electrically isolated until submerged.

5.4.3 Inspection of wells using a camera

Camera inspections may be required to find a failure in the containment system. A CCTV-type camera is lowered into the well along with a suitable light source. Wells are usually designated as a zone 1 throughout under the guidance in ESA ICoP 2, and uncertified electrical equipment is *not permitted* in a zone 1 unless it is first shown to be free from a potentially explosive atmosphere.

Therefore, if uncertified cameras and lights are used, the atmosphere must be shown to be or rendered outside the explosive range by suitable means, e.g. by gas monitoring, purging.

5.4.4 De-silting procedures for wells

There are a number of ways to achieve de-silting, for example:

- ♦ suction from above: a pipe from a tanker is lowered into the well and a pump on board the tanker sucks out the water/silt – this method is limited to a maximum hydrostatic head of approximately 10 m, although the operating maximum is less than this;
- ♦ venturi suction method: a pipe is lowered down the well with slots in the pipe just above the liquid level - a large volume of gas that enters the pipe via the slots allows liquid to be sucked up to much greater heights than the limit of hydrostatic head;
- ♦ temporary insertion of a specialised pump to loosen the sediment, the power being supplied from outside the well – the silt/water is pumped out from below and there is no limit to the pumping head;
- ♦ jetting – a unit on the surface powers a water lance that is lowered into the well to clear more compacted blockages; the silt/water is pumped out from below or above

There are a number of issues with the use of the venturi method:

1 landfill gas is sucked out at a substantial rate – this is vented via the vacuum pump of the tanker and may create a large potentially explosive atmosphere; however, it is likely that the gas will be already diluted to below its LEL by the flow of air.

2 landfill gas is sucked out at such a rate that air may enter the well, creating a potentially explosive atmosphere where none may have existed before.

These factors should be considered if this method is used and should be addressed in risk assessments and method statements.

The potential ignition sources of pumps are dealt with in section 5.4.2. One additional ignition source introduced by de-silting operations is static discharge, which is possible with high pressure water jets from the water lance. Guidance from the Institute of Petroleum[7] indicates that liquids like water that have a high conductivity (>1000 pS/m) do not normally give rise to electrostatic charge build-up *unless spraying occurs*, as is the case in this operation. However, it is highly probable that the charged droplets will be able to dissipate their charge harmlessly when they first make contact with the structure of the well and no charge

z At the time of writing, no small (less than 6") electrically-powered ATEX-marked borehole types pumps are available.

accumulation will occur, since all parts of which are well earthed. Thus, it is only necessary to consider the possibility of the spray falling onto non-earthed conductive parts.

5.4.4 Surface, borehole and target[aa] monitoring

Surface monitoring may be by means of a FID, a flux box, or other similar device. Generally, these devices are not certified, but the monitoring is for environmental compliance and the levels detected are almost invariably far below the LEL; such monitoring devices are unable to measure concentrations in the explosive range[bb]. Uncertified monitoring devices are unsuitable and must not be used where there is a potential explosion risk unless an ignition hazard assessment has been undertaken, the results of which have shown it to be safe to operate. Such a risk might occur where there is containment of a potentially explosive atmosphere, such as inside a well or around sampling points. Where surface monitoring is performed around a well, the device itself gives an early warning of high methane concentrations, at which point it should be withdrawn from the area and a certified analyser used instead. (A safer system of work may be to monitor firstly with a portable IR analyser to determine that there is no explosive atmosphere present prior to using the surface monitoring equipment).

Borehole (including perimeter borehole) monitoring requires a different instrument to surface monitoring because the measured level of methane (from landfill gas) are high and possibly mixed with air and within the explosive range. IR analysers are typically used and intrinsically safe versions are available - only this type should be used unless a risk assessment has been completed and the results of which have shown that the analyser is safe to use.

Likewise, for target (specific location) monitoring, an intrinsically safe analyser should be used unless the results of a risk assessment have shown the analyser to be safe to operate in these circumstances.

A method statement for the use of surface monitoring equipment is included in an Appendix when this ICoP is re-issued.

5.4.5 Cutting down wells

Settlement of the waste mass means that the upper part of the pipework of a well becomes increasing exposed. This requires the headworks to be removed, the well to be sawn off and the headworks re-attached.

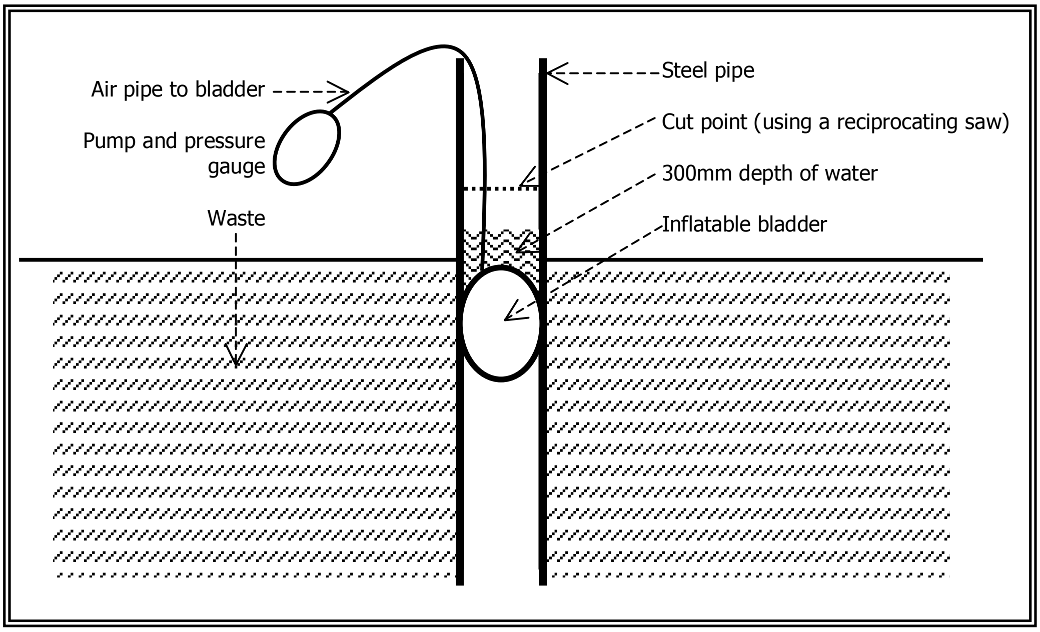
If the pipework is made of steel or other metallic material, there is an unacceptable ignition risk if this is sawn off in the presence of a potentially explosive atmosphere. One possible procedure is as follows:

1. remove headworks
2. insert an inflatable stopper into the pipe to block the flow of gas (see Figure 9 below)
3. pour water onto the top of the stopper to a depth of approximately 300 mm
4. cut off the excess section of well, preferably with a reciprocating saw
5. re-attach the headworks

aa Target monitoring is when a specific area is monitored for the purpose of working in the area

bb For comparison purposes, the scale on a FID might go up to 1000 ppm or 10,000 ppm, whereas the LEL of landfill gas is 44,000 ppm.

Figure 9: Typical isolation method for cutting down a steel-cased gas well



If the work is carried out in a chamber below ground level, the work should be preceded by a gas test.

A method statement for this activity is included in Appendix 8. Permits-to-work are discussed in section 5.5.13.

5.5 Temporary works and other day-to-day operations

5.5.1 Pin wells

The installation of a pin well usually involves pushing a metal spike into the waste mass, which is then removed and a perforated tube inserted, during which operation landfill gas is likely to be released. Fires and explosions during installations are rare, particularly those causing injury. Nevertheless, a risk remains and must be minimised. The safety case is based on:

1. minimising the probability of an ignition source being introduced;
2. minimising the number of workers within range of a possible fire or explosion;
3. maximising the distance between essential personnel and the installation operation;
4. providing suitable PPE or other protection for essential personnel.

The installation of pin wells is commonly performed by the site operator, whereas outside contractors are usually used for the installation of other wells. Both types of drilling are covered in ICoP 6.

A further risk occurs when the pin well is connected to the existing infrastructure; refer to section 5.2.6.

5.5.2 Scavenger pipes

Scavenger pipes are horizontal gas collection pipes laid in the waste. The only aspect that poses a flammable atmosphere risk is the connection to extraction system. Refer to section 5.2.6.

5.5.3 Temporary gas collection

This is usually used prior to the installation of the permanent gas collection system. The temporary gas collection system takes the form of a pipe system that is laid on the ground, for example for odour control. These are then connected to either the extraction system, a temporary flare or other gas management facility as appropriate.

In principle, this activity is no different to the installation of scavenger pipes and the only flammable risk is when the pipe is connected to the extraction system – refer to section 5.2.6.

5.5.4 Pipe repairs

This is covered in section 5.2.6.

5.5.5 Excavations

It is sometimes necessary to dig an excavation, for example to repair a section of damaged well. Landfill gas tends to collect in excavations and trenches such as shown in Photo 7, especially where there is damage to or removal of the Bentonite seal or the well is leaking. The possibility of landfill gas accumulations in excavations to explosive concentrations should always be considered, even where there is no obvious release point, if gas migration is a possibility. In addition to the explosion potential, the toxic risk should also be assessed.

Photo 7: Excavation with the potential for landfill gas to accumulate

5.5.6 Daily cover

This is a routine operation to cover waste. Soil (or another material) is deposited on top of the freshly-tipped waste at the end of each day and spread with mobile plant. This is done to deter vermin, reduce the fire risk, litter control and reduce the odour.

The waste below the surface is likely to be capable of generating landfill gas, so this operation raises the same issues of the use of vehicles in such situations – see section 5.3.

Additional techniques include:

1. application of foam, sprayed onto the surface at the end of each day – there is a potential static ignition hazard from this activity, but the quantity of gas ignited is likely to be small and the risk to personnel low;
2. HDPE (or similar) sheets spread over the waste – this method does tend to collect gas, but does not involve welding, so ignition sources are unlikely to be introduced.

5.5.7 Portable and mobile generators

Portable generators are distinguished from mobile generators in that they are generally mounted within a frame and are small enough to be manually handled by one or two persons. Mobile generators are generally accepted as those that require lifting into place with a crane (or similar) and/or are fitted with wheels to allow them to be towed from location to location using mobile plant. As a general rule, portable generators are fuelled by petrol, whereas mobile generators are operated on diesel fuel.

Portable generators are introduced on a temporary basis, for example:

- electrofusion welders
- hand tools
- hot air guns
- odour control units (although not necessarily using a portable generator)
- pumps

A generator is a potential ignition source in the following respects:

- the electrical control equipment close to ground level is usually uncertified and is a potential ignition source, particularly if landfill gas emitted from the ground collects inside an electrical enclosure;
- incandescent particles emitted from the exhaust may travel some distance into an adjacent hazardous area, where there is a probability of a potentially explosive atmosphere being present and ignited

Clearly, generators should not be sited within a zoned area (e.g. typically within 2.2 m of a well) unless the area is known to be free of a potentially explosive atmosphere. Also, the generator should be installed in an area where emissions of landfill gas from the ground either do not occur or are unlikely to be significant. If emissions of landfill gas are reasonably likely, installing the generator on a concrete or other impermeable apron will prevent flammable gas building up inside the enclosure.

Where there is a possibility of emissions of landfill gas underneath the generator, care should be taken to prevent build-up in the generator as far as is reasonably practical, e.g. by siting it where fissures are unlikely. A FID sweep will confirm the absence of landfill gas at the time of installation, but the ground conditions may change. Mounting the generator slightly off the ground, with free ventilation underneath the generator, will greatly reduce the probability of flammable quantities building up inside the enclosure. Leaving the generator on the back of the truck or within a fuel oil bund achieves this.

Leaks of fuel also need to be considered. If the fuel is diesel, if it is spilled on the ground, it can only form a potentially explosive atmosphere if it falls onto an absorbent material to act as a wick. Pools of diesel can normally be regarded as non-hazardous.

