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Hazardous Area Classification using Quadvent

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Summary

In this paper we discuss hazardous area classification (HAC), the safety regulations which require a HAC to be carried out as part of your risk assessment, some of the challenges presented by HAC, and how the software tool **Quadvent** can be used to help you complete your assessment quicker and more effectively.

Carrying out a HAC assessment can often be perceived to be a difficult and time consuming task. It is clearly very important that the conclusions from the assessment are appropriate to avoid the accidental ignition of flammable substances. The **Quadvent** software tool helps make this task easier however, by providing output quickly that can be used directly in your HAC assessments, managing your workplace risks and meeting the needs of the safety regulations.

DSEAR – the need for Hazardous Area Classification

The Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR) apply to all workplaces in Great Britain and cover risks to employees, contractors, visitors and the public. The regulations apply where dangerous substances are or are liable to be present (for example materials classified under the Classification, Labelling and Packaging (CLP) regulations as flammable or explosive). It is a requirement under DSEAR to ensure that the risks from dangerous substances are eliminated or reduced so far as is reasonably practicable.

Regulation 5 requires a company to undertake an assessment of the risks from the dangerous substances present. The assessment should be suitable and sufficient and include consideration of:

- The hazardous properties of substances including information provided by suppliers
- Work processes using hazardous substances, the amounts used and risks from a loss of containment
- Arrangements for safe handling, storage and transport for substances and waste
- Higher risk activities e.g. maintenance

When carrying out the risk assessment, Regulation 6 requires that consideration should be given to eliminating or reducing of risks from dangerous substances so far as reasonably practicable, substituting with less hazardous substances where possible. Where this is not possible the risks should be controlled and mitigated.

As part of the **risk assessment**, Regulation 7 requires that areas where explosive atmospheres could occur should be identified as part of a **Hazardous Area Classification** exercise. These areas should be zoned and signs provided. In these zones suitable ATEX[1] compliant equipment and protective systems should be installed, and suitable work clothing provided. The classification of these zones is known as area classification.

[1] http://www.hse.gov.uk/fireandexplosion/atex.htm #whatatex

Hazardous Area Classification: further details

Grades of Release

As part of the process of hazardous area classification, releases of dangerous substances are divided into three categories or grades:

Grade	Description of release
Continuous	Expected to occur frequently, or occur for long periods
Primary	Expected to occur occasionally during normal operation
Secondary	Not expected to occur during normal operation, and if it does occur, is only likely for short periods

Zone Definitions

For outdoor releases or indoor releases with adequate ventilation, Continuous releases give rise to a Zone 0, Primary releases give a Zone 1 and Secondary releases lead to a Zone 2. For less than adequate ventilation, Secondary releases lead to a Zone 1 and Primary releases to a Zone 0, due to the ventilation not being sufficient to disperse the flammable atmosphere. The adequacy of the ventilation can be judged from the size of the hypothetical gas cloud volume, V_Z, or the average concentration of flammable gas in the enclosure during a steady release.

If the hazard posed by a release is deemed to be so small that significant injury or damage to equipment won't occur then a zone can be defined to be of Negligible Extent (NE). This effectively means that the extent (or size) of the zone is set to be zero.

Approaches to Hazardous Area Classification

There is a need to calculate zones in a cautious manner, but not to obtain overly conservative results, such that money can be spent on ATEX equipment in areas of genuine risk and not wasted on excessively large zoned areas. Area classification is often perceived to be difficult and many different sources of guidance are available.

Some of the more common sources of guidance are briefly reviewed below. The approaches include standard zone sizes for specific types of equipment and/or estimation of zone sizes through calculations for each potential release. The **Quadvent** software, described in more detail below, provides a quick and convenient way of defining the type and size of zone for each specified release.

• HSE DSEAR Approved Code of Practice (ACOP) and Guidance (L138)

This publication provides advice on how to comply with the law, but does not specify how to classify and calculate the size of zones. The legislation and guidance are not prescriptive and dutyholders can use any appropriate methodology in the hazardous area classification exercise. This paper describes the use of the HSE system **Quadvent** but other systems and software are available.

