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

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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

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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.

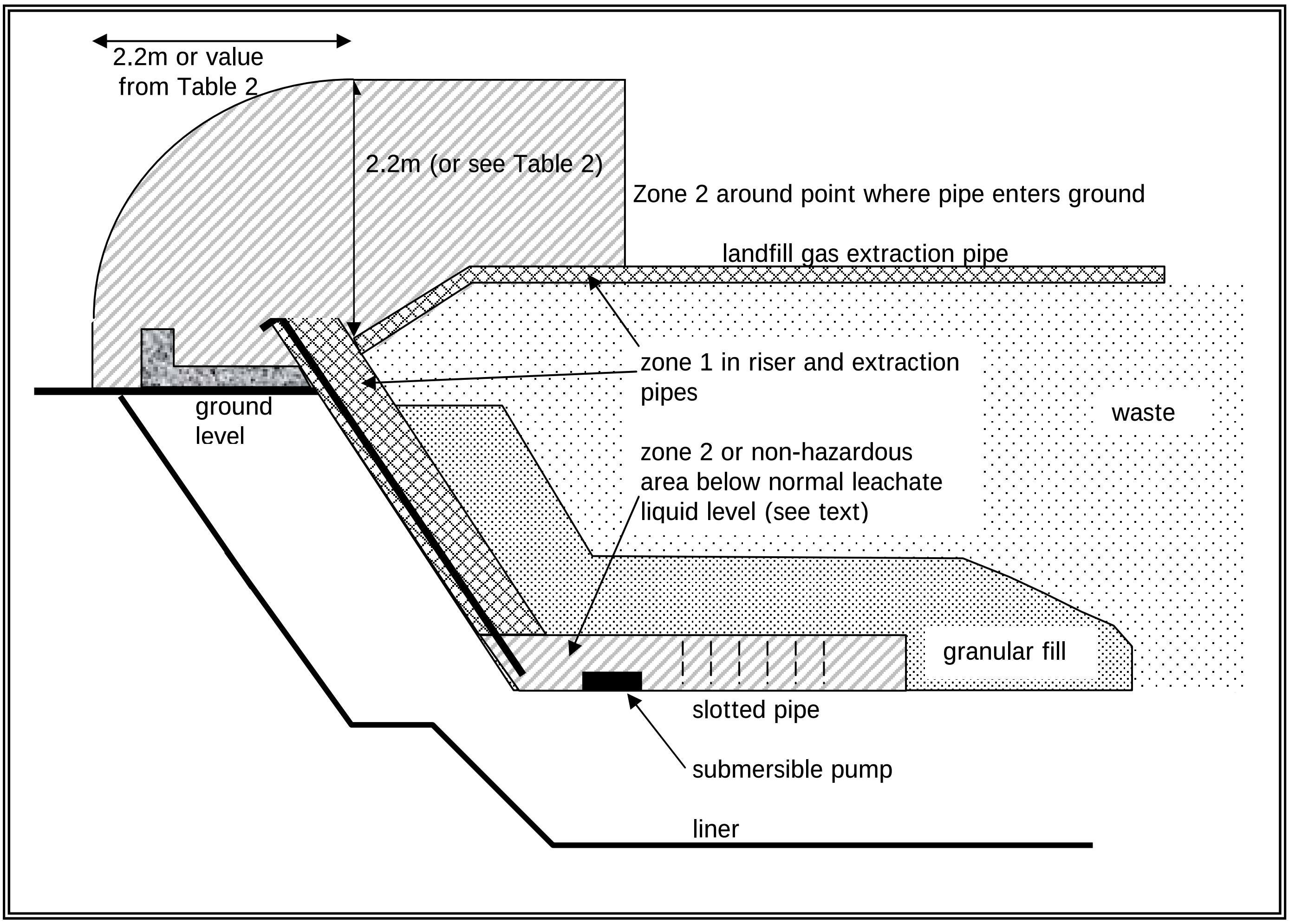
Table 7: zone radii around wells due to failure of the Bentonite seal

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

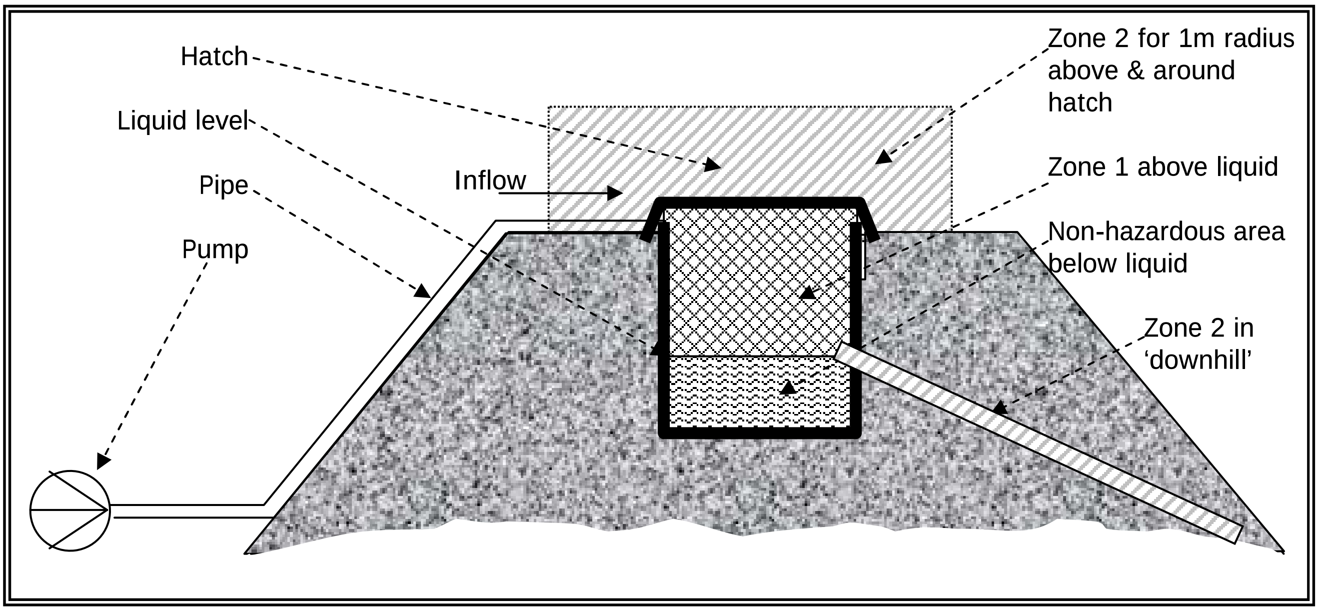
Refer to Figure 2. A break tank is sometimes located at the highest point of a pipe run. If this is the case, air will enter because the hatch is not completely sealed. Methane is likely to build up in this space, so it is classified as zone 1 above the liquid level (i.e. above the outflow pipe).