If the fuel is petrol, this is highly volatile and a potentially explosive atmosphere will form during fluid transfer; a larger potentially explosive atmosphere will form if a spillage occurs. Re-fuelling should not take place close to potential ignition sources. The generator must be switched off for refuelling.

5.5.8 Mobile pumps

As with all equipment, pumps should be operated outside the zoned areas where possible. Further guidance on pumps is in section 5.4.2.

5.5.9 Mobile flares

A mobile flare is useful in remote locations and may be used for odour or gas control to burn off gas from a well or series of wells that cannot be used for power generation (low methane or high oxygen).

Usually such a system is used where the methane quantity within the landfill gas is low or the oxygen content is raised and therefore is unsuitable for utilisation within a landfill gas engine. It has a connection to the gas collection system and is usually sited on top of or close to the waste mass.

Clearly, the flare should be located outside a zoned area[cc]. The flare is an ignition source in three respects:

- the flame from the flared gas, which will not pose a significant risk if in a safe location;
- the electrical control equipment close to ground level is usually uncertified and is a potential ignition source, particularly if landfill gas emitted from the ground collects inside an electrical enclosure – consideration should be given to providing an air gap between the electrical enclosure and the ground;
- incandescent particles emitted from the chimney may travel some distance into an adjacent hazardous area, where there is a probability of a potentially explosive atmosphere being present and ignited.

[cc] The general landfill surface may be classified by ICoP 2 as zoned, possibly a zone 0, but the zone is of "negligible extent". This is effectively a non-hazardous area for the purpose of placing plant on the surface, taking due account of landfill gas collecting in enclosures.

Photo 8: Flare located too close to a vent

The area classification of flares is covered in ESA ICoP 2.

5.5.10 Odour control systems

There are two types of odour control system:

1. odour suppression type: contains a generator supplying a motor and fan and emits a perfumed mist – these items are covered in section 5.5.7;
2. scavenger system using pipework – see section 5.5.2 - to take the gas to a flare or other treatment

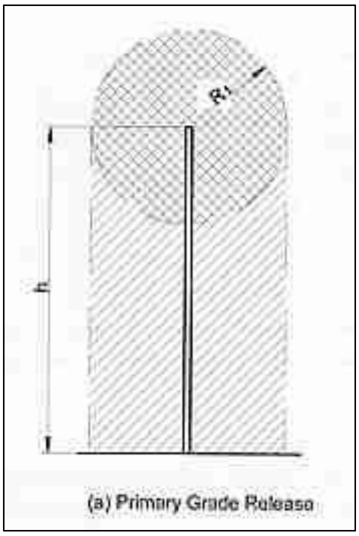
5.5.11 Temporary buildings

Temporary buildings, such as site cabins, have their own electrical supply; many are not fitted with gas detection. Such buildings should not, ideally, be located in areas where landfill gas may be emitted from the surface. Where this is not possible, the same considerations apply as for mobile plant equipment discussed in the previous sections.

Of particular concern is the possibility of landfill gas migrating along buried cable ducts directly into the building and collecting in a panel or other source of ignition. It is essential that this route is avoided and it is recommended that all buildings have a well-ventilated air gap underneath, such that any cable ducting ventilates into this air gap. This greatly reduces the possibility of flammable gas migration into the building. If the design includes consideration of the problem of gas accumulation, gas detection will not be necessary. The initial design considerations should consider the elimination of the need for 'bottom' entry of cables into the building.

Septic tanks are installed close to most temporary buildings. If conditions within the tank are anaerobic, which is highly likely, methane will form and mix with the air above the liquid level. Therefore the interior of the tank should be classified as a zone 0. If a vent pipe is fitted, a zone 1 of nominal radius 1 m is appropriate, with a zone 2 extending to ground level. The zoning of the vent shown in below is based on IP15 Figure 5.3(a). R_1 is 1 m.

Figure 10: Zoning for a vent



If work is carried out in these hazardous areas, appropriate precautions are required as detailed else where in this ICoP.

5.5.12 Banding

Banding involves multiple injections of a 'sock' up to 15 m into the waste. The process causes release over a large area. Mobile plant will be working on top of this area during installation and subjected to the released gas.

Photo 9: Banding

This is a specialist activity and outside the scope of this ICoP – a site-specific risk assessment will be required.

5.5.13 Permit-to-work system

The following three pages show a sample permit-to-work pro-forma that can be adapted as required. Ideally, a single permit should cover all risks, rather than having a separate permit, for example, when there are DSEAR issues relating to explosive atmospheres.

Enterprise Limited

PERMIT TO WORK

1) To: ………(Recipient).

2a) Sections of Site ………

2b) Location ………

3) Work to be carried out: ……………………………………………………………………………………………………

4) The following services have been isolated / locked off-

	Method of Isolation Employed	By whom
Electricity		
Gas		
Process Fluids		
Air/Water		
Drains/Vents etc		
Instrument Connections		
Others		

5) Special precaustions which need to be taken:

(a) Personnel to be notified: ____
(b) Fire fighting equipment/personnel:____
(c) Rescue equipment/personnel:____
(d) Sparkproof tools:____
(e) Suitably-certified (e.g. Ex d, Ex ia/ib) equipment: ____________________________________
(f) Burning and welding:____
(g) Ventilation:____
(h) Atmosphere testing:____
(I) Presence of sludge____
(j) Other factors:____

6) Results of atmosphere tests:

Location of Test	Date	Time	Test For	Result	Repeat Time 8 hrs ?	Competent Person

7) Subject to the conditions stated in section 5, the work which is detailed at 3 above can then be undertaken.

This permit is valid until (Time) ……………a.m./p.m. after which time a new permit will be required for work to proceed:

Signed:………………………………………………………………… (Initiator)
Date/Time:…………………………………………………………….a.m/p.m.
Position:…………………………………………………………………………

8) I understand the work, and the precautions which are necessary which are necessary to carry out the work safely.

Signed:………………………………………………………………… (Initiator)
Date/Time:…………………………………………………………….a.m/p.m.
Position:…………………………………………………………………………

9) The work detailed at 3 above is / is not complete *

Signed:………………………………………………………………… (Initiator)
Date/Time:…………………………………………………………….a.m/p.m.

10) The plant has been inspected and tested and is / is not * available for return to service.

PERMIT TO WORK

Notes and Instructions for use.

1) If the recipient is an external contractor, the name of the firm and the site-representative should be shown.

2a) To show an area of the Works and not a specific part of equipment.

2b) To indicate the most hazardous zone in the area in which the work is to be carried out.

3) This permit is to be issued for work carried out under the site manager's own or his delegated authority.

4) At this stage isolation/locking off will have been carried out on all the services. The method of carrying out the task shall have been agreed between the initiator and the recipient.

If necessary, the work shall have been carried out under a separate authority (the Supervisor's Authority) and be governed by the same conditions as are applied to the Supervisor's Authority.

The detail given should show the services involved, the method of isolation employed and by whom the work has been carried out.

5a) To show personnel to be informed other than those actually carrying out the work.

5b))
5c)) To show the equipment and personnel to be on standby at the location of the work.

5d)) To show details of any requirements for special tools, bearing in mind the zone area which has been shown at (2b)
5e))

5f) To show whether burning or welding may be carried out in the working area.

5g) To show if natural ventilation is sufficient or if mechanical means are necessary, and if so, to what extent.

5h) To show if the frequency of testing and the type of test is required.

5i) To show if sludge is present and if so any extra precautions which should be taken.

5j) Note any special precautions which may be necessary including the use of protective clothing.

6) To be completed by a chemist/designated competent person.
If the continuous monitoring is required, and there is sufficient room on the Manager's Authority for the results obtained, a separate sheet shall be issued for the results which shall be apended to the Manager's Authority.

7) The permit shall only be valid for the duration of the recipients current shift. The permit shall be returned to the initiator by the time stated or earlier if the work has been completed earlier than envisaged.

8) To be signed by the recipient on the understanding that he has received the necessary verbal or written instructions sufficient to be able to carry out the work safely. Further - if unforseen difficulties occur - especially where an external contractor is involved, he must have been instructed to seek further guidance from the initiator before continuing the work.

9) If the work is not complete, a further certificate will be required before the work can proceed.

10) This section should be completed by the initiator after handing back by the recipient. It serves as a reminder of the current state of the equipment. If the initiator is not the Manager, arrangements must be made to keep the Manager informed of the current situation.

11) Copies to be distributed as follows:-

Top copy to be issued to the recipient, encapsulated in a clear plastic sleeve and posted immediately adjacent to the working location.

Bottom copy - to remain in the book of certificates which itself should be kept under the immediate jurisdiction of the Site Manager.

Clients Drawing of Section of Site Operating Under Permit To Work

Appended Here

5.5.14 Photographs of unacceptable practices

Photo 10: Badly repaired cable joint using electrical tape

This would be a potential source of ignition on failure.

Photo 11: No headworks installed on leachate chamber

Photo 12: Poorly installed control panel – too close to potential release point of landfill gas

Photo 13: Lack of maintenance – excessive corrosion of borehole pump.

This pump was used for leachate extraction.

Photo 14: Poor standards of installation

There are bolts missing in the blanking plate and valve flanges, which would potentially give rise to larger releases of landfill gas than assumed in the ICoP for calculating the zone radius. The wooden bungs are not a standard sealing arrangement.

Photo 15: Poor standards of installation – control panel Located within zoned area

Photo 16: Control panel installed too close to leachate chamber

The control panel is installed such that it is within the zone 2 around the leachate chamber.

Photo 17: Unprotected leachate extraction point

The leachate extraction point is unprotected from vehicle movements & there is no indication of the zone extent around the potential release point.

Photo 18: Open side riser producing a large potentially explosive atmosphere

Photo 19: Control panel showing signs of corrosion

It is likely that the panel is not manufactured to the correct specification.

Photo 20: Open side riser

This open side riser will produce a large potentially explosive atmosphere. There is evidence of other poor installation design: the pump is supported down the side riser by rope secured around a local tree and then attached to the discharge pipework from the installation.

Photo 21: Poor installation - control panels left on the ground within zoned areas

Photo 22: Blanking plate on the leachate chamber not secured

This gives a potential for a substantial release of landfill gas.

Photo 23: Poor Design - bucket used as a head works and sealed with tape

This is a leachate extraction point – there is significant potential for landfill gas release

5.6 Personnel on site

5.6.1 Employees and contractors

Where there are two or more employers sharing a workplace, DSEAR regulation 11 requires the Site/Facility Manager to ensure that all workers are aware of the site safety procedures and that contractors who are not familiar with the site are made fully aware of the risks. Contractors must be alerted to the possible presence of dangerous quantities of landfill gas in certain operations, such as

- wedge-welding and patching during capping operations,
- digging down alongside existing gas and leachate wells when repairing damage, etc.

This information should be communicated at the contract stage as well as when the contractors appear on site

Compliance with Regulation 11 should be by means of an appropriate site induction in addition to an explanation of, plus adherence to, the permit-to-work system, where the work requires this. Training is covered more fully in ESA ICoP 1 section 9.

No unescorted access to the site should be permitted without the permission of the Site/Facility Manager.

It is commonly the case that two employers share a site (e.g. a gas management compound) on a semi-permanent or permanent basis. The same principles still apply regarding the duty of co-ordination placed on the Site/Facility Manager but the permit system may not need to be as frequently renewed.

5.6.2 Customers

'Customers' in this context refers to companies using the landfill site to dispose of waste, carried in by trucks. There are a number of explosion hazards associated with these activities, due to the necessary use of vehicles, sometimes close to potential releases of landfill gas (or other flammable hazards such as aerosols).

Customers should be made aware of the safety procedures relevant to their activity by an appropriate method, e.g. the issue of site safety rules, signage, etc. The routes of the access roads are intended to avoid the vehicles driving close to or through a zoned area.