• BS EN 60079-10-1 Classification of Areas – Explosive Gas Atmospheres

The 2003 version of this standard introduced the concept of the hypothetical gas cloud volume, V_z, which is defined as 'a hypothetical gas cloud with an average concentration equal to half the lower flammable limit (LFL)'. This gas cloud volume can be used to judge the degree of dilution and whether a release is of negligible extent (NE):

- If the value of V_z is less than 0.1 m^3 then the zoned area is considered to be of negligible extent and protective equipment is not required
- For secondary releases indoors, Zone 2 is applicable if V_z is less than the volume of the enclosure, but larger than 0.1 m^3.

However, the methodology used to calculate V_z in the 2003 and 2009 versions of the standard was very conservative and could lead to calculations of V_z several orders of magnitude larger than through using well-established gas jet models, including Computational Fluid Dynamics and **Quadvent** (see Worked Example 1). The overall approach of linking the zone classification to the size of V_z is sound and some validation of the approach has been published in the HSE Reasearch Report RR630.

The 2015 version of the standard, which was voted against by the UK, uses a completely new graphical method to assess the degree of dilution and hazardous distance. The UK has concerns with some of the methodologies in this standard and these are raised in the UK national foreword. In particular there are concerns that the methodology can produce non-conservative (i.e. potentially unsafe) results in some circumstances and at times contradicts advice contained in other standards, such as those described below. Work carried out by HSE supports this position.

• Energy Institute Model Code of Safe Practice Part 15: Area Classification for Installations Handling Flammable Liquids (EI15), 4th Edition

This is a standard aimed at the petroleum industries and as such is typically concerned with high hazard sites dealing with large quantities of flammable liquids and high pressure gases. It uses both direct examples for common facilities and a risk based approach.

The concept of a Zone of negligible extent is not used in EI15 and the least onerous classification that can be obtained is a Zone 2 of 'less than 1 m'.

• Institute of Gas Engineers and Managers Hazardous Area Classification of Natural Gas Installations (IGEM SR25), 2nd Edition

This standard is used for classifying natural gas installations operating at pressures up to 100 bar. The standard contains a detailed and somewhat complex methodology to assess ventilation rates taking into account factors such as the number of release sources, the failure frequency of components and inspection intervals.

The available guidance above tends to provide simplified methods, e.g. by means of look-up tables or simple calculation methods for specific types of release, that are generally conservative (excepting 60079-10-1:2015 in some cases). This approach makes the HAC relatively quick but the associated generality can, in some cases, lead to excessive conservatism.

Quadvent: a scientific approach to Hazardous Area Classification

Challenges with HAC methodologies

HSE has played a leading role within the UK on the development of scientific approaches to area classification over the last ten or so years. The work started through a joint industry project led by HSE's Buxton laboratory that was funded by HSE and industry. The aim of this work was to develop a more scientifically based approach to area classification, which in the past had been frequently based on rules of thumb or engineering judgement. The work was published by HSE in Research Report RR630 (2008).

The output of this work was used as the basis for changes to the key industry area classification codes EI15 4th Edition (2015) and IGEM/SR/25 Edition 2 (2010).

The Development of Quadvent

Initially **Quadvent** was developed as a very simple model that could be expressed as a single equation for estimating the gas cloud volume V_z for pressurised gas releases. More details can be found in the papers by Webber et al (2011) and Santon et al (2012). This was then built into software to make it easy to use as part of an area classification exercise. The latest version of this software, **Quadvent 2**, adds functionality to also calculate hazardous areas from releases of pressure liquefied gases, such as LPG, and buoyant plumes.

Quadvent is based on well-established modelling methodologies based on research carried out over very many years studying major accident hazards. The derivation of the gas jet model and its validation has been published in a peer reviewed journal (Webber et al, 2011). Three further papers will shortly be submitted to peer-reviewed journals describing the three models in **Quadvent 2** including their validation against experimental data. The aim of the models is to provide realistic estimates of the gas cloud volume V_z and zone extent, while not being overly conservative.