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.

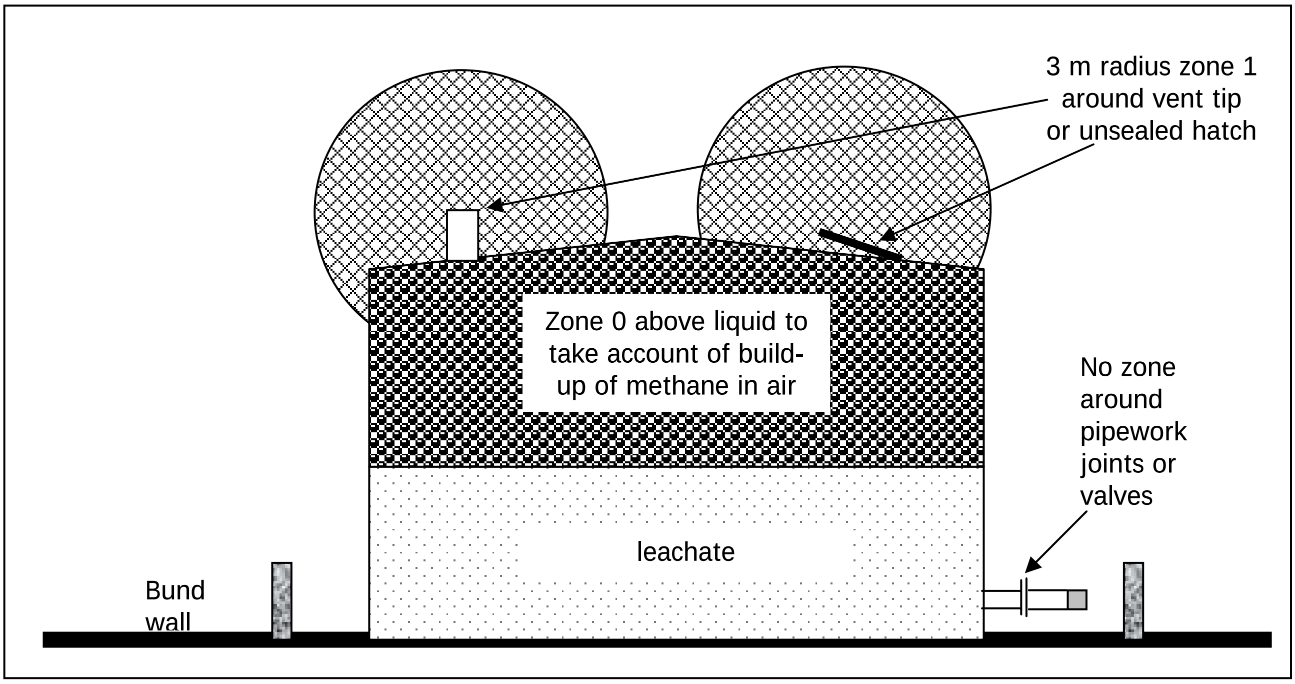
7.2 Closed tanks (passive ventilation)

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)