It is recommended that key information be presented to customers on their first visit to the site. This may be included along with key information relating to other risks and site procedures. A suggested format is as follows:

Key information regarding explosion risks

Tipped waste generates methane!

Where you see this sign:

it indicates areas where landfill gas may be present.

There is an explosion risk if ignited.

Follow the instructions on the sign.

No smoking anywhere on the site

5.6.3 Visitors

Visitors are those who are not engaged in 'work' but who may be shown round the site. The danger of explosion is not the main risk facing visitors, since being hit by vehicles or machinery is a far higher risk. The following minimum requirements should be in place to protect their safety:

1. a basic site induction, outlining the risks: the visitor may sign to indicate he/she has received the induction
2. provision of appropriate PPE;
3. escorted at all times.

A written record of those receiving the induction should be held.

No access to the site should be permitted without the approval of the Site/Facility Manager.

5.6.4 Regulatory authorities

Members of regulatory authorities (e.g. Environment Agency, Health and Safety Executive, Customs and Excise) are visitors, but they have statutory powers of entry and may arrive on sites unannounced. Every assistance should be given to enable such persons to carry out their duties, however their safety during their visit remains the responsibility of the Site/Facility Manager and a suitable induction must be carried out before going onto the landfill site.

The Site/Facility Manager cannot deny these regulatory authorities access to the site, unless there are exceptional circumstances where there is an unacceptable risk to safety. The Site/Facility Manager cannot obstruct the regulatory authorities in their duties. However, he/she should ensure that any access to the site, in particular any hazardous area, is in accordance with the local site rules and permit to work system.

The regulatory authorities themselves must comply with the local site rules and permit to work system and provide adequate risk assessments or other information. In addition, they should implement suitable control measures to demonstrate to the Site/Facility Manager that they can safely access the hazardous areas. The regulatory authorities should have due regard to this Code of Practice in planning site visits.

The regulatory authorities may bring monitoring or other equipment onto site. This equipment must be suitable for the zone in which it might be used and be maintained and calibrated in accordance with the manufacturer's instructions.

5.6.5 Accident, incident and emergency protocols

DSEAR Approved Code of Practice L138 paragraphs 300 to 303 are particularly relevant. The recommendations in these paragraphs can be summarised as follows: as a minimum, the Site/Facility Manager is responsible for contacting the emergency services (during a non-emergency period) to outline the risks and be available, if required, to meet the emergency services to discuss emergency procedures.

Such discussions help the emergency services to prepare their own response procedures and precautionary measures. The information that may be required includes:

a the identity, location and possible quantities of flammable materials – mainly this will be landfill gas, but other flammables on site (e.g. gas cylinders) should be identified;

b the foreseeable types of accident/incident/emergency and the hazards that may result;

c where on site such incidents could occur, the effects, other affected areas, possible escalation;

d internal emergency arrangements.

Equally, some fires do not constitute an emergency and the industry has proven methods of dealing with them. This applies particularly to fires underground.

With an ever-changing site topography, it is important to plan for the emergency services, particularly the fire brigade, to have access to all areas where they might be needed. If an incident occurs, the Site/Facility Manager, or a designated person, should be available to assist the emergency services when they arrive on site.

5.6.6 Public access and security

Some sites have been restored and are available for public recreation, e.g. converted to golf courses, country parks, etc. Sensitive equipment such as manifolds may have been buried but certain features such as wells) may still protrude from the ground. A risk assessment is required and consideration should be given to a range of options, such as restricting access with physical barriers, re-directing footpaths or disguising the equipment with foliage.

On sites which are about to be transferred to public access, all equipment should be fenced off or in a suitable locked chamber. ICoP 2 Edition 2, Figure 5 indicates that chambers such as those used to house pipework manifolds will be zone 2 internally, but there is n o external zone.

Some operational sites have a public footpath running across the site but otherwise only restricted access. Such footpaths should be fenced off, indicating that access to the rest of the site is restricted. See also section 5.6.7.

5.6.7 Marking hazardous areas and pipes

DSEAR Regulation 7 requires that, *where applicable*, zones should be marked with the sign shown below. The purpose of signs is to warn of areas where an explosive atmosphere may occur in such a quantity that employees need to be warned of its presence, so that they can take the necessary precautions in relation to the risk.

On a landfill site, there are a large number of relatively small zoned areas (e.g. in and around gas wells, pin wells, leachate risers, etc.) but the majority of the site surface is not zoned. The key question to consider is how best sign the site to inform workers and other persons most appropriately.

It is recommended that a sign at the main entrance is installed to alert anyone entering that the site contains zoned areas, but this sign should not give the impression that the entire site is one large hazardous area.

The following sign is therefore suggested:

Some sites have other entrances and some even have public footpaths across the site. Consideration has been given to the fact that signs that are too explicit may increase the risk of malicious damage by unauthorised persons if they are made aware of the explosion potential within a gas well, etc.

At such secondary entrances, a sign such as the following is recommended:

Consideration should be given to fencing the footpath.

Each individual well or other zoned area should be marked. It is helpful to also mark the zone extent, so a small sign as follows would be ideal:

A small, self-adhesive label is sufficient. The zone information may be omitted if workers are made aware by other methods regarding the zone extent. The above sign is suitably informative to legitimate personnel but does not unnecessarily alert others to the explosion potential.

Landfill gas pipes should also be marked where necessary to avoid confusion.

5.7 Equipment used in zoned areas

5.7.1 General

Zones 0, 1 and 2 all indicate the *probability* of a potentially explosive atmosphere being present:

zone 0: high probability (more than 1000 hours/year)
zone 1: medium probability (between 10 and 1000 hours per year)
zone 2: low probability (less than 10 hours/year, typically much less than this)

However, the zones do not indicate whether a potentially explosive atmosphere is *actually* present. There are two basic approaches to doing work in hazardous areas that does not involve breaking into the containment system (which is usually covered under maintenance):

1) work with suitably-approved equipment, tools and clothing that are designed to avoid introducing an ignition source (sparks and hot surfaces), *or*

2) work under a permit system that ensures that the area is gas free while the work is being carried out – this allows the use of non-approved equipment, such as grinders, welders (strong ignition sources), petrol generators (medium ignition source) and uncertified instruments (weak ignition source).

An example of 1) would be going into a zone 1 with an intrinsically safe sampling instrument to open the sample point and make a measurement.

An example of 2) would be the cutting down of a well that has been isolated and purged to remove explosive concentrations of landfill gas – the worker would be following a method statement and be working under the permit system.

The permit system, therefore, allows operations in zoned areas that are likely to introduce an ignition source, but the risk is controlled.

5.7.2 PPE

Suitable PPE need not exceed that usually employed in general engineering situations, i.e. (anti-static) safety boots or shoes with an *internal* toe protector[dd], eye protection, hard hat, high-visibility jacket/waistcoat, ear protection, personal gas monitors, etc. as appropriate, in line with site rules. However, note that COSHH issues are outside the scope of this ICoP, which deals only with the flammable risks.

5.7.3 Anti-static clothing

PD CLC/TR 50404[8] clause 9.4 states that "In spite of the fact that modern clothing, made from synthetic textiles, can readily become electrostatically charged it is not, in general, an ignition risk providing that the wearer is earthed by means of suitable footwear and flooring".

The DSEAR ACoP L138 requires that anti-static footwear and clothing should be provided when the risk assessment identifies that it is required. Paragraphs 263 and 264 are particularly relevant and the requirements may be interpreted as follows: anti-static footwear and flooring that is not highly insulating (e.g. concrete, earth) are generally sufficient for areas where there is a flammable gas or vapour risk

A minimum requirement, therefore, is that anti-static footwear is used whenever work is done in a hazardous area, unless done under a relevant permit or where the risk of a person becoming electrostatically charged is low.

Anti-static footwear is potentially ineffective when walking on an HDPE geomembrane or other insulating surfaces. There is currently no evidence to quantify the hazard that this poses but personnel should be aware of the potential risk.

5.7.4 Existing non-approved non-electrical work equipment in zoned areas

Appendix 1 deals with non-electrical equipment. The situation may be summarised as follows:

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dd External steel toe protectors may be a spark ignition risk

- Before 1 July 2003[ee], there was no need to give non-electrical equipment in a hazardous area more than a basic assessment for its ignition capability but for DSEAR, a formal (if simple) ignition hazard assessment is required;
- Non-electrical equipment installed after 1 July 2003 should be ATEX-marked (usually by the manufacturer) to indicate that it is suitable for hazardous area use.

Currently, most non-electrical equipment clearly fits into the first category, i.e. it is not new and was already installed on 1 July 2003. A basic ignition hazard assessment using the guidance in Appendix 1 should be undertaken. For equipment in zone 2, this is generally straightforward; a little more thought is required for zones 1. There is very little such equipment, if any, in zones 0.

5.7.5 Existing non-approved electrical work equipment in zoned areas

Appendix 2 deals with non-approved electrical equipment. The situation may be summarised as follows:

- Apart from 'simple apparatus' in intrinsically safe circuits, uncertified electrical equipment is not (and never was) permitted in zones 0 and 1[ff]
- In zone 2, electrical equipment installed before 1 July 2003 was probably certified, although uncertified equipment was (and still is) permitted. Equipment installed after 1 July 2003 should be at least ATEX-marked by the manufacturer and will usually also be certified by a third party.

A typical example of an uncertified item of fixed electrical equipment is a pump motor submerged in a well. This could be a zone 2 or even a non-hazardous area – see ICoP 2. In a zone 2 location, provided the motor was assessed by the end user as being 'safe in normal operation', certification was not required. DSEAR requires such equipment to be re-assessed and the results recorded. This need not be particularly onerous for some equipment (particularly motors, junction boxes and other simple to assess items), but the guidance in Appendix 2 should be referenced.

Uncertified portable equipment (such as mobile phones, PAT testers, hand-held sampling instruments, surveying equipment, etc.) pose a bigger problem. In zone 1 (and 0) they must not be carried into the hazardous area, even if switched off. Although there is provision for equipment to be assessed for zone 2 use, the end user is not generally equipped to assess such complex items.

There are zones 2 around most sampling points on the gas collection system (see ICoP 2). However, the operator may locate the instrument outside the zone and sample the gas via a tube of a suitable length.

Also, it is permissible to use uncertified equipment in hazardous areas provided the hazardous area is demonstrated to be free of a potentially explosive atmosphere while work is being carried out. Therefore, uncertified equipment may continue to be used provided there is continuous gas monitoring or another suitable method to ensure that the worker and the associated electrical equipment do not come in contact with a potentially explosive atmosphere.

A risk assessment approach can be used in specific cases, but there needs to be a good reason why the normal practices of using certified equipment or operating under a relevant permit cannot be used. Mobile phones are one such case and are discussed in section 5.7.7.

5.7.6 Hand torches

Only certified torches should be used in hazardous areas unless the area is known to be free from a potentially explosive atmosphere.

5.7.7 Mobile phones used by lone workers

Lone working is used extensively in the waste management industry. A central part of the safety case for such workers is that they report periodically by mobile phone to a controller. At the present time, the vast majority of mobile phones are uncertified.

Wherever work in zoned areas takes place, it is almost always in a zone 2, so the risk is low. Ideally, no uncertified electrical equipment should be taken into any hazardous areas, but it is a greater risk for the operator to leave the uncertified phone outside the zone than to have it on his/her person, as he/she may

ee 1 July 2003 was the date that the ATEX Directives and much of DSEAR came into force.

ff Apart from 'simple apparatus', there are a few exceptional circumstances where uncertified equipment is legitimately used in zones 0 and 1, but this is outside the3 scope of the ICoP.

be unable to reach the phone if injured. It is not feasible for every area to be checked for flammable gas before the worker enters, although this should be done where reasonably practicable.