Features of Quadvent

- **Quadvent** is very **easy to use** and the calculations can be performed quickly by inputting the parameters of the release and the environment into the graphical interface as shown in the worked examples below.

- **Any hole size can be used** to calculate the hazardous area in **Quadvent**. Different industry standards have different approaches for specifying hole sizes for secondary grade releases ranging from small hole sizes used by the gas industry (IGEM/SR/25) to much larger ones used in the petroleum industry (EI15). Users of Quadvent can use the hole sizes that are most appropriate for their particular application.

- **Quadvent** can be used for **both indoor and outdoor releases**. One of its distinguishing features is the ability of the models to **account for the effect of the build-up of flammable gas within an enclosure on the gas cloud volume**. This feature is not generally included in even the most sophisticated consequence models. The software also provides a very useful feature which allows the user to estimate natural ventilation rates based on the size and position of openings in an enclosure.

- The outputs of **Quadvent** are **tailored for use in a HAC assessment**. Three measures of the 'flammable gas cloud volume' are provided. These include the volume of gas above the lower flammable limit and the volume of gas above half the lower flammable limit. More significantly though it **provides an estimate of the gas cloud volume** V_z which can then be used to determine which zone should be applied based on the approach in BS EN 60079-10-1:2009. Although this version of the standard has now been superseded, HSE Research Report RR630 showed that the general approach of using V_z to determine the zone is valid, as long as an appropriate method, eg Quadvent, is used to calculate V_z.

- **Quadvent** also provides **the calculated distances** from the release point to the point where the gas concentration has reduced to the lower flammable limit and half the lower flammable limit. These values can be used to specify the size of a zone.

Quadvent software overview

Feature	Benefit
Quick and easy-to-use	Saves you time
Produces realistic V_z estimates	Saves you money, for example, the capital and maintenance costs of unnecessarily protecting electrical and non-electrical equipment for use in hazardous areas
Uniquely calculates V_z both for ventilated enclosed areas and for outdoors	Saves you time and money – one software tool can be used for a variety of areas
Rigorously tested and validated	Provides you with assurance and peace of mind: you can trust the output of the tool
Provides realistic estimates of the natural ventilation rate of a building and covers a variety of gas and liquid release scenarios	Saves you time and money by providing comprehensive information in one software tool

Worked examples

The following examples demonstrate the difference that using **Quadvent** can make.

Worked Example 1: Outdoor natural gas pipework

In this first simple example we consider some outdoor natural gas pipework operating at a pressure of 10 bar gauge. We can use a typical hole size for a secondary release from a flange or joint of 0.25 mm^2 (BS EN 60079-10-1:2015). The table shows the estimates of V_z using both **Quadvent 2** and the old (2009) version of BS EN 60079-10-1. The results highlight the over-conservatism in the V_z equations in the old standard as discussed above. For $V_z < 0.1\ m^3$ this would indicate that a Zone of negligible extent could be applied.

	V_Z (m^3)	Zone
BS EN 60079-10-1:2009	93.9	Zone 2
Quadvent	0.002	Zone 2 NE

Worked Example 2: Ammonia release in a room with forced ventilation

In this example we consider a release of ammonia liquefied under pressure from a refrigeration system. The enclosure containing the refrigeration system is force ventilated with 5 air changes per hour. Figure 1 shows the **Quadvent 2** output where the 'Choked two-phase flow model' has been used to calculate V_z. As V_z is smaller than 0.1 m^3 and the volume of the enclosure is greater than 10m^3, a hazardous area classification of Zone 2 NE could be applied in this case.