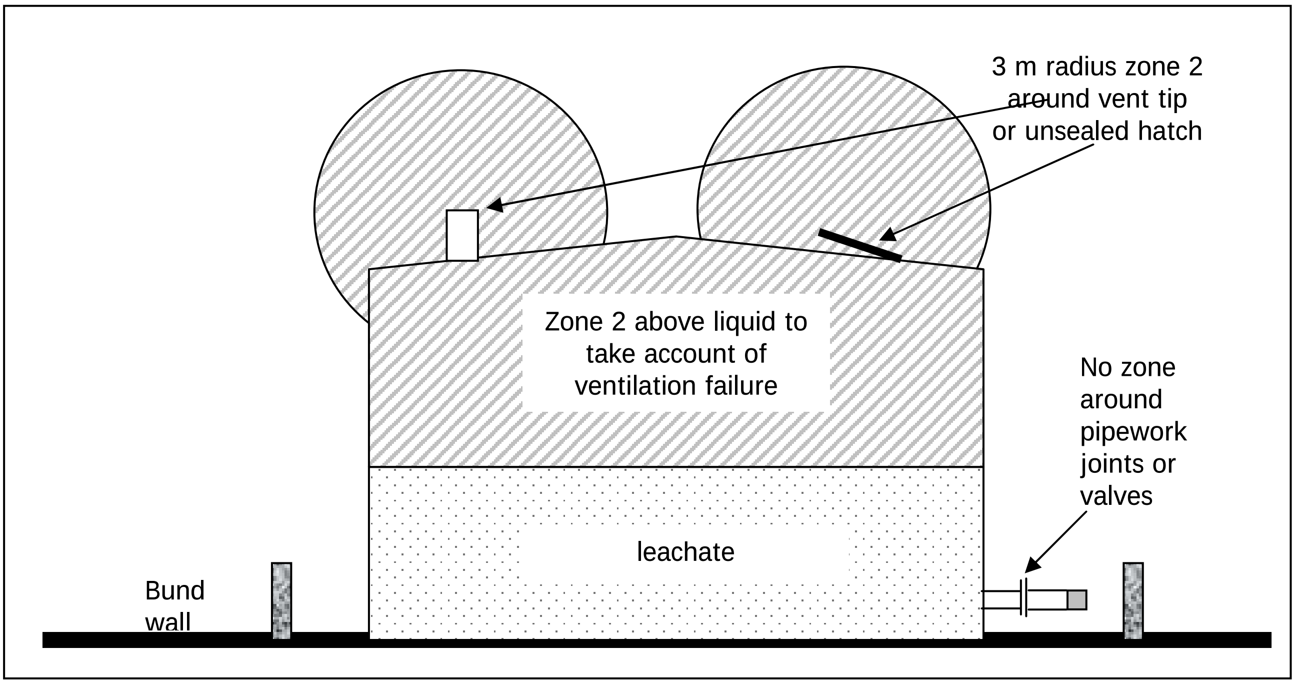


[28] Some pumps are inherently incapable by design of pumping themselves dry, whereas others may need further control measures such as a level switch. This subject is dealt with more fully in ICoP 2.

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

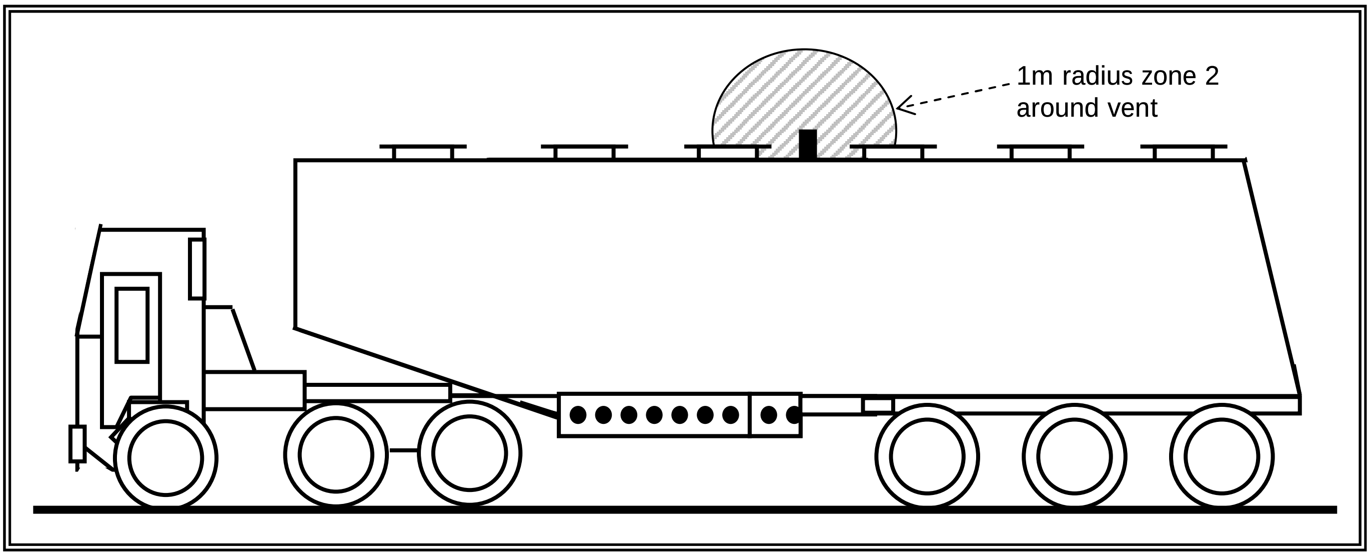
The discharge of leachate may be by gravity or pumping. All leachate should be below 0.14 mg/litre methane in order to comply with the water utility company's normal requirements as defined within the sewer discharge consent. This concentration has been set in order that the utility company can comply 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.