It is extremely costly to replace all mobile phones in use with certified equivalents. The HSE have stated that they believe that the risk associated with the use of a mobile phone on a landfill site is lower than, say, that associated with the electrostatic discharge that could occur from clothing being worn[gg]. However, they have reported that there are concerns where phones have a metal case - these have been reported as being capable of producing an electrostatic discharge of sufficient energy to ignite methane gas[hh].

The HSE have indicated that a risk assessment should be undertaken but have indicated that, where working in a zone 1 or higher risk, mobile phones should not be used and two people should be in attendance for such work; this should be covered under a permit-to-work system. Method statements etc. should detail what actions are required.

To summarise, uncertified mobile phones without a metal case may be used in zones 2 but not zones 1 or 0. Mobile phones with a metal case cannot be used in any zones. They should not be used for work that involves the deliberate generation of a potentially explosive atmosphere, e.g. breaking into the containment system.

5.7.8 Non-approved personal electrical equipment in hazardous areas

There are a number of items of personal electrical equipment that may be inadvertently or deliberately carried by a worker into a hazardous area:

1. digital watch
2. infra-red key fob
3. pacemaker (with battery beneath the skin)
4. hearing aid
5. personal stereo
6. electronic organiser
7. site radio
8. camera
9. mobile phone, possibly with camera/flash facility, MP3/headphone facility

The general rule is that non-approved equipment should not be brought into a hazardous area. However, digital watches and infra-red key fobs are usually not specifically prohibited and are, in fact, extremely unlikely to be capable of igniting methane.

Pacemakers with a battery under the skin are acceptable because the flammable gas cannot come in contact with the device.

Hearing aids are clearly essential items, but a certified device should be used unless a risk assessment shows otherwise. However, it is unlikely that a modern in-the-ear hearing aid would be capable of igniting landfill gas.

Personal stereos, personal organisers, personal mobile phones and other items that are not essential should not be carried into hazardous areas.

5.7.9 Tools for use in potentially explosive atmospheres

EN 1127-1:1998 Annex A gives guidance and the part referring to gases is quoted below.

> "Instructions on the use of hand-held tools shall take the following into account. Two different types of tools have to be distinguished:
>
> a) tools which can only cause single sparks when they are used (e.g. screwdrivers, spanners, impact screwdrivers);
>
> b) tools which generate a shower of sparks when used during sawing or grinding.

[gg] This hazard can be mitigated by the use of anti-static footwear – see section 5.7.3.

[hh] Although plastic is capable of generating and storing electrostatic charge, being a good insulator, the charge does not readily move to an earthed object. An unearthed conductor, however (such as a metal mobile phone case) could become charged and will readily conduct charge into a spark if earthed.

> "In zone 0, no tools which can cause sparks are permissible. In zones 1 and 2, only steel tools according to a) are permissible. Tools according to b) are only permissible if it is ensured that no hazardous explosive atmosphere is present at the workplace. However, the use of any kind of steel tools is completely prohibited in zone 1 if the risk of explosion exists because of the presence of substances belonging to explosion group IIC (according to EN 50014) (acetylene, carbon disulphide, hydrogen), and hydrogen sulphide, ethylene oxide and carbon monoxide, unless it is ensured that no hazardous explosive atmosphere is present at the workplace during the work with these tools.
>
> "The use of tools in zones 1 and 2…. should be subject to a 'permit to work' system. This shall be included in the information for use."

In summary, therefore, EN 1127-1 does not require the use of non-sparking (e.g. phosphor bronze) tools in zones 1 and 2 for landfill gas and normal (e.g. steel) tools that are 'single sparking' can be used without the requirement to ensure that a potentially explosive atmosphere is absent.

Note that maintenance activities that deliberately create a potentially explosive atmosphere are not covered under zoning and a separate risk assessment is required. However, provided the spark risk is only that the tool may be dropped onto the ground, steel tools are permissible, since the spark risk is very low. Great care should be taken to prevent steel tools (or other large metal objects such as well covers) from being dropped into open steel- or concrete-lined wells that contain landfill gas.

5.7.10 Bird scarers

These should not be operated in a hazardous area and, for those involving a projectile, consideration should be given to where the projectile might land.

5.8 Off-site issues

5.8.1 Infrastructure/support activities

Such activities may include:

- temporary road crossings
- pipe corridors and service ducts (with gas, leachate, electrical cables) under public roads
- lighting/CCTV towers
- radio masts

Although the temporary generation of a potentially explosive atmosphere during installation is permitted in an off-site location (with measures being implemented to prevent public access), it is not permissible for areas to which the public have access to be permanently zoned. In other words, the edge of zones must be inside the site boundary. For existing installations where this cannot be achieved, existing zones 2 may remain where the installation cannot be readily moved further inside the site boundary, subject to a risk assessment, since the risk to the general public is very low. Where zones 1 exist on public land, this is usually due to an operational activity such as sampling and the public can be excluded from the area while the operation is carried out.

The consequence of this is that, where installations close to a public road or other space require a zoned area, this should be located sufficiently inside the site boundary. Examples that may be close to public areas include:

- perimeter boreholes
- the point where service ducts under public roads come above ground – these will only require a zone if they contain a potential release such as a flanged joint
- pipe manifolds

5.8.2 Methane monitors in off-site buildings

Methane monitors may be provided to dwellings close to landfill sites where migration of landfill gas is a possibility. Where these are required to monitor gas levels up to and exceeding the LEL, they will be intrinsically safe. There should be a procedure in place for re-calibrating them at the required interval. Where such monitors are required only to measure levels of methane well below the LEL, they need not be intrinsically safe.

5.8.3 LPG heaters in cabins, etc.

Liquefied petroleum gas (LPG) is a mixture consisting mainly of propane and butane in varying proportions. It is a gas that liquefies under a modest pressure and is stored in fixed tanks or portable cylinders.

The zoning associated with the delivery, storage and distribution of propane (LPG) in fixed installations is dealt with in ICoP 3.

APPENDIX 1: ASSESSMENT OF ALREADY-INSTALLED NON-ELECTRICAL EQUIPMENT

The following appendix is supplied for information only and is not intended in itself to impart a level of training necessary for a competent person

A1.1 Legal requirements

DSEAR Regulation 17(2)(a) reflects the ATEX 1999/92/EC[9] Worker Protection Directive and states: -

"…. a workplace which contains places where explosive atmospheres may occur …. which is or has been in use on or before 30th June 2003 shall comply with the requirements of regulations 7 and 11 no later than 30th June 2006 …."

DSEAR Schedule 3(1) states: -

"Equipment and protective systems for all places in which explosive atmospheres may occur must be selected on the basis of the requirements set out in the EPS Regulations[10] unless the risk assessment finds otherwise."

New equipment should be marked as ATEX-compliant. With specific regard to non-electrical equipment installed before 30th June 2003, it will not be marked in any way as being suitable for use in a potentially explosive atmosphere. DSEAR requires such equipment to be assessed for its ignition capability, although it is not required to meet the constructional requirements of new equipment found in the EPS Regulations. The assessment should be completed by 30th June 2006. *There is no requirement to retro-fit ATEX-marked equipment* unless a risk assessment indicates a replacement is required.

What follows is guidance of how non-electrical equipment that is already installed can be assessed as suitable for continued use. Typical examples that require an assessment are: -

- pumps
- couplings (e.g. between a motor and the associated pump)
- conveyor belts
- hoists
- solenoid valves
- gearboxes
- brakes

The ignition hazard assessment for equipment in the following zones will now be discussed. The level of protection required for the various zones is summarised in Table 4:

Table 4: Levels of protection required for different zones

Gas/vapour zone	Probability of explosive atmosphere	ATEX Category	Requirements
2	low	3G	Safe in normal operation
1	medium	2G	Safe even with 'expected malfunctions'
0	high	1G	Safe even with 'rare malfunctions'

Similarly, Category 1D equipment can go into a zone 20, Category 2D into zone 21 and Category 3D into zone 22.

A1.2 Already-installed non-electrical equipment in zone 2

Zone 2 is the low risk zones where an explosive atmosphere arises only very occasionally, usually as a result of the failure of plant equipment (e.g. leaking flange or seal) or human error (accidental spill). As such, the requirements for the installed equipment are not excessively onerous and often are easily met by normal well-designed industrial equipment.

The requirements for equipment in these zones can be broadly summarised as follows: -

in normal operation, the equipment should not spark and should not have excessively hot surfaces; its ingress protection should be suitable for the environment

EN 1127-1 lists thirteen type of ignition source:
1 hot surfaces
2 flames and hot gases
3 non-electrically-generated sparks
4 electrical apparatus
5 stray static currents, cathodic corrosion protection
6 static electricity
7 lightning
8 electromagnetic fields in the frequency range 9 kHz to 300 GHz
9 electromagnetic radiation in the frequency range from 300 GHz to 3000 GHz or wavelength from 100 μm to 0.1 μm (optical spectrum)
10 ionising radiation
11 ultrasonics
12 adiabatic compression, shock waves, gas flows
13 chemical reactions
However, most or all will not apply to non-electrical equipment in normal operation.

When considering non-electrical equipment, and whether it is acceptable for continued use in zone 2 hazardous area, it is usually self-evident whether it sparks or not. With regard to temperature rise, very few of those parts exposed to the flammable gas or dust will exceed even 100°C, which makes the item acceptable for the vast majority of flammable materials[ii]. It should be stressed that only normal operation needs be considered for these zones; fault conditions (such as a seized bearing) are not taken into account, due to the low probability of such a fault occurring at exactly the same time as the explosive atmosphere. It is important to stress that the above assumes that the equipment is properly maintained.

Table 5 below shows a typical ignition hazard assessment for a range of devices in zone 2. Only normal operation is included, but loss of lubrication, for example, caused by poor maintenance is also included. The last column (Reference) is not important to users, but is included for information only, as it cross-references the measure to the relevant constructional standard.

Table 5: Typical ignition hazard assessment for non-electrical devices in zone 2

Potential ignition source in normal operation (Cat 3)	Examples of measures taken to prevent ignition source from becoming effective	Reference
General		
Loss of coolant	There is no immediate source of ignition as a result of coolant loss. Is the cooling water monitored by a level detector linked to the control system?	EN 13463-1
External impact causing failure or reduced clearances	Are all parts robustly manufactured and would withstand a likely impact?	EN 13463-1
Sparking caused by static charging	CLC/TR 50404 does not impose restrictions on plastic parts for Category 3 equipment.	CLC/TR 50404
Poor earthing	Are suitable earth facilities provided? Are all electrical parts earthed?	EN 13463-1
Hydraulic pump		
Pump surface temperature	What is the design running temperature? Highly unlikely to be excessively hot in normal operation.	EN 13463-1
Pump oil temperature	Highly unlikely to be excessively hot if suitably topped up.	EN 13463-1

ii For those flammables with very low auto-ignition temperatures (e.g. carbon disulphide, CS_2), then a more careful approach will be required, possibly involving actual measurement of the surface temperature or contacting the manufacturer. Regarding flammable dusts, be aware that a 75 K safety factor must be applied to the AIT of the dust layer and a 2/3 safety factor to the AIT of a cloud.