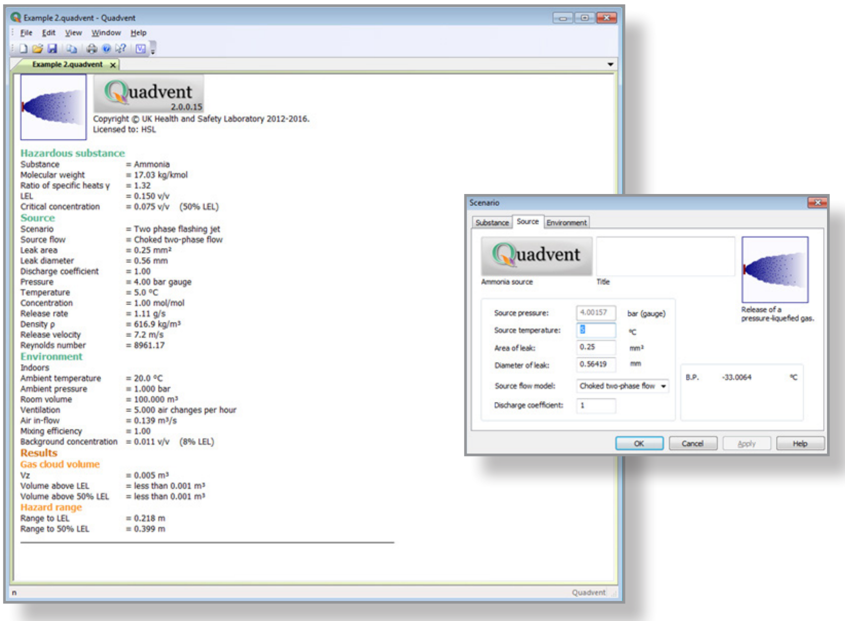

Figure 1: Calculation of the hazardous volume, V_z, from **Quadvent 2** for an indoor release of pressure liquefied ammonia. The inset window shows the dialogue box for inputting or adjusting the details of the source of the release

Worked Example 3: Hydrogen pipework indoors

This example has hydrogen pipework at 5 bar gauge in a naturally ventilated enclosure. Secondary sources of release (such as flanges and valves) are considered. Two **Quadvent 2** calculations have been carried out using a hole size of 0.25 mm^2 (no adverse conditions) and 2.5 mm^2 (adverse conditions).

The natural ventilation rate was calculated in **Quadvent 2** using the natural ventilation model (see Figure 2). This resulted in a Zone 2 NE: V_z is smaller than 0.1 m^3 and the volume of the enclosure is greater than 10 m^3. **Quadvent 2** also displays the background concentration (as a fraction of LFL) in the output window, in this case it is 1 % LFL. Figure 3 shows the effect of changing the hole size to 2.5 mm^2 to represent adverse conditions within the same enclosure. In this case V_z is greater than 0.1 m^3 and therefore a standard Zone 2 should be applied.