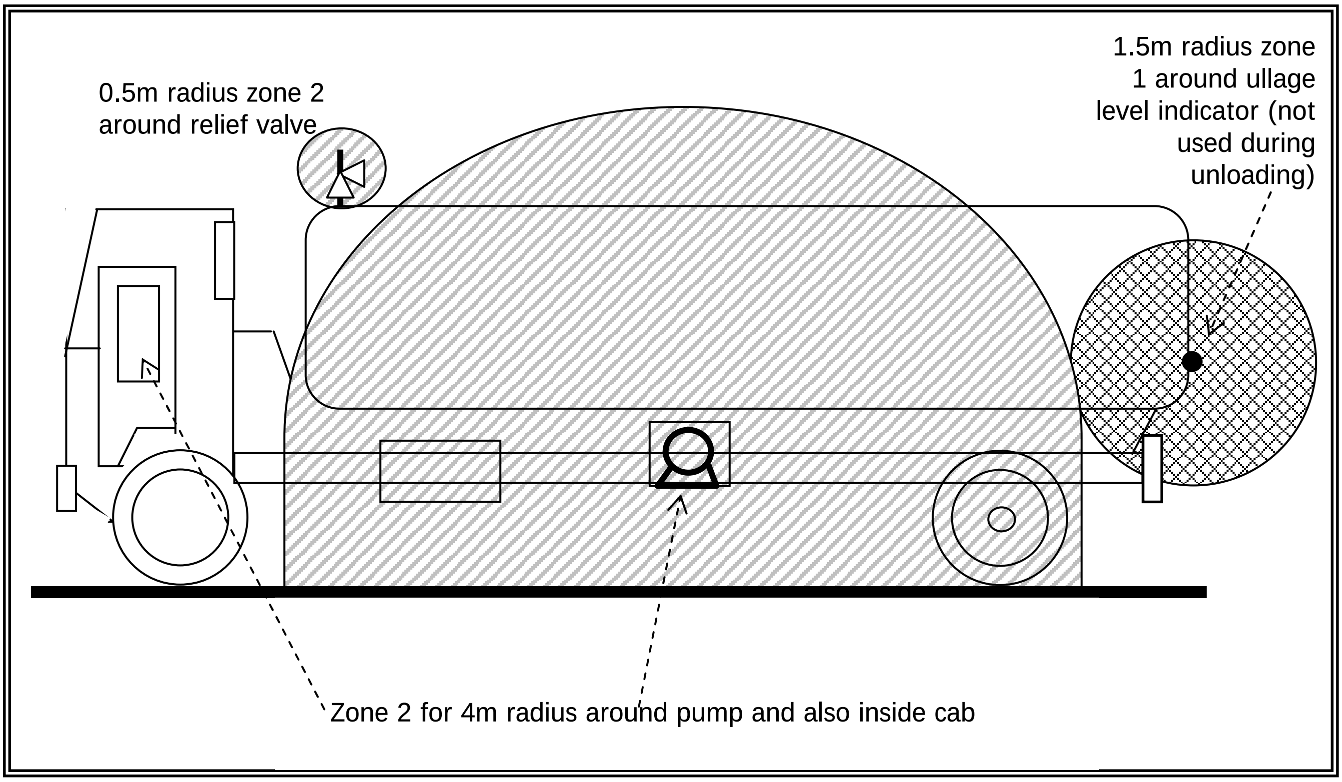
10.1 Propane

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

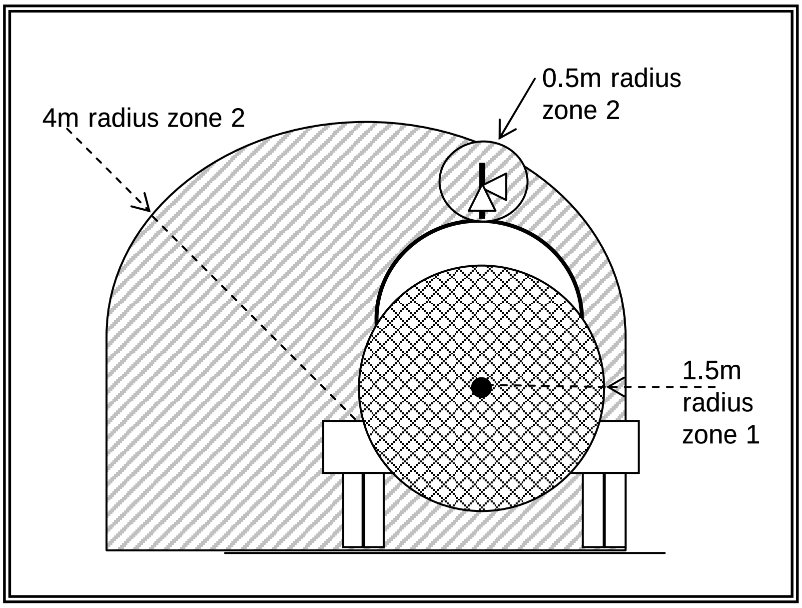
Ideally, there should be a dedicated area assigned to tanker unloading that is not shared by other vehicles. If this is not practical, then measures should be taken (e.g. use of cones) to ensure that no vehicles can be accidentally driven close to the tanker when unloading is taking place. Refer to Figures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

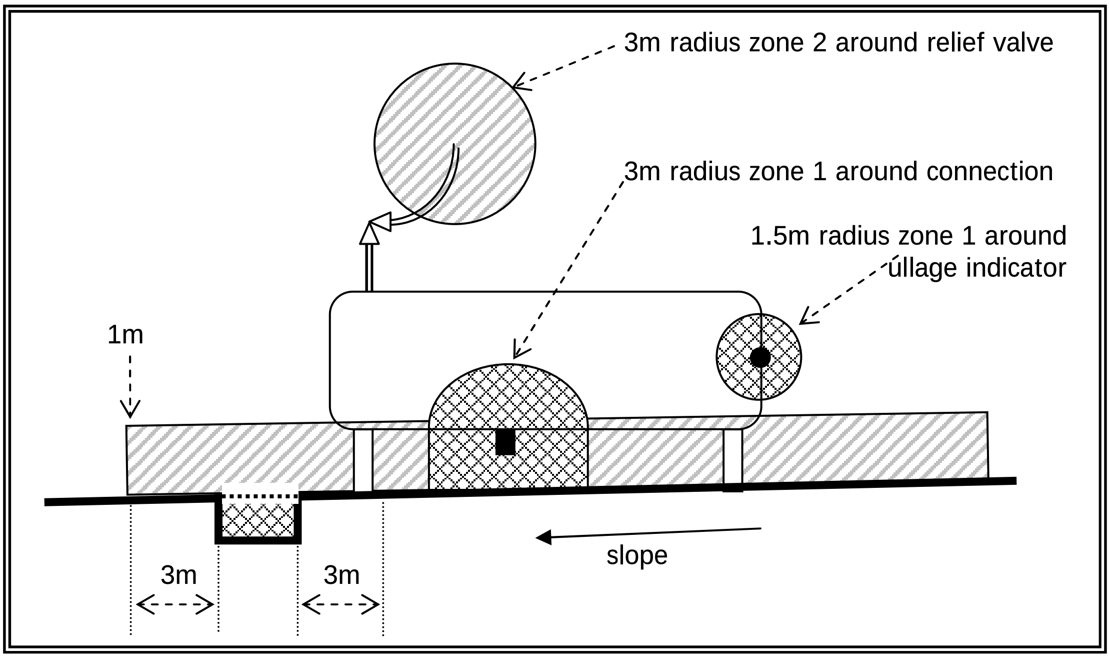
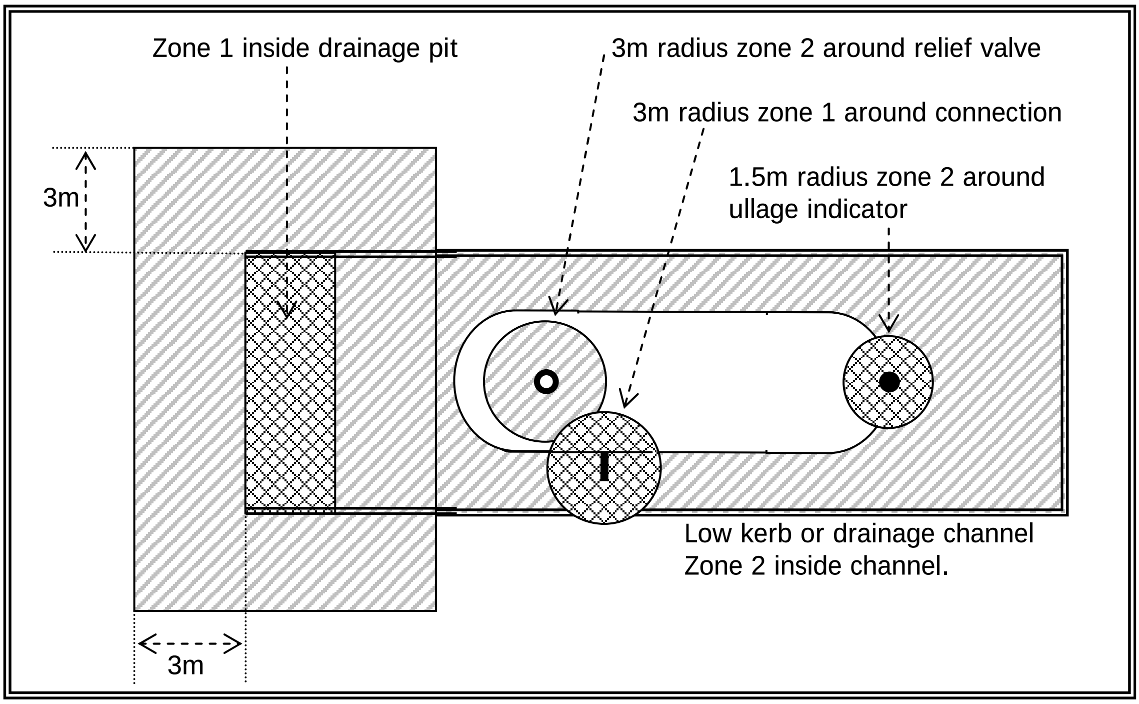