Table 5: Typical ignition hazard assessment for non-electrical devices in zone 2		
Potential ignition source in normal operation (Cat 3)	**Examples of measures taken to prevent ignition source from becoming effective**	**Reference**
Loss of lubrication causing overheating	Regular oil level checks recommended in user instructions.	User instructions
Coupling (vibration absorption type, laminations)		
Vibration exceeds coupling manufacturer's specification, causing failure	Is the vibration within the manufacturer's limits and has it been checked by test?	EN 13463-1
Fixings work loose	Are all fixings tightened to manufacturer specified torque?	EN 13463-1
Coupling (vibration absorption, rubber tyre type)		
Surface temperature	Can usually be assessed as not exceeding temperature of other parts.	EN 13463-1
Vibration exceeds coupling manufacturer specification, causing failure	Is the vibration within the manufacturer's limits and has it been checked by test?	EN 13463-1
Pump (piston type)		
Surface temperature	Is a temperature switch fitted? Has the casing temperature been measured?	EN 13463-1
Loss of lubrication through leaks causing overheating	Are regular oil level checks carried out as recommended in user instructions?	EN 13463-5
Seal temperature	Seals are manufactured from a low coefficient of friction material (nitrile, PTFE, Viton, etc.) and are not expected to achieve a running temperature in excess of other parts of the equipment.	EN 13463-5
Rotating shafts		
Debris falling onto shaft creates sparks or hot surfaces	Are shafts guarded to prevent inadvertent contact?	EN 13463-1
Mixers		
Contact between rotating and stationary parts	Is the construction suitably robust to maintain clearances under load?	EN 13463-1
Blades become loose and separate, causing impact sparks	Are all fixings torque tightened to manufacturer's specification?	EN 13463-1
Bearing and seal temperature (if supported by separate bearing not on motor)	Is the speed within the limit prescribed by the manufacturer? Does the equipment have a temperature sensor?	EN 13463-1 EN 13463-5
Gearbox		
Oil loss	Are periodic checks on lubricant level and condition of oil seals performed?	EN 13463-8

The principles of the ignition hazard assessment in Table 5 will be applied to specific examples in the following sub-sections. For simplicity, each ignition hazard assessment is complete in itself, although this involves some duplication of the information in Table 5.

A1.2.1 Ignition hazard assessment of an already-installed electrically-driven pump in zone 2

Figure 11: Typical diaphragm pump

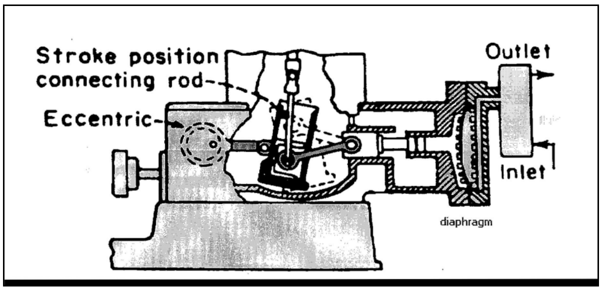


Table 6 shows a typical ignition hazard assessment for this type of pump

Table 6: Typical ignition hazard assessment for an electrically-driven pump in zone 2

Normal operation	Compliance
External impact causing failure or reduced clearances	All parts are robustly manufactured and would withstand a likely impact
Poor earthing	Suitable earth facilities are provided. All electrical parts are earthed
Pump surface temperature	Highly unlikely to be excessively hot in normal operation.
Pump oil temperature	Highly unlikely to be excessively hot if suitably topped up.
Loss of lubrication causing overheating	Regular oil level checks recommended in user instructions.
Vibration exceeds coupling manufacturer's specification, causing failure	Vibration limits for coupling verified by checking the manufacturer's specification.
Fixings work loose	All fixings tightened to manufacturer specified torque
Debris falling onto shaft creates sparks or hot surfaces	Shafts are guarded to prevent inadvertent contact
Oil loss from gearbox	Periodic checks on lubricant level and condition of oil seals
Summary	Pump is acceptable if suitably-protected against impact and maintained/lubricated at the required intervals; avoid excessive vibration.

A1.2.2 Ignition hazard assessment of an already-installed air-driven pump in zone 2

Table 7: Typical ignition hazard assessment for an air-driven pump in zone 2

Normal operation	Compliance
External impact causing failure or reduced clearances	All parts are robustly manufactured and would withstand a likely impact
Pump surface temperature	Highly unlikely to be excessively hot in normal operation.
Pump oil temperature	Highly unlikely to be excessively hot if suitably topped up.
Loss of lubrication causing overheating	Regular oil level checks recommended in user instructions.
Fixings work loose	All fixings tightened to manufacturer specified torque
Summary:	Pump is acceptable if suitably-protected against impact and maintained/lubricated at the required intervals; avoid excessive vibration.

A1.2.3 Ignition hazard assessment of an already-installed gas booster in zone 2

Figure 12: Gas booster

The gas booster has a zone 2 internally (this is the classification given to the landfill gas pipework from the manifold to the gas compound) and also externally (due to leaks from its own seal).

Table 8: Typical ignition hazard assessment for a gas booster in zone 2	
Normal operation	**Compliance**
External impact causing failure or reduced clearances	All parts are robustly manufactured and would withstand a likely impact
Sparking caused by static charging	There are no plastic parts in contact with the process medium. Plastic parts are not subjected to a charging mechanism.
External surface temperature	Highly unlikely to be excessively hot in normal operation.
Vibration exceeds coupling manufacturer's specification, causing failure	Vibration limits for coupling verified by manufacturer checking on test.
Fixings work loose	All fixings tightened to manufacturer specified torque
Seal temperature	Seals are manufactured from a low coefficient of friction material (nitrile, PTFE, Viton, etc.) and are not expected to achieve a running temperature in excess of other parts of the equipment.
Debris falling onto shaft creates sparks or hot surfaces	Shafts are guarded to prevent inadvertent contact
Contact between rotating and stationary parts	All clearances generous. Construction is suitably robust to maintain clearances under load.
Blades become loose and separate, causing impact sparks	All fixings torque-tightened to manufacturer's specification
Bearing and seal temperature (if supported by separate bearing not on motor)	Check that the speed is within the limit prescribed by the manufacturer.
Oil loss from gearbox	Periodic checks on lubricant level and condition of oil seals
Summary:	Booster is acceptable if suitably-protected against impact and maintained/lubricated at the required intervals; avoid excessive vibration.

A1.3 Already-installed non-electrical equipment in zone 1

Unlike in zone 2, foreseeable malfunctions should be considered when assessing non-electrical equipment in zones 1. Thus, the situation is somewhat more complicated. However, relatively little equipment, if any, falls into this category in the waste management industry.

When first considering the issue, the difficulty usually arises as to what constitutes a 'foreseeable malfunction' and whether such should be tolerated in a zone 1. Useful guidance on how to do the ignition hazard assessment can be found in EN 13463-1:2001, which is one of a suite of standards giving the constructional requirements for hazardous area non-electrical equipment. It should be stressed that there is no suggestion in the ATEX Directive that existing equipment should either be made to comply with these standards or else replaced, but they can be used for guidance.

A note in EN 13463-5 section 5.1 is included here because it gives guidance that is of general use: -

"Slow-moving parts with a circumferential speed of less than 1 m/s do not normally require protection against heating by friction and non-electrical sparks".

The general approach, which takes care of most of the ignition hazards, is as follows: -

ensure that the equipment is maintained in accordance with the manufacturer's guidelines and that all parts with a potential to become ignition sources are replaced at or before the specified interval

A1.4 Already-installed non-electrical equipment in zone 0

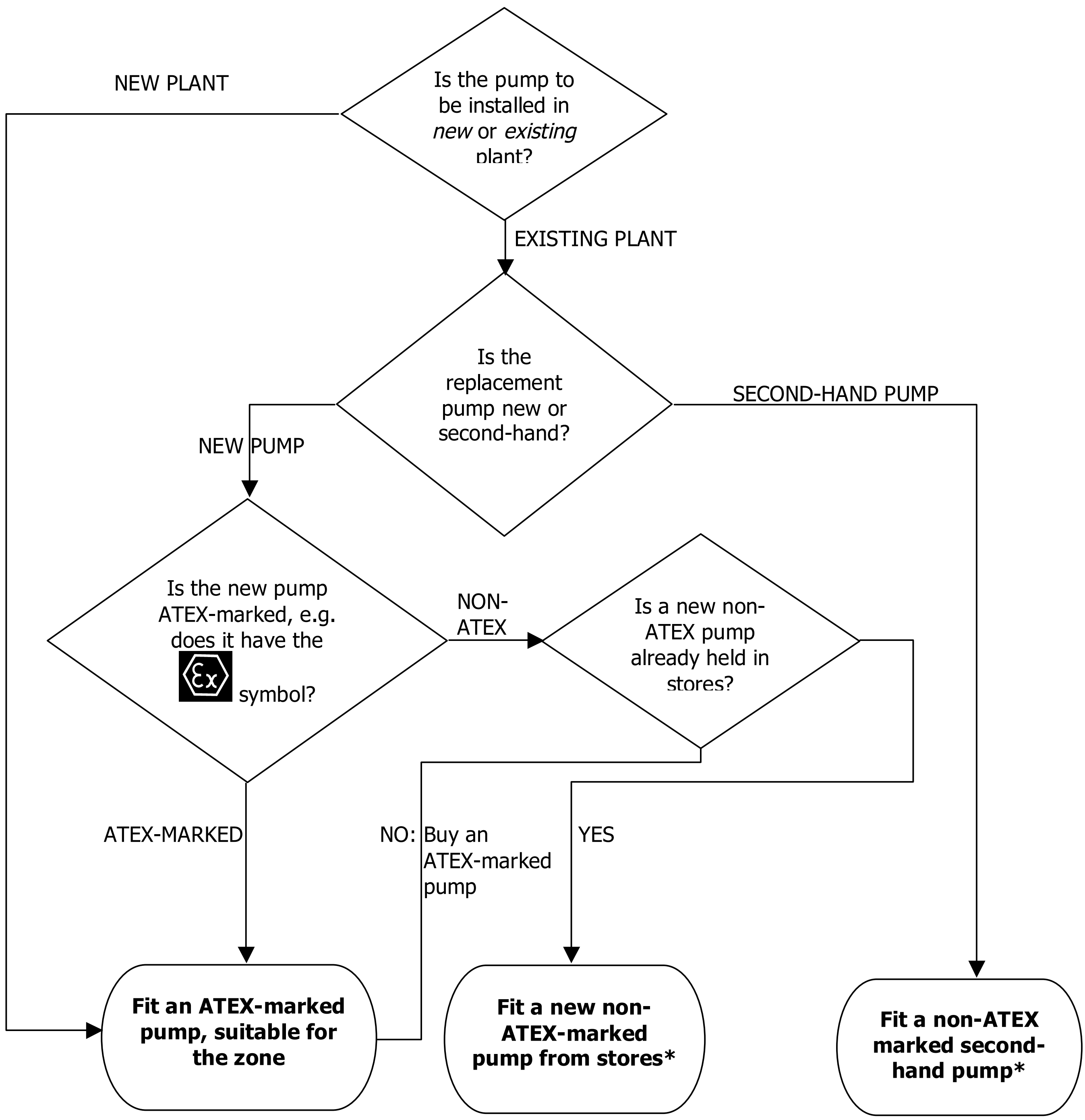
Such equipment is relatively rare, but certain examples may require consideration. The ignition hazard assessment should consider 'rare malfunctions' as well as 'expected malfunctions'. To take the example of sealed bearings, the mechanical seal protecting the bearings could be in contact with the zone 0. Possible approaches could be: -

- monitoring the barrier fluid level or pressure or flow
- an analysis of past failure rates
- periodic vibration or temperature monitoring
- as for equipment in lower risk zones, the routine maintenance and scheduled replacement of the bearings should be as recommended by the manufacturer.

A1.5 Selection flowchart

Figure 13 summarises when ATEX-marked pumps are required and when they are not. It can equally be applied to other items of non-electrical equipment, such as gas boosters, hoists, etc.

Figure 13: Flow chart for selecting a pump or other item of non-electrical equipment



* Note: before any non-ATEX item can be installed, an ignition hazard assessment is required, but this is the task of the Site/Facility Manager, not the installer. In many cases, the pump will be fitted into a zone 2, in which case the ignition hazard assessment for non-ATEX equipment is straightforward. Only properly-maintained, correctly-installed pumps should be used.