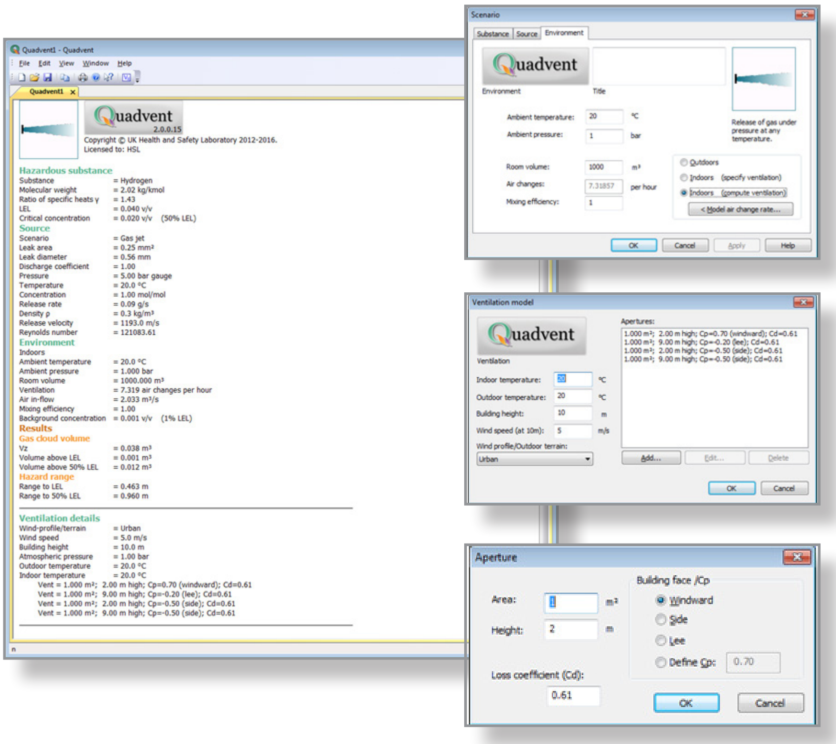

Figure 2: Calculation of the hazardous volume, V_z, using **Quadvent 2** for an indoor hydrogen release at 5 bar gauge. The inset window shows the dialogue boxes for calculating the ventilation rate for a naturally ventilated enclosure.

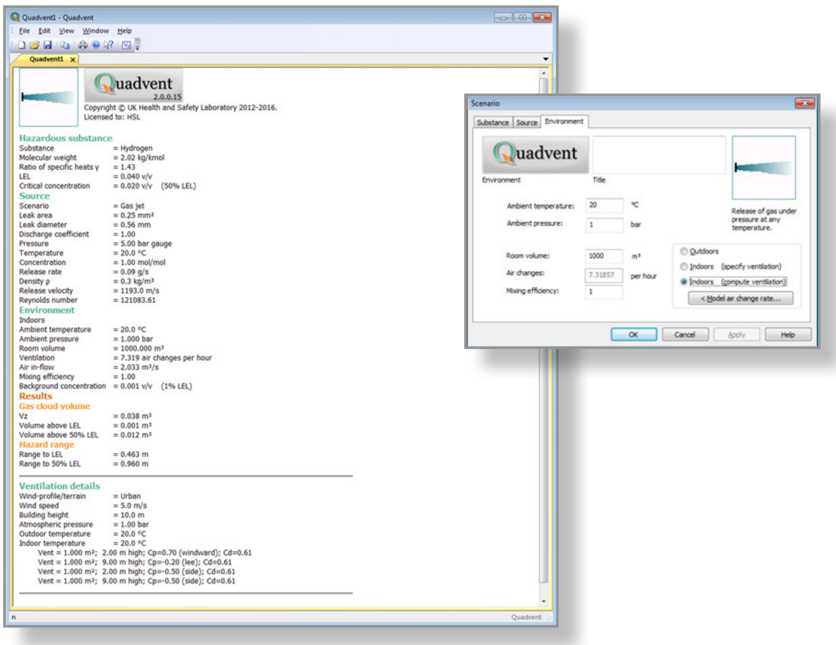

Figure 3: Calculation of the hazardous volume, V_z, using **Quadvent 2** for an indoor hydrogen release at 5 bar gauge. The inset window shows the dialogue box for changing the hole size for a releases under adverse conditions.

Hazardous Area Classification training and advice

HSE's Buxton Laboratory provides regular training courses on DSEAR and Hazardous Area Classification, including the use of **Quadvent**. We can also deliver bespoke training relating to DSEAR, Hazardous Area Classification and associated matters at your organisation.

With a wealth of knowledge in area classification and the DSEAR regulations, HSE scientists are also well placed to be able to advise you on your area classification and DSEAR assessment needs. HSE scientists provide consultancy services to help ensure DSEAR assessments and hazardous area classification are robust and correctly carried out. As our scientists provide technical advice and support for HSE inspectors, work with relevant industry bodies at a national level, and investigate when things go wrong, they are uniquely placed to provide you with relevant and pragmatic support.

Visit our Risk Management pages (https://www.hsl.gov.uk/what-we-do/risk-management-and-process-safety) to see how we can help you, or contact us on: risk.management@hsl.gsi.gov.uk

Disclaimer

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