Figure 9: zoning of a propane storage tank – plan view



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.

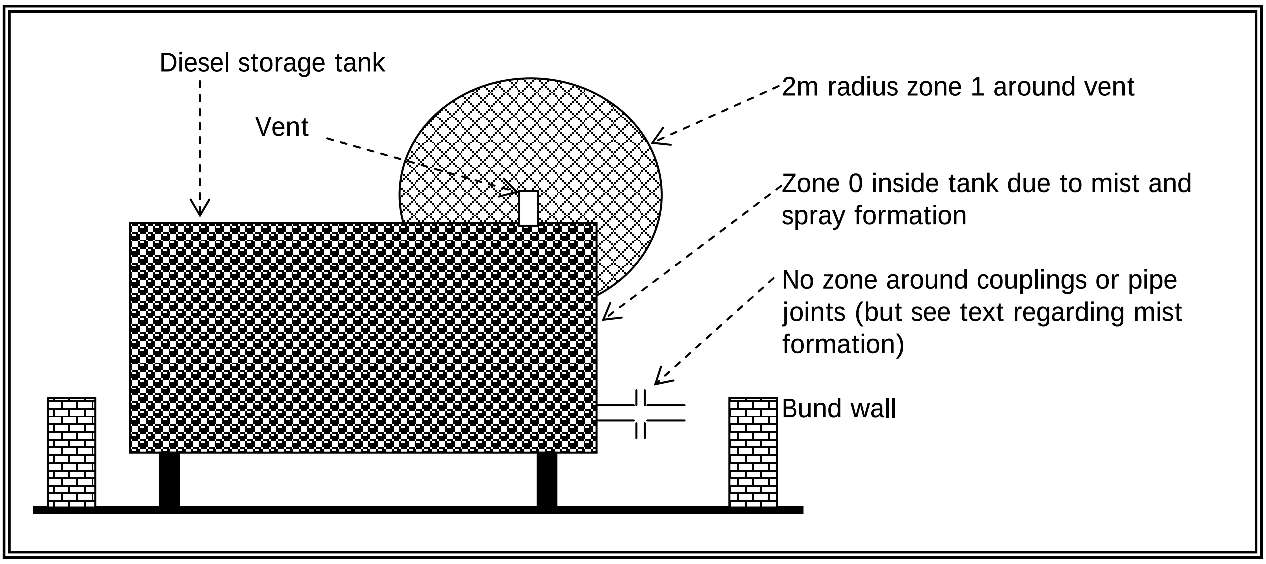
Propane pipework joints should be avoided inside buildings where possible. The zone extent cannot be calculated without consideration of the local ventilation characteristics, but will be considerably larger indoors. To ensure that secondary grade releases do not persist in excess of the time allowed 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:

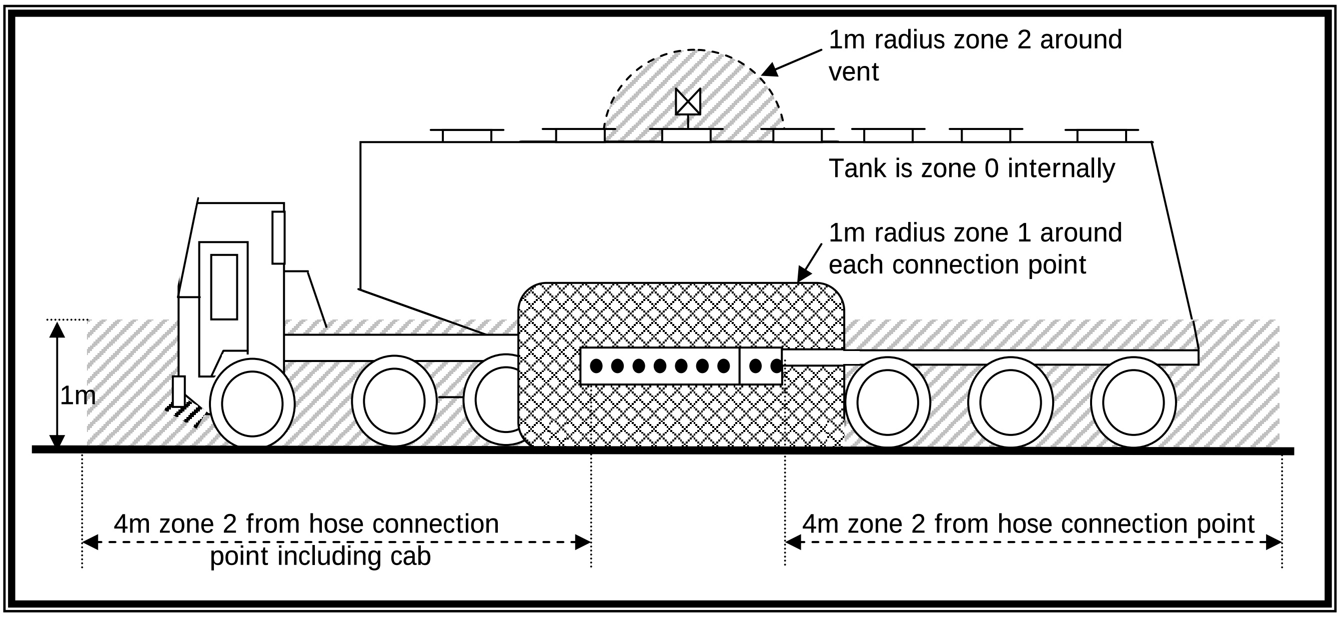
- tanker delivery
- storage tanks
- pipework
- pumps

These are covered in the following sub-sections.

10.5.1 Tanker delivery of methanol

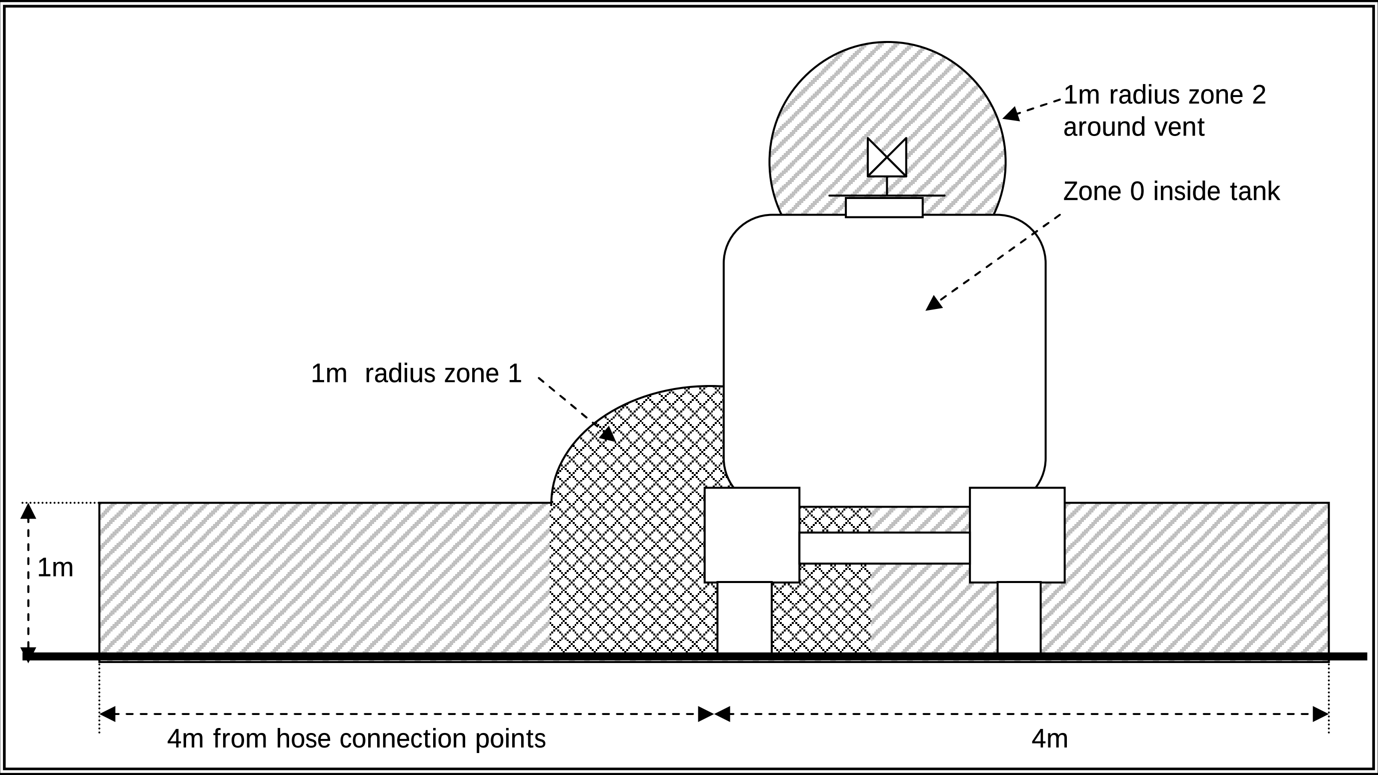
Refer to Figures 11 and 12, which are based on IP15 Figure 3.12 for a tanker unloading a low flashpoint liquid. Ideally, there should be a dedicated area assigned to tanker unloading that is not shared by other vehicles. If this is not practical, then measures should be taken (e.g. use of cones) to ensure 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.