A1.6 Summary

An assessment of already-installed non-electrical equipment in zone 2 is relatively straightforward but a more careful analysis is required for the higher-risk zones. It is not possible to give a detailed approach for all situations, but the application of sound engineering judgement and implementation of reasonable precautions, proportionate to the zone classification, to prevent potential ignition sources becoming active is sufficient to comply with the requirements in the ATEX Worker Protection Directive. New equipment should be ATEX-marked.

APPENDIX 2: ASSESSMENT OF ALREADY-INSTALLED UNCERTIFIED ELECTRICAL EQUIPMENT

The following appendix is supplied for information only and is not intended in itself to impart a level of training necessary for a competent person.

A2.1 The legal situation

DSEAR Regulation 17(2)(a) reflects the ATEX 1999/92/EC Worker Protection Directive and states:

"…. a workplace which contains places where explosive atmospheres may occur …. which is or has been in use on or before 30th June 2003 shall comply with the requirements of regulations 7 and 11 no later than 30th June 2006 …."

DSEAR Schedule 3(1) states: -

"Equipment and protective systems for all places in which explosive atmospheres may occur must be selected on the basis of the requirements set out in the EPS Regulations unless the risk assessment finds otherwise."

With very few exceptions, newly-installed equipment must be marked as ATEX-compliant. With specific regard to electrical equipment installed before 30 June 2003, it will generally be certified if it is used in a gas/vapour zone but *may* not be certified in the following instances: -

- ♦ electrical equipment for gas/vapour zone 2 may be uncertified if the end user (typically) had assessed it as acceptable – for such equipment, see below;
- ♦ electrical equipment for dust zones may be certified for gases/vapours but no certification for dusts existed – for such equipment, see below;
- ♦ simple apparatus in an intrinsically safe circuit is, by definition, uncertified – this is outside the scope of this Appendix.

A2.2 Uncertified electrical equipment in zone 2

This section deals with equipment installed in zone 2 before the ATEX directives came into force on 1 July 2003. The requirements for zone 2 were and are considerably more relaxed than for zone 1 and EN 60079-14:2002[11] clause 5.2.3c permits the use of uncertified equipment in zone 2, provided it is assessed as meeting the requirements of the relevant standard. These requirements can be summarised as follows for the commonest form of Type n equipment ("Ex n non-sparking"):

a) the enclosure is normally required to be IP54 minimum, though protection by location (e.g. indoors) permits a lower level of ingress protection;
b) the equipment shall contain no sources of ignition in normal operation, i.e.
   - **hot surfaces:** no surfaces hotter than the ignition temperature of the hazard gas
   - **sparks:** no normally-sparking components are permitted, e.g. switches, relays unless encapsulated), contactors, circuit-breakers, potentiometers (unless the spark is current-limited) and easily-separated connectors (secure with adhesive if necessary). Such items are acceptable if certified to another concept, e.g. Ex d switches.

It should be stressed that the assessment takes account only of normal operation, and not fault conditions (e.g. a conductor coming loose from a terminal or a fuse blowing), since it is considered a sufficiently low risk that such a fault could occur at exactly the same time as a flammable gas is present in the enclosure. The enclosure is not required to be gas-tight for this method of protection.

There is no upper voltage limit and uncertified terminals are permitted. It is also possible to use test-disconnect terminals (non-sparking in normal operation), fuse terminals and other terminals incorporating components such as diodes. However, it is usual to use test-disconnect and fuse terminals that are *certified* as Ex n/N, since these are readily available.

Common examples of uncertified items of equipment that may be thus assessed are: -

- A.c. induction motors (paying particular attention to maximum temperature; sometimes a guide is that the limiting temperature for the wiring insulation is stated on the marking plate as a "Class"[jj], having no relationship to North American Classes I, II and III)
- Junction boxes
- Non-purged panels with no sources of ignition
- Panels containing potential ignition sources that are protected by the pressurisation principle

This relaxation in EN 60079-14 clause 5.2.3c does not apply to zone 1: all electrical equipment should be certified: an assessment and subsequent use of uncertified equipment is not recommended.

Note that the ATEX 1999/92/EC Worker Protection Directive requires *new* equipment (electrical and non-electrical) for zone 2 to be marked as ATEX-compliant.

[jj] Class A = 105°C, class E = 120°C, class B = 130°C, class F = 155°C, class H = 180°C, class N = 200°C (values from EASA Electrical Engineering Handbook)

APPENDIX 3: OVERVIEW OF HAZARDOUS AREA TERMINOLOGY

A3.1 In which zone can equipment be used?

Before the ATEX Directives, the method of protection defined the zone of use for electrical equipment as shown in Table 9:

Table 9: Relationship between protection method and zone for pre-ATEX equipment

Zone 0 equipment	Zone 1 equipment	Zone 2 equipment
intrinsically safe, type Ex ia	intrinsically safe, type Ex ib flameproof, Ex d increased safety, Ex e pressurised, Ex p encapsulated, Ex m quartz-filled, Ex q oil-filled, Ex o special, Ex s	Non-incendive, Ex N or Ex n

This method of deciding on the zone is no longer used. The ATEX 94/9/EC Directive additionally covers non-electrical and dust-protected equipment and introduces the concept of 'Categories', which may be summarised as shown in Table 4 below:

Table 10: Relationship between ATEX Category and zone

ATEX Category	Level of protection	Zones of use	
		G = gas and vapour zones	D = dust zones
1	Safe with two independent faults *or* safe even when rare malfunctions are considered	0	20
2	Safe with one fault *or* safe when foreseeable malfunctions are considered	1	21
3	Safe in worst-case normal operation	2	22

ATEX marking is given in more detail in the following Appendix. If an item of equipment is ATEX-marked, this marking shows the zone in which it may be installed or used. For example, if equipment is marked as follows:

II 2G

The 'II' indicates it is certified for surface use (non-mining) and the '2G' indicates it is Category 2G equipment. From the table above, it can be seen that this can be used in zones 1 and 2 only. Even then, it is important to check that the apparatus group and temperature class are appropriate for the gas hazard.

Equipment marked:

II 3GD

is again suitable for surface industries but this time it is Category 3GD. It can be used in zones 2 (gases) and 22 (dusts).

Thus, ***it is the category, not the protection concept, that should now be used to determine the applicable zones of use***. However, the apparatus group and temperature class must also be suitable. This is not an issue for landfill gas, since methane is among the least sensitive of gases, but the following information is given for general guidance.

A3.2 Apparatus groups

Both items of equipment and gases/vapours are assigned apparatus groups. The apparatus group may take one of the following four forms:

Table 11: Apparatus group

Apparatus group	Description	Suitable for use with gases and vapours with apparatus groups:
IIA	Equipment suitable only for gases that are least likely to transmit a flame or are relatively insensitive to spark ignition	IIA only
IIB	Equipment suitable for gases that are moderately likely to transmit a flame or are fairly sensitive to spark ignition	IIA and IIB
IIC	Equipment suitable for gases that are highly likely to transmit a flame or are very sensitive to spark ignition	IIA, IIB and IIC
II	Equipment suitable for all gases (effectively the same as IIC equipment)	IIA, IIB and IIC

Landfill gas is a IIA gas, meaning even IIA equipment is suitable. Clearly, IIB and IIC (or 'II') equipment is also suitable. There are therefore no limitations with respect to apparatus group.

A3.3 Temperature class

Dust-protected equipment is marked with an actual maximum surface temperature. For other equipment, a "temperature class" is used. This is based on the hottest surface where igniting the flammable gas/vapour would destroy the protection and may refer to the inside or outside of the enclosure.

Table 12: Temperature class

Temperature class	Description	Suitable for use with gases and vapours with temperature classes:
T1	The hottest temperature class – the maximum temperature does not exceed 450°C	T1 only
T2	The maximum temperature does not exceed 300°C	T1 and T2
T3	The maximum temperature does not exceed 200°C	T1, T2 and T3
T4	The maximum temperature does not exceed 135°C	T1, T2, T3 and T4
T5	The maximum temperature does not exceed 100°C	T1, T2, T3, T4 and T5
T6	The maximum temperature does not exceed 85°C	All temperature classes

Most equipment on the market is T3, T4, T5 and T6.

The temperature class is always quoted in relation to an ambient range. If the ambient temperature range is not marked on the equipment (e.g. T_a = -20°C to +60°C), then the default range of -20°C to +40°C can be assumed. Using the equipment outside its ambient range invalidates the certification, though such use is not necessarily unsafe; responsibility for such use lies with the installer, not the manufacturer or certification body.

Landfill gas is a T1 gas, meaning an item of equipment with any temperature class is suitable. There are therefore no limitations with respect to temperature class.

APPENDIX 4: HAZARDOUS AREA EQUIPMENT MARKING

A4.1 General

Prior to the issue of the ATEX Directives, only electrical equipment for gases and vapours was marked for hazardous area use. From 1 July 2003, the ATEX Directives came into force and required all equipment to be marked if it was to be used in hazardous areas. Not only electrical equipment, but also non-electrical, as well as dust-protected equipment now requires marking.

A4.2 Pre-ATEX marking for electrical equipment

An example of typical marking for an item of intrinsically safe equipment would be similar to the following

Armageddon Industries

Nemesis 666 Toxic Gas Monitor
EEx ia IIC T4 (Ta = -20°C to +60°C)
Ui = 28V, Ii = 120mA, Pi = 0.84W, Ci = 0, Li = 58μH
STATIC HAZARD: clean only with a damp cloth
Serial number: nnnnn
PTB Ex 99E2100X

(Ex mark)	is the European mark that indicates the equipment is explosion protected
EEx ia IIC T4	is the certification code and tells the user the zones of use
Ui = 28V …. etc.	is the safety description, indicating what the equipment may be connected to
Sira Ex 99E2100X	is the certificate number
X	at the end of the certificate number indicated special conditions for safe use, that are written in the certificate and should always be referenced when installing or inspecting the equipment.

A4.3 How to work out the zone of use

On pre-ATEX equipment, only electrical equipment for flammable gases and vapours was marked as suitable for hazardous areas. The zone could be worked out from the type of protection, as shown in Table 13:

Table 13: Zones for pre-ATEX equipment

Equipment suitable for zone 0	Equipment suitable for zone 1	Equipment suitable for zone 2
Intrinsic safety, EEx ia	Equipment for zone 0 *plus* Intrinsic safety, EEx ib Flameproof, EEx d Increased Safety, EEx e Pressurised, EEx p Encapsulated, EEx m Oil-filled, EEx o Quartz-filled, EEx q Special, Ex s	Equipment for zones 0 and 1 *plus* Ex N or Ex n, EEx nA, EEx nC, EEx nL, EEx nR, EEx nP, EEx nZ

With the advent of the ATEX Directives, ***it is the <u>category</u> that determines which zone the equipment can go into.***

A4.4. ATEX categories

The more onerous the zone, the greater the requirements for equipment installed in it. The ATEX 'Product' Directive[kk] introduced the concept of 'Categories' of equipment. This is summarised in Table 4 for equipment protected against flammable gases[ll].

A4.5 ATEX marking for electrical equipment

Armageddon Industries, Salem, USA
CE nnnn Ex II 2G
Doomwatch 999 Flammable Gas Monitor
EEx ia d IIC T4 (Ta = -20°C to +60°C)
Ui = 28V, Ii = 120mA, Pi = 0.84W, Ci = 0, Li = 58μH
STATIC HAZARD: clean only with a damp cloth
Serial number: yy/nnnnn
Sira 06ATEX2999X

There is additional marking for equipment which has ATEX certification:

- ♦ the address of the manufacturer
- ♦ the CE mark followed by the reference number of the notified body responsible for issuing the quality notification (not necessarily the certificate)
- ♦ II = the ATEX Group, i.e. non-mining
- ♦ 2G = ATEX Category
- ♦ the year of manufacture

Examples of ATEX Group and Category marking:

II 2G	indicates that the equipment is Group II (non-mining use), category 2, for gases (allowing it to be used in zones 1 and 2), compatible with T4 equipment
II 1D (T90°C)	indicates that the equipment is Group II (non-mining use), category 1, for dusts (zones 20, 21 and 22). T90°C is the external surface temperature of the equipment. The latest dust standards introduce additional marking, but this is outside the scope of this ICoP.

[kk] ATEX Directive 94/9/EC

[ll] Mining equipment has different categories

A4.6 ATEX marking for non-electrical equipment

Atlantis plc, Wastewater, LA6 6UW, UK
Scirocco Mk II Pump
30/600 r.p.m. IP65
ATL 06ATEX0001
Serial number: yy/nnnnn
II 2GD c k T4

Non-electrical equipment for all but zone 0 need not be certified by a third party Notified Body such as Sira, Baseefa, PTB, etc. Instead, the manufacturer can declare compliance and mark the equipment according to the ATEX Directive. In the example above:

ATL 06ATEX0001	is *not* a certificate number, but the manufacturer's technical file reference number
CE	indicates the equipment meets all the relevant European Directives
Ex	is the European mark that indicates the equipment is explosion protected
II	tells the user that the pump is for non-mining use ('I' is for mining)
2	is the Category
G	stands for Gas, so Category 2G equipment can go into zones 1 and 2
D	stands for Dust, so Category 2D equipment can go into zones 21 and 22
c	stands for 'constructional safety' (perhaps the commonest of a number of protection methods for non-electrical equipment
k	stands for 'liquid immersion', another common non-electrical protection method
T4	is the temperature class (135°C maximum)

APPENDIX 5: METHOD STATEMENT FOR DRILLING INTO GAS PIPELINES

Scope

This Method Statement covers drilling into PE landfill gas pipe work under negative and positive pressure.

PPE Required

Hardhat, high visibility jacket, leather type gloves, anti-static steel mid-soled shoes or boots, eye protection, hydrogen sulphide personal monitor (which should be worn at all times during the task).

Introduction

This method statement has been prepared to cover the activity of the drilling and formation of a hole within a landfill gas pipe manufactured from HDPE (or similar material). Two scenarios have been considered in this document: where the operating pressure relative to atmosphere at the commencement of the activity could be either positive or negative.

Depending upon the pressure within the pipe work at the time of the activity, there is a potential to form an explosive atmosphere either within the gas pipe (if under negative pressure) or external to the pipe, centred on the resultant hole if under a positive pressure.

DSEAR requires operators to have systems in place to reduce or mitigate the risk of an explosive atmosphere forming and where it does to eliminate or reduce the risk of personal injury or harm to an acceptable level. The activity described by this method statement is considered a maintenance activity as described by DSEAR.

Where possible, all drilling of pipe work required for the installation of sample points, etc. into the landfill gas infrastructure should be done before the system (or part of) is connected to the existing or made live.

Description

To aid in the management of landfill gas or the process of isolation of landfill gas from a particular part of the landfill gas infrastructure, there is a requirement to install either sample taps, plugs etc as monitoring locations or points at which an inflatable bladder can be inserted to provide a gas seal. In general the largest hole that would be drilled into the gas line would be 38mm (1 ½”) in diameter.

As a rule, the gas collection infrastructure installed within the body of the waste up to the inlet of the gas booster plant is operated under a negative pressure. Exceptions to this could arise if blockages (partial or full) occur in any part of the gas system resulting in a positive pressure developing.

Under normal operating conditions, all gas delivery pipe work from the outlet of the boosters will be under a positive pressure.

Pre-Start Checks

A Inform your supervisor or site management of where you are going and what you are doing.

B Obtain a ‘Permit to Work’ for the task

C Check for additional hazards that may be present.

D Make sure that the results of any Risk or CoSHH assessments applicable to this have been taken into account.

E Ensure that all the tools and equipment necessary to carry out the task is available and in good working order. No electrical equipment (including battery powered tools) should be used during this activity unless they are ATEX certified and designed for use in a hazardous area. Priority should be given to the use of mechanical hand operated tools such as a brace and bit to drill the hole into the gas pipe work.

F Using a suitable representative location of the gas passing through the pipe line at the point of drilling, using an appropriately-certified portable gas analyser, measure the concentration of the methane, carbon dioxide, oxygen and hydrogen sulphide present within the pipe line. Note and record the results of the measurements.

G If the measured value of hydrogen sulphide is above 10ppm seek further guidance before undertaking the task. Hydrogen sulphide is toxic and at elevated concentrations is extremely flammable.

H Check to ensure that all the correct personal protective equipment (PPE) is available and is worn at the appropriate time. The PPE must be in good order.

I Make sure that a mobile phone is readily available (refer to any Additional Guidance Note on Lone Working if applicable).

1) DRILLING A HOLE WHEN THE GAS LINE IS UNDER A POSITIVE PRESSURE

Carrying out the task

1 Isolate the section of gas line, if possible, where the hole is to be drilled using any gas valves that may be installed within the system. Acceptable means of isolation include closure of existing valves within the gas line, squeeze clamps (with vent arrangement) or other methodology as appropriate.

2 If it is not possible to isolate the section of gas line, turn off the gas booster(s). This may have a knock-on effect and should be discussed in full with the unit manager.

3 Using an appropriately-certified instrument, at a representative location, measure the pressure within the gas main and monitor the pressure until it reduces to either a balance position (neutral pressure) or negative pressure within the pipe line.

4 If a negative pressure is achievable, go to the section 'Drilling a hole when the gas line is under a negative pressure.'

5 If it is not possible for operational reasons to reduce the pressure within the gas line, ***no drilling should take place on a positive pressure system***.

2) DRILLING OF A HOLE WHEN THE GAS LINE IS UNDER A NEGATIVE PRESSURE

1 At a representative location, down stream of the drilling location, on the gas collection system, using an appropriately-certified analyser, measure the pressure within the gas line to confirm that it is under a negative pressure relative to atmosphere. Measure the concentration of methane, carbon dioxide and oxygen within the gas stream; note and record the readings.

2 Using the brace and bit, drill the hole into the pipe line

3 Restrict the air ingress into the gas pipe by temporarily placing a piece of polythene sheet or similar over the hole.

4 Offer up the 'tap', remove the polythene and cut the thread into the pipe as quickly as possible.

5 Remove the 'tap' and again temporarily restrict the air ingress into the pipeline using a piece of suitable material.

6 Offer up the plug, sample tap etc, remove the material and screw in the fitting until tight and no air leak into the pipe line can be detected.

7 Using the monitoring location as in item 1 of this section, confirm that the gas quality is in line with the measurements taken earlier. If there are any differences between the readings outside of expected tolerances, and there have been no changes on the gas field or gas management system has occurred since the initial reading, determine whether or not the change is due to the installation of the pipeline fitting; repair as required. Check the gas readings on completion and confirm that they are in line with the initial readings.

8 Remove all equipment and materials from the area ensuring all control panels, chambers etc. are closed or locked where applicable.

9 Check that the area has been left in a safe and acceptable condition.

10 Contact your supervisor or site management and inform them that the work has been completed.

11 Sign off the Permit to Work.

APPENDIX 6: METHOD STATEMENT FOR LOWERING A GAS WELL IN THE OPERATIONAL AREA

Scope

This method statement has been prepared as a generic approach to the task of reducing the height of gas extraction well located in a restored area of a landfill site. For this particular safe system of work it has been assumed that the gas well and connecting head works and collector pipe (discharge line) has been constructed from HDPE or similar materials.

PPE Required

Hard hat, high visibility jacket, leather type gloves, anti-static steel mid-soled shoes or boots, eye protection, hydrogen sulphide personal monitor (which should be worn at all times during the task).

Introduction

Landfill gas (of which methane is the primary flammable constituent) is explosive in certain concentrations with air (4.4 to 16.5% by volume). Trace gases present in landfill gas, such as hydrogen sulphide, are also potentially explosive, but only at much higher concentrations than found in landfill gas. However, if present at significant concentrations, then a far more important COSHH[mm] issue prevails for which additional safe systems of work should be initiated.

This particular task is carried out on a frequent basis on a landfill facility and tends to arise as either the land 'naturally' settles or works are undertaken whereby the ground around the gas well is lowered artificially as part of site engineering works.

This task is usually required to be carried out for reasons, which include:

A Enabling safe access to the control valve and monitoring points on the gas well as part of the environmental management of the landfill gas to be maintained.

B Planning conditions imposed on the facility may require the gas well to be at a pre-determined height above the natural level of the ground.

C The prevention or the reduction of the potential for air to ingress into the gas management system through the reduction of the depth of the bentonite seal in relation to the perforated sections of the gas well liner.

Pre-start checks

1 Communicate with the site/facility manager and check that no other extraordinary works or activities are taking place on the site that could impact on either the task of lowering the gas well or that could impact on the 'other' activity in an uncontrolled/adverse manner without additional precautions being put in place.

2 Ensure that all equipment/tools for carrying out the task are readily available, in sound condition and good working order.

3 Ensure that all Personal Protective Equipment (PPE) is available, in good condition and suitable for the task being carried out. Generally, the only PPE to meet the requirements of the Dangerous Substances and Explosive Atmosphere Regulations (DSEAR) is anti-static footwear, but other PPE will usually be required for other reasons.

4 Raise a Permit to Work (PTW).

5 Carry out a gas test and pressure/vacuum measurement at the gas well to be lowered. Analyse the results to verify that the atmosphere within the gas well is both under a vacuum and an explosive atmosphere is not already present. If the gas well is under positive pressure, make the necessary change to the control valve position to produce a vacuum within the well – again attempting not to form an explosive atmosphere/mixture within the well. If a vacuum cannot be produced within the gas well, review the system, carry out any changes until a resultant vacuum can be achieved. If an explosive mixture is formed within the gas well, identify the source of any potential air ingress and remediate prior to commencement of the task. Record all results of measurements taken.

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mm COSHH = Control of Substances Hazardous to Health

6 Carry out a gas test around the external vicinity of the gas well to check that there is no methane (landfill gas) as significant concentrations (should be less than 25% of the lower explosive limit of methane i.e. <1.1%). If methane levels are detected in excess of this value, identify the source of landfill gas and eliminate prior to commencement of the task. Record all results of atmospheric testing.

7 Identify suitable means of isolation of the landfill gas within the gas well originating from the waste mass. Acceptable means of isolation could be squeeze clamps, inflatable bladders etc. (For this safe system of work described here, the use of an inflatable bladder has been incorporated into the procedure).

8 As required, mark out a safe working area around the gas well and identify by suitable means (e.g. warning tape etc.) and restrict access to the working area to those persons involved with the undertaking of the task.

9 Where there is potential for vehicles to approach close to the working area, consideration should be given to the installation of a temporary barrier to prevent vehicle movements in the area.

Carrying out the Task

10 With the gas well proven to be under extraction, drill a hole of suitable size (nominally 25mm dia.) at a location in the gas well liner below the point at which the gas liner will be cut.

11 Keeping to a minimum the air ingress through the newly-drilled hole, produce a thread of an appropriate specification on the internal surface of the hole to enable a bung to be screwed in to form a seal on completion of the task.

12 Insert the inflatable bladder through the hole and inflate.

13 Using an appropriate test meter, measure the atmosphere within the well head/collector line (dependent upon the sample point location) and check that the gas well including head works is free from landfill gas ('gas free').

14 Close the control valve on the head works.

15 Check that the bladder has sealed by carrying out a gas test within the gas well. If sufficient space is available, this could be done either through the drilled hole or via the gas sample point provided it is located prior to the control valve on the collector line. Only when proven to be sealed should the task continue. In the event that a positive seal has not been achieved, consideration should be given to the installation of a second inflatable bladder, in effect producing a 'double block' arrangement. Good practice would be to include the use of a pressure gauge or other pressure-measuring device on the 'bladder' to ensure that it retains its pressure whilst the task is being carried out.