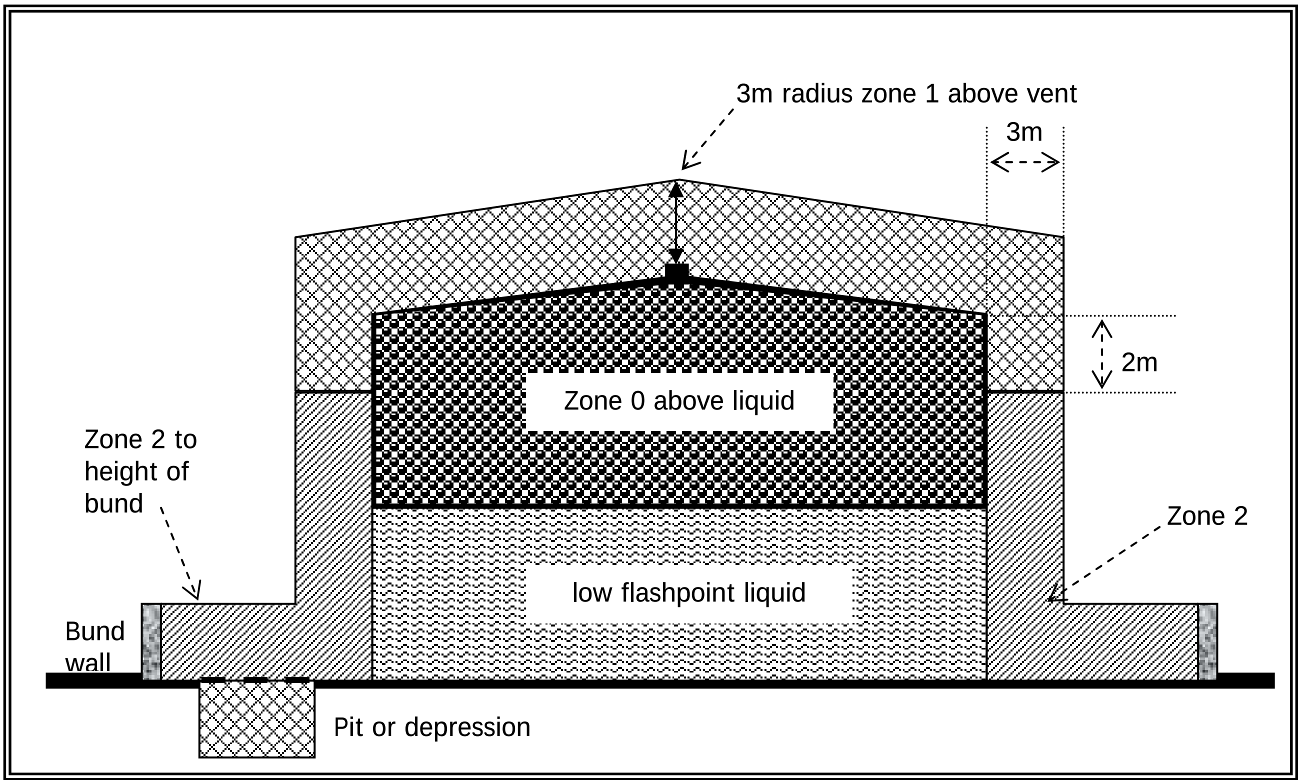
Figure 12: zoning drawing for tanker unloading a low flashpoint liquid (rear elevation)



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.

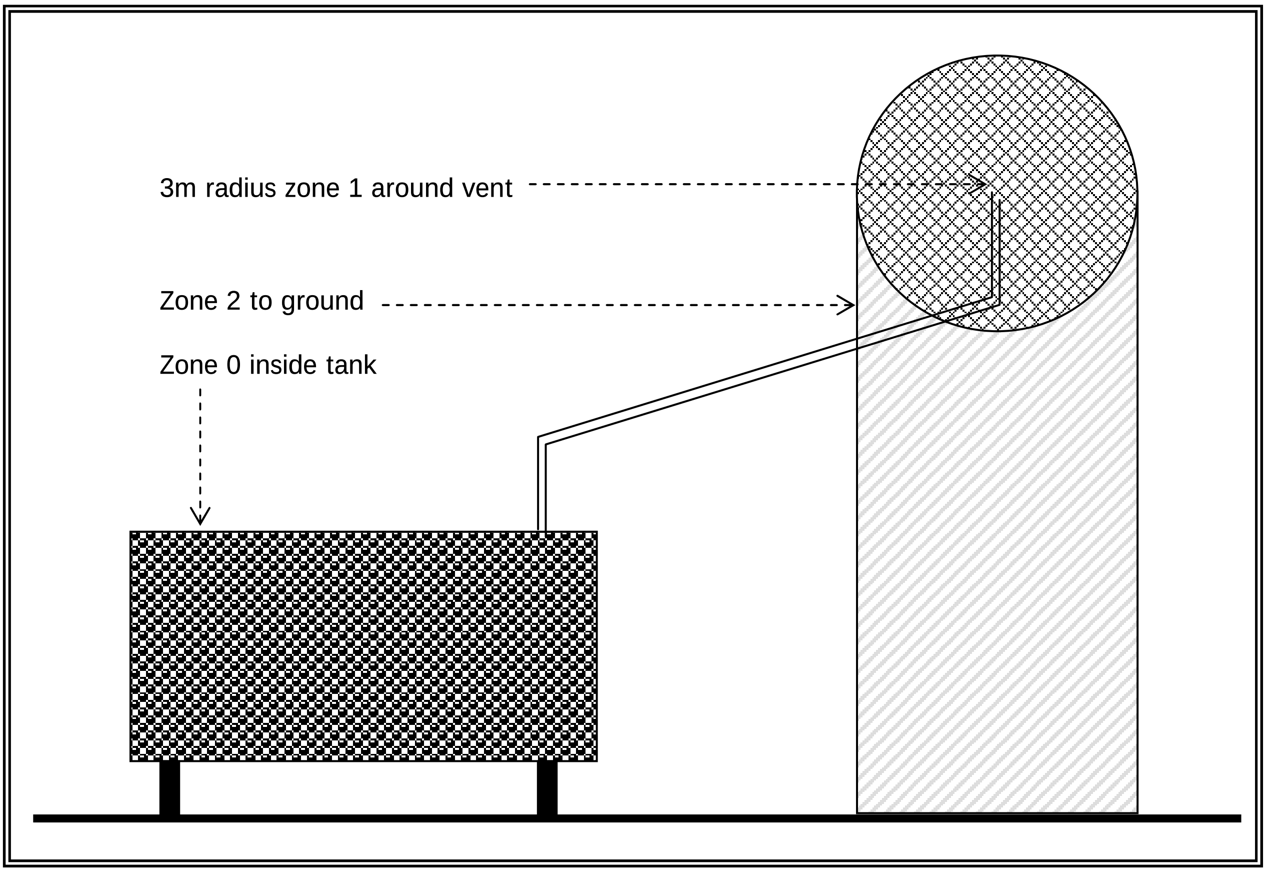
Figure 13: bunded storage tank for low flashpoint liquid (e.g. methanol)



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.