16 Isolate the collector line after the control valve. This could normally be achieved by the use of an appropriately-sized squeeze clamp.

17 Split the mechanical (bolted) seal at the control valve.

18 Remove the gas wellhead works. This is generally a manual operation; therefore the requirements of the Manual Handling Regulations should be taken into account. Depending upon the degree of settlement of the land, gaining access to the head works may require working at height and hence suitable and sufficient measures should be put in place to reduce the risk of an accident occurring. Remove the head works to a safe, secure location for re-use.

19 Identify the location of where the gas well liner is to be cut.

20 Using an appropriate hand saw, cut the gas well liner down to the appropriate length.

21 If required, cut the section of pipe on the inlet of the head works (this would normally be sized to slot inside the well liner and form an interference fit).

22 Renew the Fernco coupler (or similar securing device) as appropriate to form a gas tight seal between the gas well liner and the head works.

23 Re-fit the head works to the well liner and tighten securing device as appropriate to form a gas tight seal.

24 Re-connect the collector line, including control valve to the head works. Ensure that all the bolts securing the pipe work are re-fitted to the appropriate torque setting.

25 Ensure that the control valve is in the closed position.

26 Remove the squeeze clamp from the collector line.

27 Open the control valve on the head works so as to impart a suction on the gas well.

28 Carefully deflate the bladder within the gas well (beware of gas pressure that may have built up behind the bladder) and remove when sufficiently deflated.

29 Fit a screwed bung of the appropriate size into the hole within the well liner ensuring a gas tight seal with no air ingress into the system.

30 Carry out a gas test on the atmosphere within the gas well or on the collector line to prove that no excess air is being drawn into the gas extraction system.

31 Remove all waste, equipment and tools from the working area.

32 Return PTW to originator, sign off as appropriate.

APPENDIX 7: METHOD STATEMENT FOR THE REPLACEMENT OF AN ELECTRIC PUMP IN A CONDENSATE KO POT

Scope

This Method Statement covers the replacement of an electric pump within a condensate knock out pot.

PPE required

Hard hat, high visibility jacket, leather type gloves, anti-static steel mid-soled shoes or boots, eye protection, hydrogen sulphide personal monitor (which should be worn at all times during the task).

Introduction

This safe system of work has been prepared as a generic approach to the task of replacing an electric submersible pump within a condensate knock out (KOP), which in turn forms part of a landfill gas management system.

Condensate forms as the landfill gas extracted from the waste mass cools. If this liquid is left within the gas management system, it could eventually restrict the flow of gas from the waste mass, giving rise to potential environmental issues. Condensate can have a number of hazards associated with it: any person working on these types of systems is likely to come into contact with the liquid and should be aware of the steps and precautions required to be taken.

Landfill gas (of which methane is the primary flammable constituent) is explosive in certain concentrations with air (4.4 to 16.5% by volume). Trace gases present in landfill gas, such as hydrogen sulphide, are also potentially explosive, but only at much higher concentrations than found in landfill gas. However, if present at significant concentrations, then a far more important COSHH issue prevails for which additional safe systems of work should be initiated.

It has been assumed for this protocol that the design of the KOP is simple in that it has the following associated characteristics:

A The KOP is an 'in line' unit with landfill gas passing through the main collector chamber unabated. The KOP is installed directly into virgin ground (outside of the waste mass).

B The electric control panel for the pump is located in close proximity to the KOP.

C Access to the collection chamber of the KOP is gained via a bolted, flanged lid.

This particular task is carried out on a frequent basis on a landfill facility and is usually required as part of a planned maintenance programme where the pumps are inspected and serviced on a regular basis or have to be replaced/repaired following failure.

All personnel involved with undertaking this task should be trained and/or competent in the required disciplines.

1 Pre-start checks

1 Communicate with the site/facility manager and check that no other extraordinary works or activities are taking place on the site that could impact on either the task of lowering the gas well or that could impact on the 'other' activity in an uncontrolled/adverse manner without additional precautions being put in place.

2 Ensure that all equipment/tools for carrying out the task are readily available, in sound condition and good working order.

3 Ensure that all Personal Protective Equipment (PPE) is available, in good condition and suitable for the task being carried out.

4 Raise a Permit to Work (PTW).

5 Isolate the power supply to the pump at the local control panel. Apply safety lock to isolator switch. Prove the power supply 'dead'.

6 If required where the local control panel feeds other electric consumers, isolate electrically the local control panel back at the distribution board or other point of supply. Apply a safety lock to the isolator switch.

7 Carry out a gas test around the external vicinity of the KOP to check that there is no landfill gas (methane) at significant concentrations (should be less than 25% of the lower explosive limit of methane i.e. <1%). If methane levels are detected in excess of this value, identify the source of landfill gas and eliminate prior to commencement of the task. Record all results of atmospheric testing.

8 Using a suitable instrument, measure the quantity of the gas within the system immediately downstream of the KOP to be worked on. Record the results.

9 Identify suitable means of isolation of the landfill gas both on the inlet and discharge sides of the KOP. Acceptable means of isolation could be

- squeeze clamps (dependent upon the size of the pipe)
- inflatable bladders
- flooding of the inlet and outlet pipe work with water
- shutting any in-line gas valves
- shutting down the entire gas extraction system (this is considered last resort as it could lead to potential uncontrolled releases of landfill gas into the atmosphere).

10 As required, mark out a safe working area around the gas well and identify by suitable means i.e. warning tape etc. and restrict access to the working area to those persons involved with the undertaking of the task.

11 Where there is potential for vehicles to approach close to the working area, consideration should be given to the installation of a temporary barrier to prevent vehicle movements in the area.

2 Carrying out the task

12 Arrange for the disconnection of the pump cable from the local control panel. Dependent upon the method of installation i.e. if 'hard wired' into the control box, arrange for a competent/trained person to disconnect.

13 Isolate the gas lines into and out of the KOP using an acceptable methodology that will produce a gas tight seal.

14 Relieve any pressure within the KOP by venting out to atmosphere through a convenient point e.g. sample point. Whilst this event is taking place, ensure that no equipment/tools etc. (which could include mobile phones) that could become a source of ignition are present and/or energised as appropriate in the vicinity of the KOP. Whilst the residual pressure within the KOP is venting, ensure that all personnel remain at a safe distance from the KOP and ideally, conditions allowing, away from the source of landfill gas being emitted from the KOP. As part of the Pre-Start checks, the measurement of hydrogen sulphide within the landfill gas should have been carried out, the results of which will determine the degree of respiratory protection required (if necessary) to be worn by persons carrying out this task.

15 After a suitable time (typically 10 minutes), take gas measurements (in particular methane and hydrogen sulphide) of the atmosphere using an appropriate instrument to check that it is 'safe' and approach the KOP to check that the residual pressure within the KOP has dissipated.

16 Close the vent point on the KOP.

17 Having isolated the gas lines, prove that the isolation method has been successful. This can be achieved by measurement of the pressure within the KOP using an appropriate measuring device. Take a measurement of the pressure within the KOP. Leave the system for 10 minutes and re-take the pressure measurement. If the gas isolation method has been successful, there should be no difference in the results of the two pressure measurements. If the pressure has increased, investigate the cause and if required apply additional/alternative means of gas isolation to the inlet and outlet gas lines. If required and conditions allow, the installation of a 'double block and vent' system on the inlet and outlet gas lines should be applied. This has the advantage that in the case of failure or seepage of gas pass the first block (e.g. inflatable bladder, in line vale) the gas will take the path of least resistance which in this case would be the vent. The vent pipe should be fed far enough away from the working area and any potential source of ignition so as not to give rise to the formation of an explosive atmosphere in the vicinity of the discharge of the gas. Where possible, the vent should preferably be allowed to discharge at height and not ground level.

18 Where level probes or other sensing devices are installed within the KOP, disconnect any instrument leads feeding to them.

19 Depending upon the design of the system, isolate the condensate discharge line from the main condensate collector line. Disconnect the discharge line (before any non-return valve or other means of isolation that maybe installed) outside of the KOP; beware of any residual condensate that maybe present within the pipe.

20 Remove the sensing device(s) (providing this can be achieved without removal of the lid from the KOP).

21 Unbolt and remove the lid of the KOP. Because of the large size of some of the KOPs installed within some gas management systems, consideration should be given as to whether or not there is a significant risk of persons falling into the KOP. If this is the case, provisions must be put in place to eliminate this risk e.g. the wearing of a safety harness appropriately secured to a fixed point.

22 Lift out the pump from the KOP. This is generally a manual operation; therefore the requirements of the Manual Handling Regulations should be taken into account.

23 Remove the cables through the glands within the lid of the KOP, taking care not to damage the glands. If the glands become damaged or would no longer provide an air tight seal if reused, they should be replaced as the new or repaired pump is installed.

24 Install the new/repaired pump into the KOP, ensuring as far as is reasonable that the pump is in the correct orientation on the base of the KOP chamber.

25 Connect the condensate discharge line from the pump to the existing system; ensuring all connections are sufficiently tightened to prevent leaks occurring.

26 Replace the top of the KOP and secure using all bolt locating points with the correctly sized bolt and ensure that they are tightened to the correct torque specification.

27 De-isolate the condensate discharge system to the pump.

28 Remove any safety locks installed on electric supply and control panels and re-energise the power supply to the pump.

29 Check the phase rotation of the pump to ensure that it is pumping as required.

30 De-isolate the inlet and outlet gas lines from the KOP. Where 'flooding' of the KOP has been used to form a gas seal, allow the pump to remove all the excess liquid before checking for air ingress into the system.

31 Take measurements of the quantity of the landfill gas within the system at the closest point downstream of the KOP (as used in point 8 of the Pre-Start Checks) to check that air ingress into the system is not taking place.

32 Review the results of the gas measurements with those taken earlier; investigate and remediate any problems identified.

33 Remove all equipment/tools and waste associated with the task from the area.

34 Return the PTW to the originator, sign off as appropriate.

APPENDIX 8: METHOD STATEMENT FOR RAISING GAS WELLS IN THE OPERATIONAL AREA

To be issued at a later date.

APPENDIX 9: METHOD STATEMENT FOR INSTALLATION OF NEW SECTIONS TO THE GAS COLLECTION SYSTEM

To be issued at a later date.

APPENDIX 10: METHOD STATEMENT FOR MODIFICATIONS TO EXISTING GAS COLLECTION SYSTEMS

To be issued at a later date.

APPENDIX 11: METHOD STATEMENT FOR REPLACEMENTS OF SUBMERSIBLE PUMPS IN PRE-BOOSTER AREAS

To be issued at a later date.

APPENDIX 12: REFERENCES

The following publications were referenced in compiling this document:

[1] Dangerous Substances Explosive Atmospheres Regulations:2002 ('DSEAR') regulation 7 requires area classification to be undertaken

[2] L138: Dangerous substances and explosive atmospheres regulations 2002: approved code of practice and guidance. HSE books. ISBN 0 7176 2203 7

[3] Environment Agency publication LFTGN03: Guidance on the management of landfill gas, page 53, section 6.2.3, downloaded August 2005.

[4] Guidance on the Management of Landfill gas, document LFTGN 03, September 2004, Environment Agency

[5] Guidance for monitoring trace components in landfill gas, document LFTGN 04, September 2004, Environment Agency

[6] Construction, Design and Management (CDM) Regulations:1994

[7] Report on the risk of static ignition during refuelling: a study of the available relevant research, May 2001, Institute of Petroleum, section 5.5.8

[8] PD CLC/TR 50404. Electrostatics - Code of practice for the avoidance of hazards due to static electricity.

[9] ATEX Directive 1999/92/EC: Minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres.

[10] Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations 1996 – these are the Regulations that implement the ATEX 94/9/EC Product Directive into UK law.

[11] EN 60079-14:2003 - Electrical apparatus for explosive gas atmospheres - Part 14: Electrical installations in hazardous areas (other than mines).