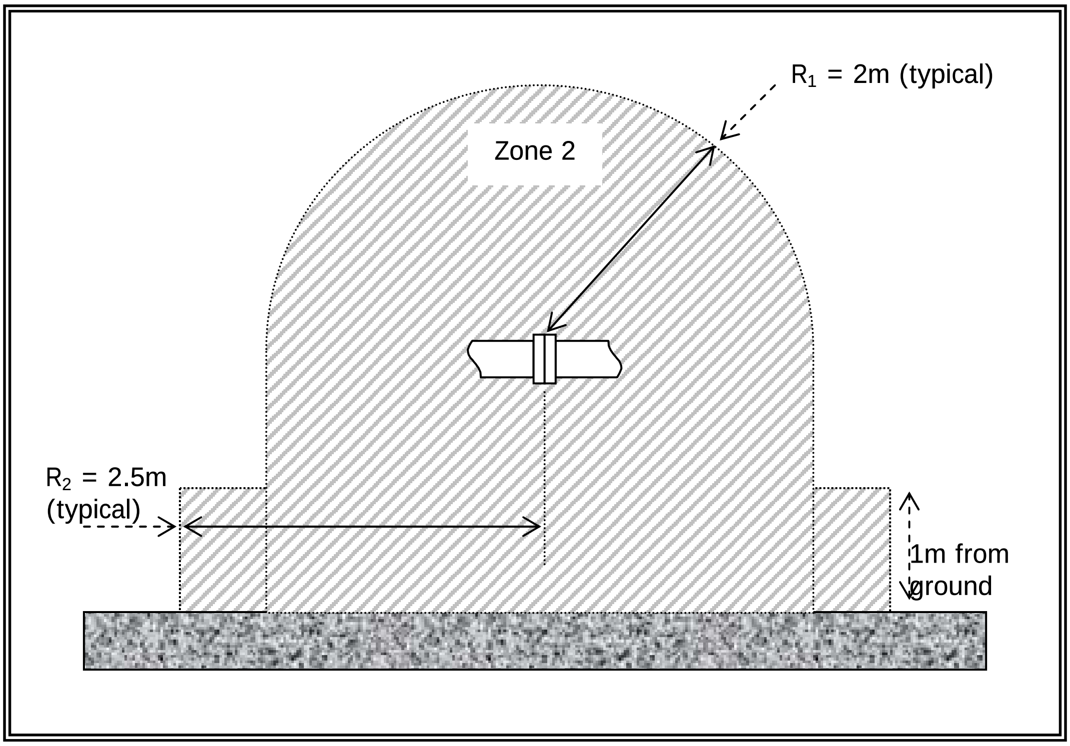
To take account of liquid drops falling to the ground, the zone extends to the ground. For flanges that are a distance greater than R_1 from the ground, two zones may be defined: one around the flange and one at ground level to take account of pool formation.

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.

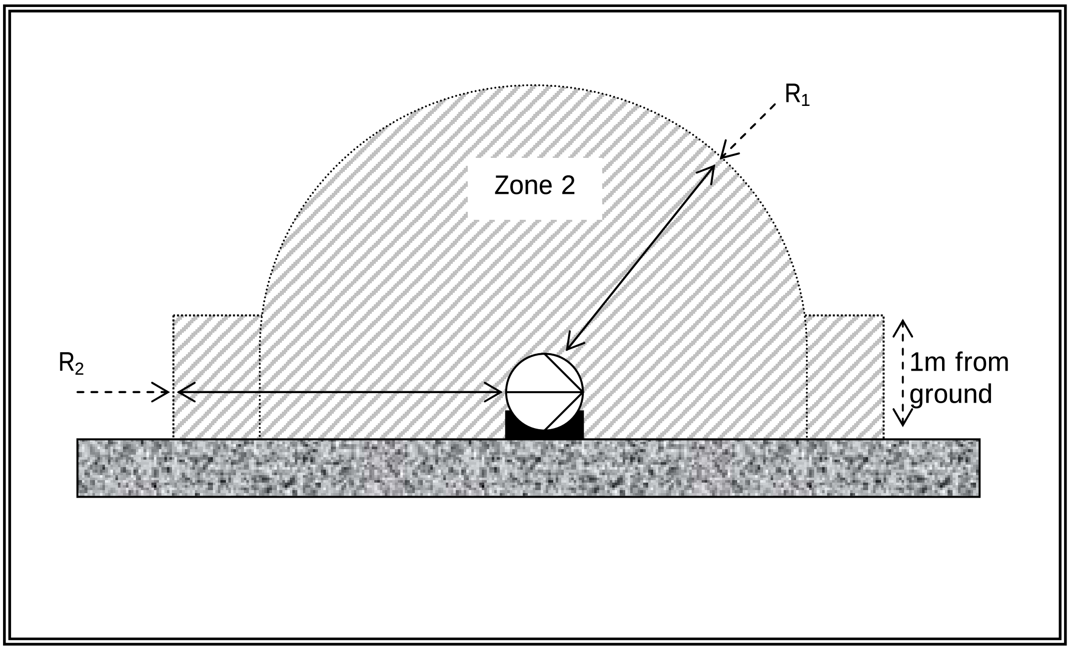
Pump design varies widely between standard industrial pumps with a fairly basic seal to high integrity pumps with a double seal that will only leak under catastrophic failure conditions, so need not be considered for area classification purposes.

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.